A NATURALISTIC INQUIRY INTO PRESERVICE TEACHERS’ EXPERIENCES WITH SCIENCE, TECHNOLOGY, AND SOCIETY (STS) CURRICULAR APPROACHES

A dissertation submitted to the Kent State University College and Graduate School of Education, Health, and Human Services in partial fulfillment of the requirements for the degree of Doctor of Philosophy

by

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National science education reform documents recognize the goal of teaching science for social responsibility, which is exemplified by the science, technology and society (STS) approaches. However, in practice, science education at the pre-college level remains content-oriented. Teachers are recognized to be the key element of change, but there is a lack of research on how preservice teachers understand STS as a result of their experiences with the approach in their methods courses.

This study takes a Deweyan perspective that focuses on "worthwhile experiences" and interactions in the world, to explore the possibilities that STS curricular approaches offer teachers to implement the national recommendations of "Scientific Literacy for All." This study explored the experiences of two groups of preservice secondary science teachers, at different points in their teacher preparation programs, with STS, using a naturalistic design informed by social constructivism and Deweyan pragmatism.

The themes that emerged from this study suggest that participants understood STS as an add-on approach rather than a curricular orientation. In addition, they associated STS with controversy, which could make them hesitant in implementing such an approach. Furthermore, for most participants, STS remained situated in the context of
a college classroom, as very few of them attempted to fully implement an STS issue
during student teaching. I found that while teachers may value STS, they are not likely to
implement it, due to practical considerations rather than stable beliefs.

The study concludes by drawing a contrast between constructivism as a research
framework, and a Deweyan perspective with a focus on interaction in the world, and
suggesting possible implications of this framework for research and teaching.
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CHAPTER I
INTRODUCTION

“I believe that all education proceeds by the participation of the individual in the social consciousness of the race” (Dewey, in Archaumbault, 1964, p. 427).

Issues in Science and Society

FDA Approves Milk From Cloned Cows

“The U.S. Food and Drug Administration announced [recently] that meat and milk from cloned animals are safe to eat. Critics immediately denounced the FDA’s conclusions, saying the agency ignored the ethical problems with cloning” (All things considered, 2008). FDA scientists concluded after studying the chemical composition of milk and meat from cloned animals that it is identical to the milk and meat that is currently on the market. Critics claim that data shows that cloning can create animals that are unable to survive and question the ethics of cloning. “But FDA officials say their job is just to look at food safety, not ethics.”

Oil in Arctic Ocean and Global Warming

Scientists working in the Arctic Ocean found recently that the rate at which ice is melting is faster than we thought. They also found something else: potential sources of oil and coal, which, if exploited, can increase global warming, which is causing the melting of ice in the Arctic. Kate Moran is a scientist who led the expedition to the Arctic Ocean and who faces the dilemma of what to do about her team’s discovery. Do they
reveal the discovery to the oil companies and risk making the problem of global warming worse? (Mullins, 2008).

*Bird Flu: The Next Epidemic*

A few years ago, we witnessed bird flu anxiety spreading over the world as scientists warned of the possibility of a pandemic if the virus mutated to allow transmission from human to human. During that time, tensions between government officials in many countries and the Swiss company Roche that holds patents for Tamiflu—an anti-viral medicine—escalated dramatically. The company asserted its right to patent protection as an essential component for the development of drugs while public health advocates were concerned over the access of poor nations to drugs (Kaufman, 2005). These patent issues continue to raise contentious debates internationally. Aren’t patents essential to insure investment in research to develop new drugs? What about poor nations who cannot afford these costly medicines, which was especially an issue with AIDS (Kaufman)? Or in the case of a world pandemic, can one company supply the world’s need for one drug? What does it mean for our society that companies can own rights to medical treatments or scientific procedures?

*Science and Society*

These news summaries are just a few examples of issues in science and technology that often come up in the public sphere. Who is eligible to decide on what actions to take in addressing these issues: scientist-experts? Policy makers? Heads of companies? The general public? Most science educators assert that science education needs to prepare citizens to be able to understand and make decisions on these issues.
However, some question whether the general public has (or will ever have) enough understanding of science to be able to make decisions on science based social issues (Shamos, 1995). McComas, Clough, and Almazroa (2002) observed that whereas science has pervasive impact on almost all areas of our modern life, the general public has a limited understanding of how the scientific enterprise operates. This lack of understanding can be dangerous, when citizens are making decisions on funding or policy matters. The authors claimed that “at the foundation of many illogical decisions and unreasonable positions are misunderstandings of the character of science” (p. 3). What kind of understanding do people need in order to make these decisions? What implications would prohibiting citizen input on scientific and technological dilemmas have on the democratic process? (Cheek, 1992). Can we instead imagine a science education that opens the door for students to explore and be able to make decisions on such issues?

Science enters our public sphere in many different ways. Through our television sets this election season, we have witnessed an increased interest in science and public policy. Some scientists have called for a science and technology debate to discuss candidates’ positions on issues that relate to science and technology\(^1\). These topics range from environmental issues such as climate change, pollution, renewable energy, and population growth, to medical/ethical issues including stem cell research and drug patents, and the implications of the human genome project (Science Debate, 2008). The

\(^1\) The idea for a science debate was introduced by few scientists and now has the endorsement of many large organizations such as the American Association for the Advancement of Science (AAAS), the National Academy of Science, among many others. As of the date of this manuscript, there was no confirmation of such a debate.
relationship between science and the public is complex. For some people, science is a “mighty knight” that provides agricultural revolutions, medicines to cure disease, and a global communication system. Yet for others, science “gives us weapons of war, a school teacher’s fiery death as the space shuttle falls from grace, and the silent, deceiving, bone-poisoning, Chernobyl” (Collins & Pinch, 1993, p. 1).

Why are these images of science in the public sphere important? Aikenhead (1994b) gave us one reason: that science relies on public funding. In fact, this is a recent development in the history of science. The social contract of science has changed through the centuries. Science as an institution was established in the 17th century by British aristocrats who were playing with ideas but did not feel the need to address the usefulness of science. This started to change as science promised knowledge that could offer humankind dominion over nature. Science offered society a new way of understanding the natural world that was based on observation and rationalism, and not on religious scriptures. In exchange, science recused itself from the domain of politics, religion, and morals.

During the next century, technological advances offered more success as was witnessed in the Industrial Revolution. As a response to this new power of technology that offered unprecedented human productivity, scientists again separated themselves from this useful knowledge, by retreating into universities and calling technology applied science. Aikenhead (1994b) recounted how science focused on knowledge for knowledge’s sake. Moreover, science distanced itself from discourses of values, ethics, and social responsibility. “Science eschewed its technological and social connections” (p.
15). Yet, science’s attempted separation from practical, societal concerns would not last. World War II brought about the marriage of science and technology into a big social unit of “Research and Development.” The gap between pure science and applied science narrowed as partnerships with the government, the military, and industry were formed.

This transformation of science had also deep implications for the understood epistemological superiority of science. Before World War II, not only did science remove itself from the realm of citizenship, but it also “claimed the moral high ground of abstract thought” (Solomon, 1994, p. 9). Solomon stated that after the war, scientists could no longer claim to be separate from—and therefore somehow, above—society. The war changed the relationship between the two. Solomon described this change in the following passage:

All belief in the moral neutrality of science should have vaporized in the searing heat of the Hiroshima explosion. This was by no means the first time that scientific research had been directed at the production of weapons, but now it was no longer possible to excuse the scientists from blame on the grounds that others had misused their inventions. Top scientists from all over Europe had flocked to Los Alamos to work, quite knowingly, on what they called “our bomb.” When it was all over, many realized that it had not been just duty or patriotism that had made them work so hard at constructing this new and devastating weapon, but the basic scientific challenge itself. (p. 10)

These interactions between science and society open up discussions about the impact of science on society on the one hand, and the impact of society on scientific work on the other.

Perhaps in part as a result of this newly established relationship, scholarship in the history, sociology, and anthropology of science during the second half of the 20th century reexamined scientists’ claim of epistemological superiority and asked how scientific
knowledge is itself a product of the culture of the time and place where it is produced. The resulting body of work is often referred as Science Studies (Biagioli, 1999). This field is very diverse, comprises work from many disciplines, and is by no means unified; however, a brief description of the field of Science Studies, especially as it relates to science education, is helpful for the perspective it provides on STS teaching.

Images of Science: Science Studies

Early accounts of science by sociologist Robert Merton portrayed science as universal and independent of the personal, social, and cultural characteristics of the scientists themselves. Scientists were assumed to be unbiased, focusing on knowledge and putting their interests aside. These images of science contributed to its epistemic stance as true knowledge, above other kinds of knowledge, and they elevated scientists’ social status and political power (Kelly, Carlsen, & Cunningham, 1993). However, more recent studies in history and sociology of science illustrated how scientists are passionately engaged in “value-laden activities to demonstrate their correctness” (p. 209) and dependent on the socio-cultural milieu in which they work. These studies of laboratory work in action (Latour, 1987) illustrated the ways in which the practice of science is socially mediated rather than objective. “Replication, the ontological status of claims, scientific discovery, and the logic of science are products of the negotiation of the community of scientists” (Kelly et al., 1993, p. 211). Latour and Woolgar’s (1979) study details the ways in which laboratory scientific work is messy and full of uncertainties. Instead of following a logical scientific method that eliminates uncertainties, scientists use persuasion to make the case for their assertions. What students read in textbooks is a
“black-box,” polished version where all uncertainties are removed. This is what Latour (1987) labeled “ready made science,” which he argued is very different from actual laboratory work or “science in the making.”

Feminists work in sociology and philosophy of science (e.g., Harding, 1991, Keller, 1985; Longino, 1990; cited in Kelly et al., 1993) discussed how research in science is inseparable from gender bias. Feminists claim that “biases do not lead to bad science (although they may be present in bad science); they are present in any scientific endeavor” (Kelly et al., 1993, p. 213). Furthermore, ethnographic studies of science showed through details of laboratory work that science is not different than any other human activity and therefore cannot sustain a claim to epistemological superiority (Collins & Pinch, 1993; Rouse, 1993).

In summary, various works in the Science Studies literature have clarified how it is that science should not be seen as a field unified by one (epistemologically-superior) method, but as heterogeneous, human made, and influenced by social factors. How is this work relevant to science education? As discussed earlier, science and technology issues that demand public participation figure often in the political process. And some scholars have argued that what citizens (including students) need to know to make decisions is more about what science is and how it works and not scientific content (Collins & Pinch, 1993).

Statement of the Problem

In a world that is increasingly dominated by science and technology, issues that demand public participation and decision making are proliferating: environmental
concerns, population growth, patents, reproductive technology, stem cell research, and nuclear energy, to name a few. However, students in high school seem to be more alienated from science than ever due largely to the way it is taught as isolated facts to be memorized (Blades & Richardson, 2004; Solomon, 1999). This situation is not at all new. Dewey wrote in 1910 that:

Science has been taught too much as an accumulation of ready-made material with which students are to be made familiar, not enough as a method of teaching, an attitude of mind, after the pattern of which mental habits are to be transformed. (p. 183)

Almost a century later, the extent to which students are given opportunities to act and be directly involved in local and global problems that affect their present and future lives remains questionable. The science curriculum in high schools “is invariably associated with preparation for college. And the courses prior to high school are thought to be preparatory for the next science course for the next academic year” (Yager, 1996a, p. 3).

As science and technology issues continue to be debated in the public sphere, there is recognition among science educators in many western countries of the importance of teaching science for social responsibility. The National Science Teachers Association asserted that “scientific literacy for citizenship should be a primary-if not exclusive-goal of science education at the pre college level” (NSTA, 2003). Science, Technology and Society (or STS) curricula emerged as a response to the perceived need to teach science for social responsibility. Whereas policy documents (National Science Education Standards, Project 2061) reflect this emphasis on social relevance, little has changed in the classroom and teachers are often blamed for a failure to implement STS curricula (Bybee, 1991). Consequently, science educators shifted their focus to the role of
teachers as key players in implementing policy documents. There is documented resistance from teachers to an STS approach (DeBoer, 1991) resulting from factors such as time, resources, and perceived lack of rigor. Some researchers cite teachers’ beliefs as a primary problem in implementation of STS curricula, but others note that teachers operate in systems that place many constraints on them (May, 1992; Solomon, 1999). Bybee (1991) identified the practice-policy gap in STS implementation two decades ago, but classroom teaching still has not changed. Since teachers are introduced to teaching STS in science methods classes, it is important to look at how they come to understand what STS means and whether they value and use (or not use) such an approach.

Purpose of the Study and Research Questions

This study seeks to explore how preservice teachers come to understand, value, and appropriate STS in their methods classes. Using an approach grounded in social constructivism (Denzin & Lincoln, 2003; Schwandt, 2003) and Deweyan Pragmatism (Garrison, 1994), the study focuses on how an understanding of STS emerges as a result of the context of the methods class. More specifically, the study asks:

1. How do preservice teachers understand STS as a result of participation in a science methods class?
2. Do pre-service teachers value STS as a result of their experiences?
3. Do pre-service teachers use STS during student teaching, and in what ways?

Significance and Limitations of the Study

This study is undertaken from a social constructivist perspective, and hence the results of the research are understood to be socially situated and contextual (Denzin &
Lincoln, 2003). In this tradition, knowledge gained from the research cannot be separated from the context where it occurred and from the researcher who will be interpreting the results. The results are not meant to be generalizable or to uncover a fundamental truth that is stable and consistent about the participants. Instead, this study seeks to add to our understanding of how teachers come to understand and use STS. It also seeks to contribute to the conversation in the science education community of how to make implementation of STS in K-12 classrooms possible and accessible to teachers by illustrating the multiple perspectives that get constructed by the participants.

Definitions of Terms

STS

STS refers to the science, technology, and society movement in K-12 science education. Other programs in science, technology, and society exist at the university level, but they are different in scope than those at the K-12 level. In fact the two programs of study seem to have evolved independently of each other (Kumar & Chubin, 2000). In this dissertation, all references to STS will be limited to K-12 settings in the science education literature.

Socioscientific Issues

Zeidler, Walker, Ackett, and Simmons (2002) suggested the use of the term socioscientific issues instead of STS. They claimed that STS traditionally did not address the ethical issues or moral development of students. “Socioscientific issues then is a broader term that subsumes all that STS has to offer, while also considering the ethical dimensions of science, the moral reasoning of the child, and the emotional development
of the student” (Zeidler et al., p. 344). However, other science educators have used the term STS while also addressing ethical and moral issues (Blades, 2006; Hodson, 1999, 2003), which suggests that not everyone agrees on a strong difference between STS and socio-scientific issues. I use the term STS since it is recognized in the literature as a broader umbrella to label the field (Solomon & Aikenhead, 1994).

Issues

The national standards for science teacher preparation use the term “issues” instead of STS. They referred to issues “as contemporary science-and technology-related issues of interest to the general society” (NSTA, 2003, p. 19). Since the science teacher preparation standards drive the education of pre-service teachers, this term came up during the methods classes, and shows up in chapter 4 at times.

Science Studies

I use the term science studies to talk about work in the history, philosophy, and sociology of science. Sometimes this work is also referred to as science and technology studies. Although these studies have different and divergent agendas, for the purposes of this work I focus on how the field as a singular entity has influenced science education.

Nature of Science (NOS)

Viewed broadly, McComas et al. (2002) defined the nature of science as:

A fertile hybrid arena which blends aspects of various social studies of science including the history, sociology, and philosophy of science combined with research from the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors. (p. 5)
Since the nature of science is contested, Lederman, Abd-El-Khalick, Bell, and Schwartz (2002, p. 499) suggested that the following historical, philosophical, and sociological perspectives on science are appropriate for science education: Scientific knowledge is tentative, empirical, theory-laden, partly the product of human inference, imagination, and creativity, and socially and culturally embedded. NOS instruction also introduces students to the distinction between observation and inference, the lack of a universal recipe like method for doing science, and the functions of and relationships between scientific theories and laws.

Summary

This chapter introduced the practice-policy gap (Bybee, 1991) in implementing STS in school science. I situated the field of STS within the broader discussion of what science is, but also what science students need to function in society. Chapter 2 explores these issues in detail, linking STS to the idea of scientific literacy for all. It also elaborates on how STS is conceived in the literature and looks at how teachers deal with STS in their classes, concluding with a suggestion for how science educators might differently see the ‘practice-policy gap.’ Chapter 3 introduces the study’s research framework that is based on social constructivism and Deweyan pragmatism, and discusses the methods used in the study. Chapter 4 reports the results, describing the field site and presenting common themes. Chapter 5 draws implications from this study for future research and teacher education.
CHAPTER II
LITERATURE REVIEW

“The fundamental weakness of valid science as it is usually taught is not what it says about the world, but what it leaves unsaid. The task of STS education is to fill that gap”.
(Ziman, 1994, p. 22)

Introduction

The field of science, technology, and society (STS) education is a complex one, with multiple orientations rather than a defined line of research (Pedretti, 1996). Ziman (1994) wrote that “the movement for STS education springs from so many different sources, and flows in so many different channels, that it does not have a shape that can be grasped mentally and described as a whole” (p. 21). Multiple volumes have been written to clarify and establish the field of STS (e.g., Bybee, 1997; Solomon & Aikenhead, 1994; Yager, 1996b). These different orientations should not be viewed as a problem, but as an inevitable consequence of the various disciplines that influence the field. This becomes more relevant as we think about teaching STS. Since science prides itself on being universal (in terms of content at least), we can arguably find a universal way of teaching science content. We cannot say the same about STS. The complex nature of interactions between science, technology, and society in local contexts “precludes a monolithic approach” to teaching about it (Solomon & Aikenhead, 1994, p. viii). In this chapter, I map out some of the different ways that educators have discussed and implemented STS. However, in order to begin to understand how STS is discussed in the literature, there is a need to situate the field of STS within the larger science education literature and the new
reform movements that focus on “scientific literacy for all” to which the STS movement in K-12 education is closely linked. I started this chapter by examining how scientific literacy has been conceptualized in the science education literature, then discussing the STS movement as a framework to achieve scientific literacy. I look at STS history, models of implementing STS, and theoretical frameworks for STS. Finally, I examined research that centers on the teacher’s role in implementing STS.

Science Education Reform and Scientific Literacy

The term “scientific literacy” has been used widely since Paul Hurd coined it in 1955 (DeBoer, 1991). More recently, science education reform documents have stressed scientific literacy for all Americans. The American Association for the Advancement of Science launched “Project 2061: Science for All Americans” in 1989 to address the concern that science education should not be taught as preparation for an elite who will go on to careers in science and engineering, but it should be taught with the goal of preparing all students to be responsible citizens. This is a shift from traditional science curricula that focused on promoting an in-depth knowledge of scientific content, which is most useful to those who will pursue science in college. Scientific literacy is also echoed in the National Science Education Standards (National Research Council [NRC], 1996) which stated that “all students, regardless of age, sex, cultural or ethnic background, disabilities, aspirations, or interest and motivation in science, should have the opportunity to attain high levels of scientific literacy” (p. 20). Policy documents in Canada, the

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2 The term itself was used in history prior to that. However Hurd popularized it in the science education literature (DeBoer, 1991, 2000).
United Kingdom, Australia, and other western countries reflect the same vision (Fensham, 2000).

But what do science educators mean by scientific literacy? Does it mean that students should know the content of science; does it mean they should know how science works; or does it mean they should know how to use science for their personal needs and for societal needs? In the science education literature, there are multiple answers to the question. Although there are many interpretations of “scientific literacy,” they all incorporate some elements or combination of the following themes: knowing the content of science, knowing the processes of science, knowing about the history and nature of science, knowing about the nature of technology, and knowing how to make decisions on scientific issues in society. These instructional goals are not new; they have been discussed since science entered the high school curriculum. However, the emphasis on any particular theme may have waxed or waned during different historical periods (DeBoer, 1991).

The National Science Education Standards (NSES), the standards document on which most current work in science education is based, define scientific literacy as follows:

Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose
and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately. (NRC, 1996, p. 22)

As can be seen, this is a very broad definition and it encompasses all the themes for science education that have been suggested over the years (DeBoer, 2000). The broad and almost vague character of this definition could be the result of the different experts involved in developing these standards (DeBoer). Although this definition is broad, in practice science educators tend to focus on specific aspects of scientific literacy. These efforts are considered below.

**Scientific Literacy and Knowledge of Content**

For some, the notion of “literacy” in science means an easy familiarity with the concepts, principles, laws, and theories of science. In fact, the version of scientific literacy with which the general public may be most familiar is of this character—a yearly survey administered by the National Science Foundation to measure “public knowledge of and attitudes about” science and technology. When the results of this survey are covered in the media, they tend to focus on American citizens’ answers to content-related questions like the following (National Science Board, 2008):

1. Does the earth go around the sun, or does the sun go around the earth?
2. How long does it take for the earth to go around the sun?
3. Human beings, as we know them today, developed from earlier species of animals. (True or False?)
4. The universe began with a huge explosion. (True or False?)
5. Electrons are smaller than atoms. (True or False?)
6. Antibiotics kill viruses as well as bacteria. (True or False?)
7. Lasers work by focusing sound waves. (True or False?)

A recent report on the findings of the annual National Science Foundation study raised concerns that the ‘low’ rate of correct answers on these kinds of questions could have a negative impact on the degree of government funding for research and the number of people considering careers in science and technology (National Science Board, 2002). For example, in 2006 only around 50% of adults in the U.S. answered correctly that electrons are smaller than atoms. In a 2001 survey, only 48% of U.S. adults answered false to the statement that humans and dinosaurs lived at the same time. In light of such survey results, Shamos (1995) suggested that scientific literacy is unattainable, since after many years of science education, and much talk about reform, the public is illiterate in science. These results may be alarming, but Cheek (1992) argued that the tests lead inevitably to the results and that more effort needs to go to debunk the tests. Would framing the question differently lead to different data? Furthermore, by relating questions like these to the notion of ‘scientific literacy,’ we come to see such literacy as a matter of understanding the content of science—but is a high score on a test like this sufficient evidence of competence? Stone (1991) also questioned the importance of these surveys:

How alarmed should we be at these answers? Does an inability to explain DNA make you an awful person? Is it more important to recognize the name Chernobyl or to have the psychological savvy to judge the guy with his finger on the nuclear button? (p. 14)

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3 This particular statement may be related to religious beliefs in creationism, and not just as a scientific misunderstanding.
4 Although the survey results presented in this section are from the 2001 NSF document, these surveys have been conducted since the 1970s. Not much has changed in the content of the questions, although the results show some improvements over the years.
These critiques illustrate the problems inherent in judging the scientific literacy of the public by out of context phone surveys— the method typically used in these national surveys.

*Scientific Literacy and Knowledge of Inquiry Methods*

Other educators hold that scientific literacy is best thought of as a skill set; in this case, the ability to use the methods of scientific inquiry to solve problems about natural phenomena. The National Science Education Standards (NRC, 1996) shift the focus of science teaching from content to inquiry. According to the standards, inquiry teaching involves students with opportunities that include:

Asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments. (p. 105)

Furthermore, inquiry teaching requires students to be involved in investigations in science questions over an extended period of time, and also for students to practice science arguments and defend conclusions in front of peers. Unlike earlier models of teaching “science as a process” that focused on teaching the process skills of science devoid of content, the new focus on inquiry requires that students learn the concepts of science as they are involved in inquiry.

However, one can question whether such involvement with scientific inquiry can lead students to use the same processes in asking questions and making decisions in everyday life. Being involved in inquiry (designing experiments and controlling variables) is part and parcel of being literate in science, but is it part and parcel of “literacy for all?” How often do we have occasion for doing this sort of experiment in
everyday life? These questions are inevitably related to the purposes of scientific literacy, which I address later in this chapter.

**Scientific Literacy and the Nature of Science**

Another set of science educators de-emphasize content and inquiry skills, defining scientific literacy as knowledge of *what science is*, that is, knowledge of the nature of science (Lederman, 1998; McComas et al., 2002; Shamos, 1995). Because those unfamiliar with science education may not be aware of the issues involved in teaching about the nature of science, these are presented in some detail below.

Nature of science (NOS) refers to the epistemology and sociology of science, or science as a way of knowing (Lederman, 1992; Lederman et al., 2002). However, the nature of science (NOS) is a contested domain as historians, philosophers, and sociologists of science disagree on relevant issues and characterizations. Furthermore, whereas the science education community agrees that it is important to teach students about the nature of science, there is no agreement on which nature of science to teach. “It is hard to argue that there is an established consensus about the nature of science, let alone agreement about a version that might be communicated to students” (Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003, p. 696). Many educators question whether NOS-related curriculum documents represent a consensus or, alternatively, the kind of compromise which is often the product of reports produced by committees? That is, do they represent the lowest common denominator around which it is possible to achieve agreement rather than any coherent account of the nature of science? (Osborne et al., 2003, p. 693)

On the other hand, Lederman et al. (2002) argued that:
Many disagreements about the specific definition or meaning of NOS that continue to exist among philosophers, historians, sociologists and science educators are irrelevant to K-12 instruction . . . at one point in time and a certain level of generality, there is a shared wisdom (even though no complete agreement) about NOS among philosophers, historians and sociologists of science. (p. 499)

These elements of the nature of science that can be taught to students include: “scientific knowledge is tentative; empirical; theory-laden; partly the product of human inferences, imagination and creativity; and socially and culturally embedded” (p. 499). More specifically, McComas et al. (2002) described statements about the nature of science that seems to enjoy some agreement among science standards in several western countries. These include:

1. Scientific knowledge, while durable, has a tentative character.

2. Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, and skepticism.

3. There is no one way to do science (therefore, there is no universal step-by-step scientific method).

4. Science is an attempt to explain natural phenomena.

5. Laws and theories serve different roles in science; therefore students should note that theories do not become laws even with additional evidence.

6. People from all cultures contribute to science.

7. New knowledge must be reported clearly and openly.

8. Scientists require accurate record keeping, peer review and replicability.

9. Observations are theory-laden.

10. Scientists are creative.
11. The history of science reveals both an evolutionary and revolutionary character.

12. Science is part of social and cultural traditions.

13. Science and technology impact each other.

14. Scientific ideas are affected by their social and historical milieu. (pp. 7-8)

These statements reflect some level of generality that K-12 students can study without concerning themselves too much with epistemological questions. It is argued in the literature that there are many reasons for students to learn about the nature of science. Some of them concern understanding science as a cultural heritage (Matthews, 1994) and others center on understanding the nature of science in order to make decisions on science issues (Driver, Leach, Millar, & Scott, 1996).

*Scientific Literacy: Critiques and Consensus*

Although various aspects of scientific literacy—content, methods, and NOS—have their proponents, they have detractors as well. Perhaps the most frequent target of critique is the tendency to consider this literacy to be measured by the results of a content-knowledge test. Solomon (1999) asserted that while the results of the public surveys may seem discouraging, people can still use scientific language appropriately and most importantly average people can and will seek information when it is necessary and relevant to their lives. For example, contrary to the passive image of Americans in interpretations of the national surveys (discussed above), studies of groups of people who had an urgent need to know science (such as parents of children with Down’s syndrome) are able to look up information (Layton et al., in Fensham, 2000).
Furthermore, studies show that realistically speaking, people can function in society very well without much knowledge in science. It appears that although people may not be responding correctly on an abstract test, they can and will use science if they need it. This suggests that scientific literacy should not be measured in its abstract form, but rather in its use (Solomon, 1999).

Given this disparity between people’s measured understanding of science and their ability to use it, most science educators tend to understand ‘scientific literacy’ as a combination of several skills and competencies. Even Jon Miller, who was instrumental in developing the NSF measures of scientific literacy, has argued that such literacy is more than mere knowledge of scientific facts. He cited “three dimensions of civic science literacy:”

(1) a vocabulary of basic scientific constructs sufficient to read competing views in a newspaper or a magazine; (2) an understanding of the process or nature of scientific inquiry; and (3) some level of understanding of the impact of science and technology on individuals and on society. (Miller, 1998, p. 205)

Miller’s definition incorporates content, inquiry, nature of science, and a fourth aspect which is the application of all three of these understandings to particular contexts.

It is this fourth component—the ability to link science’s content, methods, and nature to actual, real-world contexts—that comes nearest to justifying the need for Science, Technology, Society (STS) education to develop scientific literacy. But perhaps an important first consideration in the debate over scientific literacy has been overlooked. After all, “scientific literacy” is not really as much a goal of science instruction as it is a means of achieving a goal. What, then, should ‘scientific literacy for all’ allow us to accomplish?
Although there are multiple meanings of scientific literacy, in order to assess the relevance of different approaches it is important to look at the various, commonly understood goals for teaching science. Rationales for teaching science usually center on several themes, including learning science for economic productivity or career preparation, learning science to make personal and social decisions, and learning science for individual fulfillment (DeBoer, 2000; Hurd, 1997; Millar, 1996; Yager, 1990).

Broadly conceived, then, the reasons for learning science include the hope that science instruction will contribute to the betterment of society as well as the betterment of the individual. The National Science Education Standards state that the goal for teaching science is to educate students who are able to:

- Experience the richness and excitement of knowing about and understanding the natural world;
- Use appropriate scientific processes and principles in making personal decisions;
- Engage intelligently in public discourse and debate about matters of scientific and technological concern;
- And increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers. (NRC, 1996, p. 13)

Although these goals are couched in the language of personal fulfillment, they clearly serve the mission of improving society, as well (assuming that society is better off for having citizens who are economically productive and able to contribute to sound public discourse). Millar (1996) presented similar arguments for teaching science, which are categorized as: economic, practical, democratic, social, and cultural.

Although there appears to be consensus around the general goals of science education, there has been some debate over whether these goals are attainable or even realistic. Based on Millar’s (1996) analysis, I consider these arguments individually.


Economic Argument

It is not uncommon for parties interested in science education to sound the economic alarm about how poorly our students are performing in science and about how this affects the U.S. economic competitiveness. In its report, “Before It’s Too Late,” The National Commission on Mathematics and Science Teaching for the 21st Century (2000), headed by astronaut John Glenn, asserted that “the future well-being of our nation and people depends not just on how well we educate our children generally, but on how well we educate them in mathematics and science specifically” (p. 4). The report pointed out that our children are falling behind and are simply not “world-class learners” when it comes to mathematics and science. The commission goes on to state that “the rapid pace of change in both the increasingly interdependent global economy and in the American workplace demands widespread mathematics- and science-related knowledge and abilities” (p. 7) and that the nation’s security depends on math and science education.

However, many educators challenge sounding the economic and security alarm as a basis to teach science and point out that our scientific and technological advances are pretty good to say the least (DeBoer, 2000; Millar, 1996; Shamos, 1995; Solomon, 1999). The nation has enough individuals highly proficient in technology (Shamos, 1995) and there are so many factors involved in economic competitiveness that assigning blame exclusively to schools—let alone science (or math) education—is inappropriate (Cheek, 1992). In the end, then, the goal of teaching science for economic prosperity is probably misguided.
Practical Argument

The argument that people need to know science in order to make practical decisions in their everyday lives has been critiqued, as well (Millar, 1996). Millar suggested that people do not need a good understanding of science to function in a highly technological society, and that as we become more technologically advanced, we often need less knowledge of science to operate this technology. Even very successful persons often lack the understanding of the science that we require of all students in high school (Roy, 2000). Furthermore, there is a weak link between scientific knowledge and everyday practical decisions. For example, there is no evidence that physicists have fewer car accidents because of their understanding of Newton’s laws of motion (Millar, 1996). In fact, Millar argued that even scientists often make decisions on practical issues based on personal, social, and aesthetic factors rather than scientific ones. It is also unclear that the simplified version of science that students study in schools is of any use to them in their daily lives (such as physics problems analyzing the fall of objects without air resistance or the movement of objects on perfectly smooth surfaces). In fact, a practical argument would suggest a curriculum that focuses on technology rather than on science, since we rarely engage in scientific problems in daily life. It is important to note that these critiques are mostly directed at teaching science as a body of knowledge, and how such knowledge may not be as relevant to practical decisions.

Democratic Argument

This argument claims that scientific knowledge is required to participate in a democracy and engage in debate and decision-making about socioscientific issues; and
once again, some educators question it. Bell and Lederman (2003) investigated the effect of understanding the NOS on decision-making on science and technology based issues of faculty members at several universities. Working from the assumption in the literature that better citizenship requires an understanding of the nature of science, the authors attempted to test how an understanding of the nature of science affects decision making. They found that understanding the NOS played little or no role in decision-making and that social, political, personal, and ethical factors dominated participants’ decision making. A question then emerges, which is also echoed by Shamos (1995): Can we really expect students to be able to understand the issues well enough to be able to make decisions, when scientists themselves don’t seem to be able to do it? Should we leave these decisions to experts and how does that impact the democratic process?

The other problem with the democratic argument is the sheer number of issues. These issues require specialization, which implies that it is probably unreasonable for students to be prepared to handle issues that are very diverse and complicated. But morally speaking, *should* decisions be left to experts alone? Solomon reminded us that:

> Since the new science-based technologies, from modern agriculture to gene therapy, clearly present us with possible risks which may be personal and intimate, this forced dependency on scientific experts is not at all trivial. Risk itself, as opposed to the older idea of hazard or chance, is redolent of our new age. We need to trust not only the experts’ understanding of what is incomprehensible to us, but also to trust that science itself has uniquely correct answers. All of us have evidence that the uniquely correct answer does not appear to exist when we most want it. Scientific experts wrangle and disagree in public. Even expertise is contested! (1999, p. 5)

Either complete dependence on experts or complete rejection of them is dangerous (Collins & Pinch, 1993). Students do and will need to make decisions on socioscientific
issues. The problem for science educators may be that it is unclear what kinds of learning experiences would most benefit students in this regard.

**Social and Cultural Argument**

Millar (1996) suggested that the strongest rationale for teaching science is the social and cultural argument: that students need to appreciate science as the major cultural heritage of our society. This is also expressed by Shamos (1995) who argued for science appreciation, and echoed in many versions of teaching the nature of science as part of the liberal arts tradition (Matthews, 1994). However, this should not be understood as appreciation of science for its own sake, because an understanding of science as part of our culture does not necessarily mean that we should glorify science. A sociological understanding of science can explore the power, values, and personal commitments involved (Kelly et al., 1993). Along the same lines, Solomon (1999) suggested the use of “scientific literacy” be replaced with “scientific culture.” This scientific culture or popular science aims at introducing to students “a science which is lighter on logic and abstraction, stronger on involvement and active evaluation, and intimately woven into the aspirations and concerns of citizens” (p. 9). Therefore for Solomon, achieving scientific culture implies a curriculum that places social issues that are relevant to students at the center of instruction, and that places science in its historical and social context as a human activity. It is a science appreciation that is intertwined with the democratic argument.

In the end, one can conclude that there is really no strong evidence for one particular reason of why students need to learn science, but it is a combination of multiple
perspectives. In addition, there is a need to examine what is being taught in the classroom, and its connection to the reform movement.

*Putting the Goals of Science Education in Perspective*

It might seem from the discussion above that science educators are trapped in the endless foundational argument over whether education is best conceived as a means of establishing appreciation for a traditional cultural heritage, or whether education is rather to be thought of as an opportunity to develop critical thinking skills necessary for life outside of the classroom. And is often the case in this debate, science educators’ preferences perhaps lie somewhere in the combination of the two.

Ultimately, it may be the case that the goal of science instruction is irrevocably tied to the needs of those who are being instructed. Ironically, as more calls for “science for all” are being made in the science education literature, science instruction in the classroom seems to maintain the status quo as science for the elite (Fensham, 2000). Instruction in classrooms still seems to focus on content which only benefit those who are pursuing science careers in college. This tension between science for the elite and science for all reflects competing goals for science education. A science education that aims at training few people to pursue careers in science would look different than one which aims at preparing the majority to live in a modern technical society (Millar, 1996). Therefore, having a policy statement that demands scientific literacy is not enough if it is not accompanied by a serious rethinking of the actual curriculum. Fensham (2000) reviewed several reform documents in several western countries such as the Benchmarks for Scientific Literacy (AAAS, 1989), the National Science Education Standards (NRC,
1996), National curriculum in England, and others. Except for the curriculum in Denmark, the curricula in the other western countries have not been seriously reduced in content. Fensham (2000) argued that in attempting to make science relevant to all students, we may have made it more content oriented than ever. Fensham explained that the content of science was not seriously examined in new reform efforts. For example, in the US, in addition to the traditional courses in physics, chemistry, and biology, new disciplines were added such as earth and space science, nature of science and technology, and applications of science and technology. These new standards require more content for all students than the content that was required from the students interested in careers in science. “In becoming curricula in practice, there was only a pragmatic reduction in the range of content in the 1990s rather than any principled excision” (p. 150).

Similarly, Millar (1996) argued that the science curriculum in England has not changed much to suit a “science for all.” Trying to fit both the minority who will become scientists and the majority who need basic scientific literacy, it becomes “unsuited to either of its purposes” (p. 10). These critiques of science curricula both in the U.S. and England reflect competing values of what knowledge is worth knowing. A vision of “science for all” is inconsistent with an increasingly content-laden curriculum. These concerns were also reiterated by DeBoer (2000) who claimed that there are too many visions for the science education reform.

Furthermore, these critiques of the standards—and by association, the instructional goals underlying them—by science educators reflect some power dynamics regarding who gets to decide what gets included in the science curriculum. In almost all
of these reform documents, scientists are consulted on what topics need to be included, which resulted in more content. This has created some debate in the literature around the role of scientists in preparing science curricula for students: Can and should scientists decide what all students should know about science? (Cheek, 1992; Fensham, 2000).

From the above discussion, we can conclude that there are various, and at times competing, visions of what science education should accomplish. Perceiving the goal of science teaching to prepare students for economic productivity can result in curricula that are overcrowded with content. The rhetoric of connecting science education to our economic and technological advancement is all too familiar. The National Commission on Mathematics and Science Teaching for the 21st Century (2000) asked: “in an integrated, global economy, whose key components are increasingly knit together in an interdependent system of relationships, will our children be able to compete?” We have seen that this sense of crisis of scientific literacy is not warranted as there is no evidence to suggest that what students learn in school influence what they do as adults, or that our economy is in jeopardy based on school performance (Shamos, 1995).

Without the discourse of preparing students for future productivity, one can ask moral questions about what is a good education for students involved regardless of how it will affect them several years down the road (AAAS, 1989). This can be conceived as a combination of several perspectives, including a practical concern, a societal concern, and above all, a sense of appreciation for science. As a product of our culture, the aspects of science for social relevancy allow students to explore the complex place of science in our culture: how it changes us as humans and as society, and how science itself is a
product of culture. More importantly, the needs of students need to be considered, not in terms of future uses, but (as discussed later in Chapter 2) in line with Dewey’s (1938/1997) focus on educative experiences, that have continuity and that lead to personal growth.

**STS As a Framework to Achieve Scientific Literacy**

One way of thinking about scientific literacy as an integrated curriculum that caters to students’ interests and needs is through the Science, Technology, and Society approach. I discuss its history, the multiple meanings associated with it, and the implications to teacher education.

*History of STS*

The idea of science for social relevance is not new. Since the turn of the 20th century, there have been tensions between several competing themes or goals in conceptions of a science curriculum, which also reflects the tensions in the conceptions of the American curriculum in general (DeBoer, 1991; Kliebard, 1995). Two of the themes that dominated discussions about the science curriculum were science as a process (or a way of thinking) versus science as a product (or content). Although both existed in the curriculum at any point, one or the other tended to dominate at any given time. The third theme that also fluctuated in importance is science for social relevance, which could mean several things depending on the educator’s values and commitment, from making science relevant to daily experiences, to structuring the science curriculum around social issues (DeBoer, 1991).
In the 1920s there was a push to teach science in a social context to accommodate an increasing student enrollment at the turn of the century. During the 40 years that followed, in a climate of progressive education in American curriculum, there was a push against traditional science, which was perceived to alienate students, towards engaging students in problems that related to their everyday lives. This pressure to adjust the science curriculum to meet students’ needs as future citizens in a democratic society was manifested in general science classes rather than in the specialized courses. During that time period, there were suggestions that instruction in these general science courses be structured around problems or issues (DeBoer, 1991). This trend towards social relevance changed in the late 1950s and 1960s (after Sputnik) to stress the teaching of science content and processes.

Advocacy for science, technology, and society curricula returned in the late 1970s and 1980s, mainly as a response to environmental problems. A 1971 NSTA position statement abandoned the idea that the scientific disciplines should be studied for their own sake and stressed the themes of “social relevance, student interest, the relationships between science and other areas of the curriculum, the interdependence of science and technology, and the human aspects of the scientific enterprise” (DeBoer, 1991, p. 177). The 1960s and 1970s calls for STS-like curricula culminated with a 1980 NSTA statement that enacted STS as a preferred policy for science education (Bybee, 1991). The statement by NSTA affirmed that:

The goal of science education during the 1980s is to develop scientifically literate individuals who understand how science, technology, and society influence one another and who are able to make use of this knowledge in their everyday
decision making. This individual both appreciates the value of science and technology in society and understands their limitations. (NSTA, 1982)

More specifically, the Science, Technology, and Society movement evolved simultaneously in several countries in Europe and North America (Layton, 1994). According to Yager (1990, 1996a), STS had its origins in the UK in the 1970s with curricula such as Science in Society and Science in a Social Context. Around the same time, Canadian scholars Aikenhead and Fleming published their work Science: A Way of Knowing (Layton, 1994). STS became prominent in the U.S. after Project Synthesis, an initiative by NSF, launched to find out where science education was and where it should go. The report concluded that the goals for science teaching should focus on four goals: (a) science for personal needs, (b) science for resolving societal needs, (c) science for assisting with career choices, and (d) science for preparing for further study (Yager, 2001, p. 84). STS curricula emerged as a response to the first three goals mentioned in the report (Yager, 1990). The movement accelerated further in the United States with NSTA’s position statement of 1982 (above).

In the 1990s, an NSTA position paper appeared to suggest that STS was the reform movement in science education. This came to a halt, however, when “purists from the discipline oriented sciences” (Yager, 2001, p. 86) became involved. These individuals, mostly scientists, sought to identify the concepts and skills that all students should know. Scientists assumed that if teachers present science in the same way that scientists understood their discipline, it would make sense to students. As a consequence, many scientists became outspoken critics of STS as not teaching real science, which
resulted in NSF halting its funding for STS projects. Despite these critiques, researchers continued to develop curricula aligned with an STS orientation.

The National Science Education Standards (NRC, 1996) re-established social relevancy in science education, as complementary to studying the content and processes of science, but not as a major organizer of the curriculum. Among the eight standards of the national science education content standards, one is devoted to: “Science in personal and social perspectives,” and another concerns “History and nature of science.” Also, one of the goals of the National Science Education Standards (NRC, 1996) is to “educate students who are able to . . . engage intelligently in public discourse and debate about matters of scientific and technological concern” (p. 13). However, it is important to note that the NSES do not use the term STS once (Yager, 2001)⁵.

**What is STS?**

STS curricula use a current problem or issue as a starting point for instruction instead of focusing on the structure of the scientific disciplines. In most STS curricula, students use all available resources to resolve a problem, even advancing to take actual actions in the community towards that resolution. STS also requires students to explore issues such as: what scientists are allowed to do, and whether limits should be placed on technology (Bybee, Harms, Ward, & Yager, 1980). Based on several surveys that solicited responses from teachers, college students, science educators, and scientists, Bybee (1997) outlined several STS issues that are most important. These issues include:

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⁵ The STS framework is also established in the social studies education field. The National Council on Social Studies (1994) lists Science, Technology, and Society as one of its 10 thematic strands in social studies education.
“air quality and atmosphere, world hunger and food resources, war technology, population growth, water resources, energy shortages, hazardous substances, human health and disease, land use, nuclear reactors, extinction of plants and animals, and mineral resources” (p. 95). We can add to this list the issues that involve biotechnology and which figure often in media outlets.

Rationale for STS

It is argued that STS motivates students to learn and that it sharpens their creativity since it starts from their questions and makes connections to their lives (Yager, 1996b). This movement has been driven by societal problems such as food and energy resources, population growth, and pollution, which caused a rethinking of the goals of science education. STS advocates stress that people need to be aware that their personal decisions contribute to larger societal decisions that can either perpetuate or alleviate social problems (Bybee & DeBoer, 1994; DeBoer, 1991).

DeBoer (1991) identified several reasons suggested in the literature for teaching from an STS approach. The first deals with motivation: when students learn science in a context that is familiar to them, they will be more interested in learning about it. The second deals with personal relevance: students need to learn the aspects of science that affect them personally and help them make decisions. The third deals with the larger societal benefits of educating students who can address local and global concerns related to science.

Although most educators would agree on the reasons for teaching a socially relevant science, there is much disagreement on the extent to which these issues should
become the focus of teaching. Organizing the curriculum around issues is critiqued mainly for two reasons: first, students do not see the organization of science. Second the socially relevant issues may change over time, thus creating a problem for a stable science curriculum.

Models of STS

There are multiple ways of conceiving of STS. The earlier models focused on examining specific issues that relate to science whereas the newer ones advocate looking at the moral aspects of these issues as well. Yager (1996a), one of the early advocates for STS, described an STS approach as “starting with students and their questions, using all resources available to work for problem resolution and whenever possible, advancing to the stage of taking actual actions individually and in groups to resolve actual issues” (p. 10). Yager stressed that students identify problems or issues that are local to their community or environment and use local resources in resolving these problems. Yager also emphasized that students learn the concepts of science as they need them in the process of solving a problem. Hence, concepts are retained because they are useful to students, which in Yager’s terms, constitute real learning.

Similarly, Aikenhead (1992) described a model to implement STS in the curriculum as follows:

1. Instruction begins with a problem or question.

2. Students need to become familiar with technology in order to understand the question (a social question creates the need to know certain technology information, then both create the need to learn science).
3. Students learn the underlying science to understand the problem.

4. Students use their technology knowledge in order to better understand technology.

5. Students make an informed decision of the social issue based on their understanding of the scientific concepts and relevant technology.

It can be seen that while Yager’s model focuses more on science, Aikenhead’s model involves an understanding of technology. More recently, other scholars have pointed out how STS curricula focus largely on science rather than an understanding of the history, nature, and role of technology in many social issues (Cheek, 2000; Roy, 2000). Roy pointed out that students often confuse technology with applied science by assuming that basic science leads to applied science which leads to technology. However, science and technology are different domains of knowledge, and can sometimes evolve separately: Science concerns itself with the study of the natural world for the purposes of explaining it, whereas technology involves human design to solve practical and societal needs (Aikenhead, 1992). However, the relationship is not that simple. Science is becoming increasingly dependent on technology as technological developments determine what can and cannot be done in science (Hurd, 2000).

Whereas earlier models of doing STS focused on the science aspect of issues, Sadler and Zeidler (2005) discussed the need to take into consideration how students reason on moral and ethical levels. Sadler and Zeidler delineated socioscientific issues as environmental or bioethical issues that are “based on science concepts or problems,
controversial in nature, discussed in public outlets, and frequently subject to political and ethical influences” (p. 113). They differentiate between socioscientific issues and STS:

Whereas STS tends to focus on the impact of science and technology on society, it typically does not explore the moral and ethical implications that underlie these issues. In contrast, the socioscientific issue movement arises from a conceptual framework that unifies the development of moral and epistemological orientations of students and considers the role of emotions and character as key components of science education. (p. 113)

This distinction can be attributed to the concurrent development of the literature on teaching “nature of science” in science education, which is discussed further.

STS and NOS

The STS field has grown increasingly complex, with the recognition that an understanding of STS issues cannot be separate from discussions of the nature of science. There are also concerns that past STS curricula glorified science as objective and rendered the debate to social issues. The science itself was never in doubt (Carlsen, Kelly, & Cunningham, 1994). Many educators now question the extent to which students need to know science in order to make decisions on issues (Kolstoe, 2000). It is clear that “scientific and technological issues figure more and more in the political process” (Collins & Pinch, 1993, p. 142). However, many science educators now argue that what the public needs to know in order to make decisions is not more content, but more of what science is, and how it is practiced in society. As Collins and Pinch noted, if “scientists at the research front cannot settle their deep disagreements through better experimentation, more knowledge, more advanced theories, or clearer thinking” then “it is ridiculous to expect the general public to do better” (pp. 142-143). Therefore, expecting students to be able to decide on issues by knowing more content is not
supported. What they need to explore are issues like the relationship between experts and politicians, and how that plays out in the media.

This section described several conceptual orientations of STS from earlier efforts that focused on the impact of science on society to more attention to the science itself as a social practice. This later move is influenced by the literature on teaching about the nature of science. It is important to consider these conceptions of teaching STS within a larger theoretical framework for science education. I next examine how STS is linked to constructivism as a theoretical framework of how students learn science, outline some problems with this approach, and discuss how a Deweyan perspective may be more suitable.

Theoretical Framework for STS

As stated earlier, STS as a movement evolved in different directions, without necessarily having common grounds. Lawrence et al. (2001) noted that “if anything, those promoting STS have not proclaimed nor elaborated its strong basis in both philosophy and theory as much as they should” (p. 4). Since the STS movement originated in different programs and several countries, it is hard to talk about one theoretical framework for STS. However, there seems to be a coupling in the literature between constructivism and STS approaches (Cho, 2002).

Constructivism in Science Education

Constructivism is presently the dominant learning theory paradigm in science education (Tobin, Tippins, & Gallard, 1994). One can hardly read a science education article that does not affirm constructivism. For example, the National Science Education
Standards (NSES) promote a constructivist approach to teaching science. Rodriguez (1997) wrote that “even though the term constructivism is not used even once in the NSES, it is clear that individual constructivism is the driving theory of teaching and learning throughout the document” (p. 30). Individual constructivism follows a psychological tradition, mainly influenced by the work of Piaget. Other science educators focus on sociological factors, following Vygotsky’s influence (Matthews, 1997). In both cases, the individual is thought to construct meaning and sense based on interaction with the world; what differs in Piagetian and Vygotskian versions is often the significance that is placed on interactions with other people in this process of knowledge-construction.

Constructivism is basically contrasted to a ‘behaviorist’ model, which sees learning as a matter of internalizing more-or-less self-contained ideas from outside the individual, based upon the (perceived) reward associated with knowing them. For constructivists, then, the meaningfulness of any particular idea is thought to relate to an individual’s own pre-existing system of understandings; conceptual development is not something that is to be ‘trained’ (through, e.g., reward or punishment), but rather, something that emerges from the proper connection with (or even re-arrangement of) the learner’s already-established network of conceptual knowledge. Matthews also described pedagogical constructivism which focuses on student-centered teaching without too much attention to questions of epistemology. I discuss below how scholars have linked the STS movement to constructivism.

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6 Educational constructivism with a focus on sociological components of learning is different that sociological constructivism in the science studies movement where scientific growth, and modifications in theories is explained with reference to changing social factors and interests; while the power of rational reasoning is dismissed (Matthews, 1997).
STS and Constructivism

In the literature of STS education, references to constructivism often integrate the educational and pedagogical varieties (Matthews, 1997) described earlier. For example, Yager (1995) situated STS as a reform movement within the broader learning theory of constructivism. He wrote:

Teaching techniques that help students formulate meaning for themselves have now been proposed and tested, especially by educators involved with STS. Such teaching strategies are now called constructivist teaching, even though that term is usually reserved for a way of describing human learning. STS by definition requires such teaching. (p. 225)

Yager suggested that teachers can provide an environment for students to learn, but ultimately, “learning is something that each person must do for him or herself,” and “when it occurs, learning occurs automatically” (p. 226). Similarly, Aikenhead (1992) outlined constructivism as a feature for developing STS materials. He stated that:

STS science shifts the focus from (a) knowledge transmittal of an academic scientist to (b) knowledge construction of a student. This student-oriented approach continues to emphasize the basic facts, skills, and concepts of traditional science, but does so by embedding that science content in social-technological contexts meaningful to students. (p. 34)

Because of its emphasis on real-world problems, this association between constructivism and STS focuses on student-centeredness and higher order thinking skills. It is clear from Yager’s discussion that his linking of STS to constructivism is primarily related to students being actively engaged in the process, and not necessarily because STS is easier for students to integrate into their conceptual structures (a concern which might be expressed, for example, by the conceptual change literature in science education). Yager

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7 While most STS educators align STS with constructivism, a few others propose alternative frameworks. Blades (2006) introduced a framework for STS that is based on a philosophy of ethics.
did not specifically attempt to describe students’ experiences with STS as a way to make conceptual representations of the world. Rather, we can say that Yager adopted a pedagogical constructivism stance, which advocated that students be engaged rather than passively listening to the teacher as a “talking head.” It seems like Yager (and Aikenhead as well) associated STS with constructivism because of the focus on students being engaged, but also because students are learning scientific concepts in the process.

Although Yager uses the term constructivist teaching to mean students being engaged, Lutz specifically addressed whether STS and constructivism are congruent. Lutz (1996) concluded that in order for learning to occur, the learner must be mentally active, and needs to have concrete experiences. In this way, Lutz explicitly linked STS as a teaching strategy to constructivism as a learning theory. She said: “constructivism is the learning theory that underlies the teaching strategy known as STS. Viewed this way, constructivist teaching methods are by definition congruent with STS teaching methods” (p. 40). Furthermore, Lutz said that STS can be viewed as a form of conceptual change. She explained:

One could argue very persuasively that the most likely cause of conceptual change is when current issues are under investigation, and result in a perceived need for a more adequate explanation or viewpoint than that which the observer currently holds. (p. 43)

For Lutz, learning “takes place within the mind of the individual learner” (p. 40), and STS provides the appropriate activity for these mental constructions to occur. In other words, STS, as a problem-based learning, is congruent with constructivism because students are actively involved in finding answers to problems rather being lectured about
content. In such a model, students are constructing better conceptions of science because they are involved in real world, interesting and relevant problems.

Another project that sought to frame constructivism as a theoretical framework for STS is the work of Cheek (1992). Cheek extended the focus on constructivism as students learn the content of science, to the area of students’ conceptions about science, technology, and society. In such an approach, STS education is thought to help students change their naïve conceptual understanding of a socioscientific issue. In addition to revealing students’ conceptions about science, Cheek observed that researchers need to uncover students’ conceptions of politics, economics, and social functions in order to develop STS approaches. Similarly, a seminal project by Aikenhead and Ryan (1992) sought to develop a questionnaire that elicits students’ conceptions of the nature of science, technology and society interactions (VOSTS). Many researchers use this instrument (or modified versions of it) to test students or teachers conceptions of science, technology and society.

It can be seen that the range of associating constructivism with STS varies from a focus on pedagogical constructivism (Yager, 1995, 2001) to an explicit discussion of the congruency of STS as a teaching strategy with constructivism as a learning theory (Cheek, 1992; Lutz, 1996). STS is viewed as providing a teaching strategy that allows students to properly construct scientific concepts, and images of science and society. In the following section, I outline some of the critiques of constructivism in science education in hope of shedding some light on some inconsistencies that arise from associating STS with constructivism.
Critiques of Constructivism as a Framework for STS

This linking between STS and constructivism is problematic. Constructivism, as a framework for learning scientific content, is challenged in the literature (Lemke, 2001; Matthews, 1997; Sherman, 2003). Science educators influenced by constructivism proposed a theory of conceptual change to account for how students learn science (Posner, Strike, Hewson, & Gertzog, 1982). Conceptual change attempts to account for how students learn to replace their “naïve” understanding of natural phenomena with the scientific accounts. First, a teacher introduces a discrepant event so that the student becomes dissatisfied with her existing conceptions. The teacher then introduces the correct scientific conception, which the student must find to be intelligible, plausible, and fruitful in a new situation. When this is done, the student rationally realizes that her old conceptions are faulty, and replaces them with the new scientific ones. This model suggests that students can rationally find flaws in their thinking with the correct teaching methods (discrepant events), which ignores other non-rational factors in learning, such as socio-cultural factors (Lemke, 2001) or emotional factors (West & Pines, 1983).

Lemke (2001) observed that there is a lot more to learning than just rational decisions. Our cultural baggage influences choices we make about what we are interested in learning in the first place. Lemke provided a dramatized, but rather telling example:

To adopt an evolutionist view of human origins is not, for a creationist, just a matter of changing your mind about the facts, or about what constitutes an economical and rational explanation of the facts. It would mean changing a core element of your identity as a Bible-believing (fundamentalist) Christian. It would mean breaking an essential bond with your community (and with your god). (p. 300)
This focus on rational factors is also challenged by Wong and Pugh (2001), who affirmed that “Dewey might argue that conceptual change science falls short because to portray students as rational and cognitive beings does not fully characterize what it means to be human” (p. 334).

Similarly, using a Deweyan perspective, Garrison (1997) argued that constructivism errs in explaining learning as mental constructions, as this introduces a new level of explanation that is not needed. As Garrison explained, constructivism separates the doing from the thinking: A person is viewed as taking in sensory information and transforming it into mental construction. Doing is viewed as inferior to thinking, which, according to Dewey, was a result of “a social class dualism that arose from the privilege of those who did not have to work and so had time for speculation” (Garrison, p. 547). Garrison questioned the value of explaining understanding in terms of mental structures and adding yet another level of ambiguity and abstraction. In addition, the problem with constructivism is in attributing the goal of learning to develop logically consistent propositional networks of the world around us in order to operate in it (Sherman, 2003). Instead, Garrison proposed a Deweyan perspective that shaves off mental constructions and focuses on meaning making in interactions with the world. As Garrison explains, Dewey believed that having a mind means being able to participate in the social practices of a community, such as speaking its language, and interacting with its members using common tools and modes of work.

It is not my intention in the above discussion to set up a straw man argument against constructivism, so that I can offer a solution. Rather, I am trying to discuss some
inconsistencies in relying on constructivism as a framework for science learning. Although there are criticisms of STS, this connection of STS as a teaching strategy to constructivism as a learning theory has not been challenged. Focusing on STS as a way to make students change their conceptions about science, technology, and society interactions leaves us in the same epistemological problems that the conceptual change movement is riddled with. I explore how using Dewey’s focus on experience as an alternative framework for doing STS might be more useful.

*Deweyan Perspective for STS*

Another possibility for conceiving of STS is through the lens of Deweyan philosophy. For Dewey (1938/1997), the purpose of education is to provide students with worthwhile experiences. These experiences need to be valuable on their own, in the present, as well as open the door to other worthwhile experiences. This is very different than a discourse that focuses on preparation of students for future economic productivity. Dewey critiqued education with a focus on having students acquire skills for the sole purpose of using them in the future. That is not to say that education should not prepare students for a future life. In Dewey’s philosophy, every experience should lead to growth. But to assume that accumulation of knowledge in a certain subject will make people better prepared for college or adult life is mistaken. Dewey affirmed that “we always live at the time we live and not at some other time, and only by extracting at each present time the full meaning of each present experience are we prepared for doing the same thing in the future” (p. 49). But what is an experience in the Deweyan sense?
Wong and Pugh (2001) contrasted a Deweyan experience to an ordinary experience. An ordinary experience is mere activity, without a clear development or flow. It stops rather abruptly, by external interruptions or internal laziness and it does not achieve its full potential. On the contrary, a Deweyan experience is more involved. It is rather like a play, where there is anticipation, a sense of possibility, a fulfillment, and consummation. At the core of a Deweyan experience is the idea of consummation. “The individual looks forward to, imagines what may or may not be, and is surprised, disappointed, or fulfilled when consummation occurs” (Wong & Pugh, p. 321).

This framework is different than constructivism in the sense that Dewey does not focus on learning as a cognitive process. Experience for Dewey is not a psychological phenomenon. It is the interaction between person and the world (Jackson, in Wong & Pugh, 2001). Learning, for Dewey is participation with others, with the natural world, and by oneself. *It is life.* Powerful ideas create opportunities for students to be in the world; not to create a mental image of the world, but to be involved, body and mind, in the world (Dewey, 1938/1997; Wong & Pugh, 2001). In other words, instead of seeing ‘learning’ as the reconstruction of mental schema, Dewey asked us to see ‘learning’ as something like ‘living an experience.’ Let’s take the example of light. Constructivists might talk about light in terms of scientific conceptions, and consider the act of teaching as changing students’ conceptions to match the correct scientific one. Deweyan notions of light would consider how light is experienced—light as ‘safety,’ ‘security,’ or ‘information.’ Similarly, an experience with dissecting an animal is more than an exercise in learning about anatomy. It might be an experience of revulsion with science as
grotesque or awe at the complexity of the animal’s body, or anger at the process of animal experimentation. The emotional part of the experience is integral to learning and not ancillary (Wong & Pugh, 2001).

How can this Deweyan perspective inform the STS movement? The lens of constructivism in science education has led educators to conceive of students’ learning as the formation of mental representations of scientific concepts. On the contrary, a Deweyan perspective allows us to focus on STS as providing students with worthwhile experiences that engage them with the natural world around them, and with other people. Furthermore, we can think of STS as providing students with worthwhile experiences that allow them to engage with ideas. Wong and Pugh (2001) discussed a very crucial distinction between the common use of students’ ideas in science education (which can be traced to constructivism) to Dewey’s sense of ideas. Dewey’s pragmatist philosophy assumes that ideas are not meaningful on their own, but with the possibilities, consequences they create. For Dewey, “ideas are educative only to the degree that they inspire action” (p. 323). Having students experience an STS issue that is meaningful and relevant to them, and having them take action on such issues is congruent with how Dewey talked about worthwhile experiences. In this sense, we can talk about students doing STS, and not constructing images of science concepts through STS.8

Another aspect of Deweyan experiences that is relevant to STS education is the place of motivation in the learning process. From the conceptual change model, students

8 It is important to note that this critique of constructivism from a Deweyan perspective is different than adopting a socio-cultural approach to learning, in that it places more emphasis on what the idea “yields for individuals as they act in the world” (Wong & Pugh, 2001, p. 332). By contrast, socio-cultural approaches emphasize the sway of social factors on learning.
are motivated to learn by a need to resolve logical inconsistencies. However, as the research on the persistence of misconceptions shows, students are not motivated to reduce inconsistencies in their logic (Wong & Pugh, 2001). The problem with this model is the focus on the rational aspect of learning. Dewey thought of learning as involving not only thinking, but emotions, and interactions with the world using our senses. What is important to note is that the emotions are not ancillary to learning, they are part and parcel of the learning experience. For example, there are many instances in the classroom where teachers use an interesting demonstration to catch students’ attention. But this type of motivation is not part of the concepts they are supposed to learn. For Dewey, the goal of education is not just understanding, but inspiration. Students are motivated by the possibilities that the idea offers them. In that sense, STS can offer students worthwhile experiences, not to construct mental constructs about the world, but that allow them to be inspired and to seek action in the world.

When students are involved in analyzing an STS issue that is local to their community (pollution in a nearby river, preserving a local bog, building a nuclear power plant . . .), they are not in the business of making mental representations of science and society. Instead, following the Deweyan perspective outline above, they are involved in experiences with the natural environment, with organisms in this environment (by seeing, hearing, or touching), with other peers as they work to investigate the issue, and with citizenship in this world. For Dewey, to know more means to work harder in the various practices of our culture (Garrison, 1997). Students are motivated with the ideas they are
experiencing (such as studying water resources in their community), because they are relevant to them, and they offer space for action\(^9\).

In this section, I described a Deweyan perspective as a framework to think of learning STS as being engaged with worthwhile experiences, rather than constructing mental schemes about scientific concepts. There have been many critiques of STS as a curriculum framework to organize science education, and this Deweyan perspective can adequately address these critiques. I present those critiques in more detail below.

**Issues and Concerns Around STS**

Although science for social responsibility may be a given in policy statements, there are many critiques of the concepts of STS coming from a variety of perspectives. Some critiques focus on the inadequacy of such curricula to teach science and on how these curricula are heavily influenced by social studies themes. Other critiques come from advocates of STS and focus on which issues should be chosen, what is the role of technology and to what extent values and ethics should enter the curriculum. While some may argue that STS doesn’t teach science at all and may contribute to the alienation of students from science, mainly because of the focus on negative consequences on society (Shamos, 1995), others argue that STS curricula focus heavily on science while ignoring technology and society (Cheek, 2000). This reflects in part the tension between traditional science education that focuses on portraying the structure of science in schools.

\(^9\) The use of the term action is slightly different in critical constructivist perspectives, which focus on political action for societal change. These perspectives tend to favor larger societal forces and ignore the individual’s interaction with the world. Dewey would not dismiss systemic social forces, but would add more focus to the individual and how they interact with society.
and the more humanist approach that places the students and their interests at the center of instruction. This section outlines these issues around STS.

*Is STS Real Science?*

One issue addressed by traditional science educators is whether STS teaches real science or even whether it teaches science at all. Shamos (1995) echoed these concerns, stating that little science is learned in STS curricula. However, these fears may not be grounded in research evidence. Aikenhead (1994a) showed that taking a high school STS science class does not affect college performance. Comparing the college performance of students who took traditional high school science versus students who took an STS high school science course, the author found no differences between the two groups, although the latter group had a larger percentage seeking tutoring outside of their college classes. Furthermore, these critiques of STS from traditional science may be mostly due to the critical anti-science attitudes of STS advocates (Cheek, 1992). These critiques raise valid concerns that STS materials may alienate students from science and technology and lead them to view science as mainly harmful.

More recently, in their review of the STS literature, J. Bennett, Lubben, and Hogarth (2007) concluded that students learn comparable science content in STS courses versus traditional science courses. However, this question seems to be ill placed because the two approaches focus on different ways of understanding science. We cannot compare which one better produces scientific understanding because the two approaches underscore different goals of teaching science.
A Deweyan perspective resolves the question of whether students are learning enough science content in STS courses. If the purpose of education is to provide worthwhile experiences to students, then it won’t be appropriate to measure how much conceptual understanding students are achieving on a test.

**Issues of Access**

The status of STS curricula is another point of concern. Often in practice these curricula are marginalized and become a watered down version of science, which raises issues of access: Does STS increase or decrease students’ access to science? (Carter, 1991). Hughes (2000) argued that the socio-scientific content of STS curriculum is often marginalized by the text, the teacher, and the students. In particular, the language used in the text devalues the STS content relative to abstract science content. Socio-science is either omitted from instruction or is only included in peripheral activities, which makes students prioritize abstract science and be less receptive to socioscientific discourse. The author pointed out that there is an association of STS with feminine science, which is perceived as less rigorous than abstract masculine science. Teachers feel the need to establish a status of experts and hence portray socio-science as less rigid. “Socioscientific discourse is symbolically associated with female students and subjective epistemologies, as it is constructed in opposition to masculine, objective, value-free, and decontextualized science” (p. 438). Hughes reported that whereas teachers who taught STS courses may believe that a socio-science curriculum could attract more girls to science, they were also hesitant to adopt an STS curriculum because they perceived that it would alienate their best male students. This is supported by other research by Mitchener and Anderson.
(1989) who found that teachers are reluctant to teach STS courses because in practice low-ability students end up in these classes. As a consequence, teachers may feel that these courses are not rigorous enough, and therefore not worthy of their attention.

Science, as abstract knowledge, seems to enjoy a higher epistemological stance not only in the academic community but also in schools. The perceived hierarchy of knowledge that places abstract science as higher than social issues need to be addressed if STS is to be accepted by teachers.

*Science or Values?*

The central position of values—as opposed to science—in discussions of STS issues often raise concerns. Many of today’s societal problems cannot be resolved using science and technology alone, as they often involve values and ethical consideration, however, they cannot be solved without them (Kranzberg, 1991, p. 238). To understand any issue involves complex analysis of science, technology, and values and the extent to which the science curriculum can address all of these is questionable. Ultimately, the problematization of values in science is due to a dichotomy between science as objective reality and values as subjective judgment. This dichotomy is due to the perception of learning as a rational activity, and rendering of the subjective to an ancillary position. A Deweyan perspective resolves the issue by focusing on learning as a way of engaging with the ideas physically, emotionally and cognitively. Students are engaged with all aspects of the issue and not just the conceptual understanding. For Dewey, “learning is compelled by the possibility of living a life more vibrant with thought, feeling, and
action” (Wong & Pugh, 2001, p. 334). By analyzing an STS issue and clarifying their values, students are not just engaged with science, they are engaged with life.

On a more practical level, teaching scientifically based social issues raises problems. It is an area of interdisciplinary study where more than science knowledge is required from the teacher. Crosthwaite (2001) raised questions about teaching ethics in science and technology. Do you teach the ethical issues in a science class or in an ethics class? In the first case, the science teacher may not have enough knowledge about ethics; in the second the teacher may lack knowledge in the science area. If you teach ethics in science as a separate course, then how much scientific background do you need to give the students? These distinctions are problematic to the extent of subject divisions in the schools. An integrated curricular approach addresses many of these concerns, as students can be studying issues of concern to them, rather than subject matter.

This section outlined some issues surrounding STS as a curriculum approach. They range from concerns that STS does not teach enough content, to complex issues around how to teach values. However, the most important factor in the STS discussion remains the role of teachers in implementing STS.

What’s Missing: The Teacher’s Role

Although social relevance continues to be a popular idea among science educators, they have had problems convincing teachers of the merits of such an approach (DeBoer, 1991). This could be due to several reasons, mainly the perceived lack of status of STS content and the confusion about what it means. Many researchers assert that there is a practice-policy gap (Bybee, 1991) and that teachers need to restructure their beliefs
about the goals of teaching science (Aikenhead, 1984). Most of them also recognize that preservice and in-service courses need to address teachers’ values and beliefs (Aikenhead, 1984; Rubba, 1991). Solomon (1999) also affirmed that curriculum reform cannot happen if the teachers do not buy in. Therefore, it is not surprising that research has turned to looking at teachers’ views of STS: “Despite the pervasive and critical role of curricula, evidence is clear and substantial that teachers are the most influential factor in educational change” (McComas et al., 2002, p. 23). In this section, I outline the research that has been done with teachers’ views and implementation of STS, and then look at alternative ways of researching teachers’ role in STS.

Research on Teacher’s Beliefs

This focus on teachers’ beliefs resonates in science education in general. The National Science Education Standards state that:

All teachers of science have implicit and explicit beliefs about science, learning, and teaching. Teachers can be effective guides for students learning science only if they have the opportunity to examine their own beliefs, as well as to develop an understanding of the tenets on which the standards are based. (NRC, 1996, p. 3)

Other researchers discuss how teachers’ beliefs about the new reform practices “are truly at the core of educational change” (Haney, Lumpe, Czerniak, & Egan, 2002, p. 171). It is no surprise then that researchers in the STS field focus on teachers’ beliefs, views, or ideologies driving their practice.

Mitchener and Anderson (1989) investigated teachers’ beliefs about an STS model curriculum in a large district in Colorado. They found that teachers adopted one of three views: (a) adopting STS, (b) adopting STS with modifications, and (c) rejecting STS. Overall, most teachers in the study had concerns about the content of the curriculum...
not being rigorous enough, especially when low-ability students were placed in the course. Consequently, this affected the status of the teachers who taught the STS courses, as they perceived that their standing among their peers was threatened by teaching a low-track science course. Finally, teachers had concerns over teaching strategies that required cooperative learning, open-ended activities, and non-traditional assessments. The authors concluded that research needs to pay attention to teachers’ values and belief systems, which are viewed as driving their practices. It can be argued, however, that the concerns of the teachers (such as student groupings, how students are placed in courses, and assessment methods) are more on the practical level of the everyday life of classrooms, rather than belief systems.

On the other hand, some research with teachers reveals positive attitudes toward including social issues in science instruction, but also many practical concerns. Cross and Price (1996) interviewed teachers from Scotland, Australia, and the United States about their perceptions of teaching controversial STS issues. All of the teachers in the study stated that they deal with controversial issues in their teaching. Responses ranged from one extreme of dealing with one issue as a curriculum requirement to the other extreme of being enthusiastically committed to social issues. In addition, biological issues were the most frequently discussed in the classroom. Many teachers in the study were aware of the political and social influences on science and some even encouraged their students to participate in democratic debate about controversial issues. In Cross and Price’s study, teachers cited many practical concerns about teaching issues. For example, the issue of indoctrination was a concern for teachers: Is it ethical for the teacher to motivate students
to take actions on issues? Moreover, teachers had difficulties getting resources. When books were available, they portrayed the opinion of the interest groups that created them. In sum, although the teachers in the study supported teaching social issues, there was not much agreement between the teachers interviewed about how to teach controversial issues and to what extent students should be exposed to such teaching, all of which can be thought of as practical concerns.

Some might argue that these concerns can be traced to lack of preparation of teachers to teach STS topics. However, teaching about social issues raises problems for the teachers, even if they are prepared to teach such content. McGinnis and Simmons (1999) asked why there is a minimal infusion of STS topics in the science curriculum, although there are many teachers who support STS teaching. In a two-year study of teachers’ perceptions about the teaching of STS issues by teachers who had in-service STS classes, the authors reported that teachers perceive the most relevant topics to students as too controversial to teach. The authors found that to maintain their job security, teachers made their STS curricular decisions based on their perception of the local school cultures. The teachers felt that they needed to respect the culture of the community where they teach, so they did not address topics that involved issues perceived as taboos by the community and did not encourage students to raise questions about those issues. Instead, teachers used non-controversial topics related to STS. The authors argued that teachers make STS curricular decisions based on their perceptions of the values of the local community rather than on their understanding of STS as taught in in-service workshops or college classes. The authors also found that when teachers
perceive themselves as outsiders to the local community where they teach, they tend to conform more to the school’s local culture and teach less controversial STS issues.

The results of the two studies discussed above (Cross & Price, 1996; McGinnis & Simmons, 1999) suggest that teachers’ beliefs may not necessarily be the cause of the lack of implementation of STS. Could the reluctance to teach this type of curriculum be the result of more practical concerns, rather than beliefs and values? Contrary to most scholars in science education (Aikenhead, 1984; Bybee, 1991; Rubba, 1991), May (1992) argued that teachers are not likely to be the key elements of change since they are not in full control of their decisions given the political constraints they face: “Teachers are viewed as bad parts, their beliefs and attitudes in need of radical restructuring, and their practice in need of quality control” (p. 78). Solomon (1999) also suggested that instead of top down models, educators need to think about democratic curriculum change where all the parties involved take part in it, which include teachers, parents, and students. Teachers do what they see best for the students regardless what the research finds.

Although teachers appear to be open to STS instruction, it is not yet clear whether they are open to viewing science as a social enterprise and addressing moral, ethical, or social issues in their teaching (Cross & Price, 1996). It is also less clear how science teacher educators can prepare teachers to feel comfortable with and confident in designing STS activities for their students. Very little research has been done with preservice teachers and STS (Scharmann, Shroyer, & Lee, 1997). The next section presents what preservice teachers are expected to learn about STS and the area of research in preservice teachers and STS.
Pre-Service Teacher Education and STS

NSTA standards for teacher preparation (2003) expect teachers to be able to design activities for their students that help them make intelligent decisions. The standards affirm that:

Many issues today are related to science and technology. Making a meaningful decision on these issues requires knowledge of related science content, the nature of science and technology, and the ways science relates to oneself and to others in society. Intelligent decision making on issues requires data and context, or decisions become mere opinions. Science teachers must be prepared to lead students in structured explorations of issues of concern, not just soliciting opinions or conducting debates with little substantive backing. (p. 21)

How teachers can reach this goal is not clear. The treatment of the “Issues” standard follows an add-on approach. If we look at the standards document, we can see that teachers are required to know several areas: content, nature of science, inquiry, issues, general skills of teaching, curriculum, science in the community, assessment, safety, and professional growth. It is worth noting that 11 pages are devoted to discussions of what content teachers should know, whereas issues take a little over one page.

Lumpe, Haney, and Czerniak (1998) noted that whereas there is some research that investigates teachers’ views of the interactions of science, technology, and society; we do not have enough research on teachers’ views about implementing STS. Many studies looked at teachers’ views of science (Rubba & Harkness, 1993; Botton & Brown, 1998; Chin, 2005) or specific views about environmental issues such as the greenhouse effect (Groves & Pugh, 1999). However, there is less research on teachers’ implementation of STS. Furthermore, there are even fewer studies that discuss issues around preservice teachers’ implementation of STS, which I present below.
Sweeney (2001) investigated the perspectives of preservice teachers in elementary and secondary methods classes regarding STS and multicultural approaches in science education. Sweeney found that preservice teachers were resistant to adopting an STS/multicultural approach and they thought that social and political issues are not within the realm of science teaching. Furthermore, preservice teachers under age 25 were more likely than their colleagues who were post-baccalaureate students to adopt an STS/multicultural perspective.

Henning and King (2005) reported on a study where pre-service elementary teachers were required to teach STS curricula. The results suggest that teachers in the study stated that they did not have enough content knowledge in science and social studies to develop interdisciplinary lessons. Most of the lessons focused on a social studies topic, whereas the STS content became tangential. Few units had coherent conceptual connections. Furthermore, the authors reported that although some cooperating teachers were supportive of teaching the entire units, others found the assignment ill-conceived. The authors raised questions about the partnership between university professors and co-operating teachers to support STS instruction. They suggested more collaboration and communication between higher education and the K-12 classroom to create meaningful STS units.

Scharmann et al. (1997) investigated through action research why preservice teachers in their classrooms are reluctant to use STS themes even after spending time designing lesson plans and reflecting on them. Data from a five year study showed that preservice teachers were more likely to implement STS when they first tried to teach it in
class in front of their peers. The authors looked at how preservice teachers’ orientations around goals for science teaching correlate with their decisions to implement STS during student teaching. They found that although the preservice teachers had orientations for teaching science for all, this orientation did not affect their decisions to voluntarily implement STS. The authors discussed how changes in the course increased implementation significantly. These changes included grouping students to allow different majors in one group, explicit modeling by the instructor and having students model teaching in front of peers. Scharmann et al. stressed that goals for teaching science that are aligned with reform are not necessarily correlated with behavior. Furthermore, they suggested that when prospective teachers perceived that their cooperative teachers would not approve of STS lessons, they were hesitant to try to implement them. For example, one participant in their study observed that he would not attempt to ask for approval from the cooperating teacher to teach STS, since the cooperating teacher would not perceive that as “real science.”

Results from the above studies suggest that there may be a problem with the focus of research in science education which locates the problem of implementation in the teachers themselves while ignoring the larger context where teachers operate. Britzman’s (1991) work with student teachers offers insights into the power struggles that they face. Student teaching “is about struggling between tradition and change, of having to negotiate one’s own territory and construct one’s own intentions amid preestablished spaces already overpopulated by the intentions and practices of others” (p. 76). Furthermore, Solomon (1999) asserted that there is a need to step back from the
deficiency model of doing research with teachers and treat them as reflective practitioners who make rational decisions based on the constraints of their everyday life.

One can argue that researchers’ focus on teachers’ beliefs can be traced back to constructivism as a theoretical framework in science education. This perspective tends to focus on the rational elements of teachers’ decision making to implement—or not—an STS curriculum. For example, following constructivist epistemologies, Rubba (1991) offered the following recommendations for teacher candidates:

Before appropriate STS teaching practices can be fully developed and put into practice, science teachers’ beliefs and values must be compatible with the notion of responsible citizen action on STS issues as a goal of a school science education. Preservice and inservice science teachers must have opportunities to (a) examine their beliefs and values about responsible citizen action on STS issues and the place of STS in school science education, (b) confront inconsistencies in their beliefs and values about STS action as a science education goal, and (c) construct more appropriate beliefs, values, and corresponding science teaching practices, all under the careful guidance of a knowledgeable science educator or model science teacher. (p. 307)

The model offered by Rubba suggests that teachers will rationally find flaws in their beliefs once they are confronted with inconsistencies. This perspective is not sufficient to explain why teachers are not implementing STS since many studies have shown that teachers’ views or orientations about the goals of teaching science do not impact their decisions (McGinnis & Simmons, 1999; Scharmann et al., 1997). I outlined above a framework based on a Deweyan perspective (Dewey 1938/1997; Wong & Pugh, 2001) that focuses on worthwhile experiences in thinking about teaching STS to students. Drawing upon this Deweyan perspective, we can research how preservice teachers experience STS, rather than investigating their beliefs. From the perspective of students learning STS, a Deweyan approach offers a framework of STS as providing worthwhile
experiences that allow students to engage with ideas. Similarly, as researchers, taking a Deweyan approach allows us to focus on the experiences of teachers with STS, as plots, rather than as specific points in time when beliefs are evaluated. Research that focuses on teachers’ beliefs tend to treat them as ends in themselves, that need to be addressed and changed. Wong and Pugh asserted that ideas are not ends in themselves, they are lived. As researchers we can focus on what teachers experience or live, not as end points, but as a process.

Summary

The practice-policy gap (Bybee, 1991) in teaching about science, technology, and society has been recognized for some time in the literature; however, we do not seem to be able to figure out how to convince teachers of the value of such an approach (DeBoer, 1991). Science teachers seem to find comfort in sticking to teaching an objective science. Science is seen as objective but values are not (Allchin, 1999). However, in the science education community, science is viewed as a social enterprise with human values and commitments. Unless schools change to center instruction around themes and issues rather than the distinct disciplines (Blades & Richardson, 2004), science teachers will still have to face the complexities of teaching about social issues while trying to maintain the integrity of the discipline, as structured by the experts. We know from the literature that there are problems facing implementation of STS such as teachers’ beliefs, lack or resources, lack of time, or community pressures. There is a wide recognition that science education programs need to address the perceived gap, but little seems to be achieved in the field. We also know that teachers get exposed to STS in preservice or in-service
classes. One area of research that has not been fully investigated is how preservice teachers come to understand STS in their methods courses and how they appropriate and use STS based on that. This study attempts to fill that gap by drawing on a Deweyan perspective to explore how novice teachers experience STS in a secondary education program that emphasizes the nature of science and STS.
CHAPTER III

METHODOLOGY

“The essential vocation of interpretive anthropology is not to answer our deepest questions, but to make available to us answers that others, guarding other sheep in other valleys, have given, and thus to include them in the consultable record of what man has said” (Geertz, 2001, p. 75).

Whereas reform documents (NSES, Project 2061) have affirmed the importance of teaching social issues in science for all students as a means for responsible citizenship, many science educators are concerned that this policy commitment has not been translated into classroom practice. The policy-practice gap (Bybee, 1991) cannot be addressed unless teachers embrace STS curricula. DeBoer (1991) asserted that teachers are not convinced of the merit of teaching STS mainly out of confusion regarding what STS means but also because of its perceived lack of status among science teachers. Whereas we have recognized some of the problems inherent in implementing STS in the classroom, such as resources, time constraints, perceived lack of rigor, or teachers’ beliefs, we have not figured how to address these problems. Since teachers are usually introduced to STS in preservice or in-service classes, we need to look at teachers’ perspectives in these classes and how possibilities can be turned into implementation. Hence, there is a need to understand how teachers make sense of teaching STS in the context of their first exposure to STS pedagogy in methods courses.
Theoretical Framework

To achieve this understanding, a qualitative design informed by pragmatism and socio-cultural approaches was used. Since different philosophers define pragmatism differently (Garrison, 1994), I focus on Garrison’s interpretation of Deweyan pragmatism. Qualitative researchers differ regarding the correspondence of research to reality. Interpretive realists locate reality in the outside world, whereas constructivists locate reality in participants’ minds. I do not ask what is real, that is, whether reality is in the participants’ minds (constructivism) or in the outside world (realism). Instead, I follow the pragmatists in asking whether it is useful to ask such a question (Garrison, 1994). Pragmatists say that we cannot possibly know whether our explanation or theory is close to reality. Pragmatists locate meaning in its consequences: “Our choice simply means that one approach is better than another at producing anticipated or desired outcomes” (Cherryholmes, 1992, p. 15). To illustrate the point that pragmatism locates meaning in its consequences, I present an example provided by Garrison when he described James’ version of pragmatism:

James’s example is water. He argues that the “real essence” of water is no more the chemists’ $\text{H}_2\text{O}$ “than it is a solvent of sugar or a slaker of thirst” and that the only reason $\text{H}_2\text{O}$ is primary for the scientists is that “for his purpose of deduction and compendious definition . . . it is the more useful.” (p. 7)

Therefore, for pragmatists, there are no real essences attributed to objects or to ideas. The object of inquiry becomes the consequences of practice rather than whether the results of the inquiry correspond to a fixed reality (Garrison, 1994).

Locating meaning in the consequences has implications for research in education. As discussed in chapter 2, researchers in science education tend to focus on teachers’
beliefs as stable real constructs that can be measured and that drive teachers’ practices. In such a tradition, research aims at accurately measuring teachers’ beliefs and then changing them. Following a Deweyan perspective, I look at preservice teachers’ understanding through practices/actions as the focal point. Deweyan pragmatism enables us to abandon the confusion resulting from talking about psychic entities. We do not need to look at people’s minds to find reality. Instead, reality is in the light of day in their actions (Garrison, 1997). As Dewey wrote:

Do not a large part of our epistemological difficulties arise from an attempt to define the real as something given prior to reflective inquiry instead of as that which reflective inquiry is forced to reach and to which when it is reached belief can stably cling? (Dewey, 1916, in Garrison, 1994, p. 7)

Therefore, reality for Dewey is not given a priori the process of inquiry.

Dewey rejected cognitive structures and focused on meaning as originating in linguistic practices. Therefore meaning is not hidden in the mind, but in a sense real and can be observed by looking at social interaction. The following quote illustrates Dewey’s focus on meaning as action in the world:

The heart of language is not “expression” of something antecedent, much less expression of antecedent thought… to fail to understand is to fail to come into agreement in action; to misunderstand is to set up action at cross purposes . . . meaning is not indeed a psychic existence; it is primarily a property of behavior . . . but the behavior of which it is a quality is a distinctive behavior; cooperative, in that responses to another’s act involves contemporaneous response to a thing as entering into the other’s behavior, and this upon both sides. (Dewey, 1916, in Garrison, 1994, p. 6)

For Dewey, there is no private language. Language is always between two people and in a social group:
Dewey felt that to have a mind was to be able to participate in the social constructions of a society, that is, to be able to do the work, use the tools and speak the language of a member of a social community. (pp. 549-550)

The other tradition I am drawing from is social constructivism. Social constructivists assume that knowledge is contextual, and socially negotiated, but not necessarily relativistic. In the social constructivist tradition, we can talk about weak or strong constructivism. In the weak constructivism tradition, we can talk about truth not in absolute, but in a practical sense (Rorty, in Schwandt, 2003). That is, not all knowledge claims are equal even though they are socially constructed. One example of weak constructivism is the work of Longino who asserted that scientific knowledge is in part the product of social negotiation but it is not only that. Although knowledge is situated and dialogical rather than representational, it is not relativistic. For Longino, not every interpretation is as good as another, and researchers are bound with the constraints of the empirical world they study (Schwandt, 2003).

Even though I am assuming that knowledge from research is bound to the context where it is produced, I am borrowing from the Deweyan pragmatist tradition that we can still talk about partial truth, about knowledge that is contextual, and yet this partial truth and contextual knowledge can lead to understanding and transformation. Drawing on these traditions, understanding is conceived as constructed in the moment rather than a description of a stable reality. Although some qualitative researchers with a realist epistemological stance may view understanding as objectively getting at what individuals make of their realities on their own terms, “for virtually all postempiricist philosophies of the human sciences, understanding is interpretation all the way down” (Schwandt, 2003,
p. 312). For the purposes of this study, understanding is perceived as performance. The research process constructs understanding rather than unfolds a stable reality. These constructions do not reside in psychic entities, but in the actions/language of the participants.

**Design**

This study seeks to describe a process: how preservice science teachers come to understand and make sense of what STS means and how to teach STS issues in the context of a science methods class. A naturalistic inquiry that relies on interviews as a primary source of data collection was used. The main research question centered on how pre-service teachers experience science-technology-society in the context of their methods class. More specific questions include:

1. How do preservice teachers understand STS as a result of participation in a science methods class?
2. Do pre-service teachers value STS as a result of their experiences?
3. Do pre-service teachers use STS during student teaching, and in what ways?

**Setting**

Participants for this study consisted of two existing science methods classes in a Midwestern state university. Students in the class were majoring in education with several different licensures in the sciences (life sciences, integrated sciences, physical science, earth science, and chemistry). The science education program for secondary teachers follows the National Science Teachers Association’s standards for teacher preparation (2003) that were discussed in chapter 2. Because of the interest of the faculty
members, the program focuses on understanding and teaching the nature of science and emphasizes the interactions between science, technology, and society. Students in the secondary education science program took science content classes and some general education classes for the first three years. In their senior year, they took two science methods classes, one in the fall and one in the spring during student teaching. The class in the fall covered teaching science as inquiry, using literature in science, planning and executing science lessons, and other topics such as safety and science in the community. The class in the spring which met intensively for the first five weeks in the semester covered the following topics: assessment, nature of science, using technology, and teaching STS. The secondary program had just recently restructured its course sequence to accommodate for student teaching. Students in the new program took the first methods class in the spring of their junior year and the second method class in the fall of the senior year. The spring of the senior year is devoted to student teaching. This structure was first implemented during the same semester I collected data, therefore there were two groups of students that took the same class during the same semester: one at the senior level and one at the junior level. The seniors were student teaching during the same semester; the juniors had one more year to go. Table 1 describes the structure.

One of the classes in my study was at the senior level, and the other was at the junior level. I refer to the classes as the senior class and the junior class. The senior class followed the old structure that I described above. They took one methods class in the fall and the second one for the first five weeks of spring semester. They did their student teaching after those five weeks. The senior class consisted of 18 students, mostly White,
### Table 1

**Old and New Course Structures of Secondary Science Education**

<table>
<thead>
<tr>
<th>Course Structure</th>
<th>Spring Junior Year</th>
<th>Fall Senior Year</th>
<th>Spring Senior Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Old</strong></td>
<td>General Pedagogy</td>
<td>Methods I:</td>
<td>Methods II (5 weeks)</td>
</tr>
<tr>
<td></td>
<td>Courses</td>
<td>(Inquiry,</td>
<td>(Assessment, NOS, STS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Curriculum and,</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>lesson design and</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>execution, misc.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Science Ed. topics</td>
<td></td>
</tr>
<tr>
<td><strong>New</strong></td>
<td>Methods I:</td>
<td>Methods II:</td>
<td>Student teaching</td>
</tr>
<tr>
<td></td>
<td>(Assessment,</td>
<td>Practicum</td>
<td></td>
</tr>
<tr>
<td></td>
<td>St. Conceptions</td>
<td>(Inquiry, curriculum</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NOS, STS)</td>
<td>and lesson planning, other topics)</td>
<td></td>
</tr>
</tbody>
</table>

10 women and 8 men. I met those students first at the end of their fall semester during their final presentations of their professional portfolios. I was working as a graduate assistant for the two professors who taught the classes. I believe that this initial encounter was important as it set the stage for how they perceived me. I then started observing in the class during the first five weeks of the spring semester in the capacity of a researcher. However, as a graduate student I had worked for several years with the professor who taught the class, which might have affected how the participants perceived my role. I interviewed 5 volunteers from this class during the last week of the semester after they student taught.

The junior class was the first one to follow the new structure. Students were taking their first science methods class one year before student teaching. This is an important difference. Students in the senior class had more experience being in the field,
and they also had more anxiety about student teaching. The junior class consisted of 11 students, 10 White and 1 African American. There were 7 women and 4 men in the class. The junior class differed from the senior class in that it met twice a week for the whole semester and covered topics such as assessment in science education, misconceptions, history and nature of science, and teaching about issues. These two classes offered a space to investigate how new teachers make sense of the goals of teaching science and the place of STS instruction in these goals. The context allowed us to ask: what happens when novice teachers start reconceptualizing what it means to teach science? How do they come to understand what STS means and how does this understanding unfold when they start teaching, given the tension between the possibilities introduced in the methods class and the realities of the field? (Britzman, 1991).

These two classes may not be typical of other preservice teachers’ classes, but they offer a rich site to understand how these students experience what it means to teach STS. Lincoln and Guba (1984) problematized the idea of transfer or generalizability in qualitative research. They proposed that the burden of proof lies with the person seeking to make the application to a new setting since that person knows the new setting best. The researcher is only familiar with her research setting and cannot therefore speak to the transferability issue. The researcher’s responsibility lies in providing enough description of the setting to allow another person to make the judgment whether another setting is similar enough to make that transfer (p. 298).
Data Collection Methods

Denzin and Lincoln (2003) wrote about the qualitative researcher as Bricoleur, using triangulation or multi-method approaches to insure an in-depth understanding. Multiple data collection methods and multiple perspectives add rigor and complexity to the study. Even though we cannot reach objective reality, by using multiple methods we can capture a phenomenon with more complexity and depth. To achieve this depth of understanding, I used participant observation, interviews, and document analysis to describe students’ experiences with learning about and teaching STS. I describe these data collection methods below.

Participant Observation

The first data collection method that I used during this study was participant observation. During the semester, I attended both classes as a researcher, taking a participant observer role. I began by observing the classes and establishing rapport with the students, then gradually increased my participation in the classroom. Students often came to me for help or with questions during class time or after class. When I asked for volunteers for interviewing, more students volunteered to interview than I had expected. This prolonged engagement in the field was important to building trust with the participants (Lincoln & Guba, 1984).

However, this participant observer stance carried with it some tensions between closeness to the setting as a participant and distance from it as an observer. On the one hand, I was seeking to experience events as a participant, and on the other hand, needed
to detach myself to be able to observe/interpret the events that were occurring (Emerson & Pollner, 2001).

Furthermore, these observations were not meant to be seen as true retellings of what happened in the field. Unlike realist perspectives that assume researchers observe and record reality, the reflexive approach (Clifford & Marcus, 1986; Denzin & Lincoln, 2003) used in this study assumes that “social reality is at least in part a product of an investigators effort to apprehend and describe it” (Emerson, 2001, p.20). Following the reflexive approaches, reality is understood to shape and be shaped by the act of representation. Observations are not as simple as “looking” and “finding” things to be reported (Emerson, 2001). They are theory-laden, shaped by the researcher’s perspectives and theoretical commitments, and descriptions are partial and selective. We do not start the process of observing and describing by coming intellectually empty-handed (Geertz, 2001). We choose what we want to attend to (Denzin & Lincoln, 2003; Emerson, 2001). In this study, I brought with me a commitment to an STS approach to science education, and was attending to those aspects of the class that dealt with this approach.

Hence, observations are inherently linked to interpretation. But the distinction between the two is blurry (Geertz, 2001). This is not to imply that these observations are false accounts. Social events do happen, and our interpretations are tied to them. As Geertz explained, anthropological writings are fictions in the sense that they are fashioned and made, and not necessarily false. The role of the researcher is not to describe a true account of social reality in the field, akin to showing a physical artifact, but to explain and interpret the meanings of what is happening.
Knowing that the act of observing and interpreting data is not a one-way interaction (Emerson & Pollner, 2001), I now describe how the participants might have perceived my presence. I worked with the professor in the class as a graduate assistant for several years before this research project. The students in both classes were aware of this relationship as I participated in class either sharing my views or helping them with specific assignments. I had a good rapport with the senior class even though the class was short. Many of them would ask for my help with their WebQuest assignment, especially when the professor showed them an example that we both worked on. I did not find that the seniors’ perception of me as an assistant to their professor in the class influenced the degree to which they trusted me and talked honestly about their views. I believe that this partly resulted from the fact that my questions were general and were perceived to be safe to answer. I did not develop the same rapport with the junior class. I believe that since the seniors had already been together for a semester, they were more comfortable together as a class. Accepting me as an outsider was easier since they had already formed a community. The other factor might have been that they were starting student teaching, and the discussions in the class were more relevant to them. By contrast, the juniors were one year away from being in a high school classroom, and they had not yet formed a group identity. These factors could have contributed to some difficulty in establishing rapport with them.

I collected data by taking field notes during my observations. I also took videotapes and/or digital audio recordings of classroom discussions while I observed to

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10A WebQuest is an online inquiry activity where most of the information that learners work with comes from the web (Dodge, 2007). Examples are available at www.webquest.org
get an idea of how students understand and struggle with teaching STS. From these observations and recordings, I developed a thick description of how STS was introduced in the methods classes. I also compared these observations to how the participants reflected on STS during the interviews.

**Interviewing**

Since I am interested in looking at how preservice teachers experience the process of learning how to teach STS, I used interviews as a main data collection method. The class observations provided a context to understand how STS was presented to these two groups of preservice teachers. The interview allowed them to reflect on that experience and to try to make sense of it. In this sense it was a new construction of the experience and not a true recounting of it. This is in contrast to researchers who come from a realist paradigm where the interview attempts at capturing participants’ views as they truly are. I conceived of the interview as conversational (Bogdan & Biklen, 1998) and evolving and I focused on how participants reflected on and talked about their experiences.

There have been many critiques of the interview as a research method. Briggs (1986) reminded us that we cannot escape the fact that the interview is another form of social interaction that generates novel reactions that are particular to the setting of the interview. Briggs outlined many problems with the interview as a primary research tool in social science research. The major issue is that researchers tend to focus on the referential aspect of interview responses and hence decontextualize what is being said. Researchers assume that what they find in an interview is a true account of what participants think/believe/do. I address these concerns of the interview by focusing on
how teachers make sense of the process through their talk. In doing so, I assume that both the researcher and the participant are involved in a performance (Fabian, 1990).

Briggs (1986) also pointed out that researchers cannot separate their presence from what is being studied. It is dangerous to assume that asking the questions will not affect our respondents’ perceptions. This does not necessarily mean that the interview does not provide insight; it just means that we cannot reify the results. Briggs recommended that we look at the interview as a social encounter in itself as a communicative event and look for misunderstanding or misinterpretation. Knowing that the interview is a new social construction, I examined what the interview questions meant to myself as a researcher as well as to the participant, asking where we misunderstood each other and how I might have misinterpreted the results (Briggs). I tried to be aware of participants perceiving the interview as a quiz rather than a conversation. For example, one participant asked me at the beginning of the interview to let him know if he is on the right track, or if he is answering the questions correctly. But as the conversation continued, he became less conscious of trying to give a right answer. Another participant was trying to make sense of her own understanding about STS during the interview, as she specifically said that her understanding is evolving and that talking through it makes her clarify her own thinking.

Another way I tried to address the criticisms of the interview as a research method is through use of multiple sources of data. Looking at documents and listening to class recordings allowed me to identify recurring patterns, but also to clarify some misunderstandings. The documents collected proved to be helpful in this regard.
Document Analysis

The third data collection method that I used was documents. I collected several assignments that participants submitted to the professor. These documents include:

1. Session products, such as materials that participants created during the class, either collectively or individually. They include reflections on what STS means and where it fits in the curriculum, objectives to teach an STS issue, and so forth.

2. Surveys\textsuperscript{11} of cooperating teachers’ views of STS and scientific literacy. Students in the class were asked to interview their cooperating teacher about their views about teaching social issues in science. I used those surveys to look at how the participants perceive what their cooperating teachers tell them about STS teaching.

3. Lesson Plans: I collected products that participants were required to do as part of the class. These included WebQuests on an STS topic in the senior class, and lesson plans in the junior class. These products allowed me to look at how the participants are applying their knowledge about STS in a pedagogical exercise.

4. Teaching Philosophy: At the end of student teaching, the senior participants had to submit a teaching philosophy that described which goals they see as important for teaching science. I collected these teaching philosophies to get a perspective on what goals they focus on to guide their teaching.

\textsuperscript{11} See the syllabus for the senior class (Appendix A) for the survey.
These documents were not analyzed specifically for patterns (except for cooperating teacher surveys), but were looked at holistically to support or challenge the themes that emerged from the research.

Participants were presented with consent forms and were informed that their participation is voluntary and that they could withdraw at any time. The consent forms also informed the participants that the purpose of the study is to learn from their experiences rather than judge their competence. The participants were assured that no one would be identified individually and that data would be reported to the course instructor as a class in general. The participants were also reassured that the purpose of the study was to gain more information about how they learn in order to improve future teaching rather than to evaluate their performance. I used pseudonyms throughout this document to protect participants’ privacy. I attempted reciprocity through being a good listener and providing help and feedback with participants’ assignments, especially with the senior group.

Trustworthiness of the Study

Working from a social constructivist perspective, I am not looking to find generalizable knowledge that can be packaged and reapplied in different settings. Research from such a perspective cannot be objective since all knowledge is socially situated and contextual (Denzin & Lincoln, 2003). Instead I think of this project as a conversation. Research is not a process of uncovering a truth that exists independent of the researcher. I am aware that what is said in an interview is a construction that is a function of how the participant and the researcher are conceiving of what the interview
represents in the first place. Not only is the interview an imagining of the social context, it is also “imagined texts that will be created through the use of interview data” (Briggs, 2002, p. 914). The participants are very much aware (through the consent forms and communication with me) of how data is going to be used as written text and their responses depend on that awareness (Briggs). Clifford (1983) reminded us that ethnography is “enmeshed in writing” (p. 120). Geertz (2001) also reminded us:

> The ethnographer inscribes social discourse; he writes it down. In doing so, he turns it from a passing event, which exists only in its own moment of occurrence, into an account, which exists in its inscriptions and can be reconsulted. (p. 67)

Researchers need to strive to understand participant observation as experience and interpretation rather than as a reproduction of reality (Clifford, 1983).

Since there is no ultimate benchmark that qualitative researchers can turn to for justification, naturalistic inquirers strive to show that they have represented the multiple constructions of their participants adequately—so that, as Lincoln and Guba put it, “the operational word is credible” (1984, p. 296).

Assumptions

Researchers do not go into the field as blank slates. Our assumptions guide our questions, the way we collect data, and how we analyze data. However, trying to eliminate the researchers’ presence is a “fruitless and theoretically unsound goal” (Briggs, 1986, p. 100). These assumptions are also not fixed, as they change in our interactions in the field. Stating those assumptions up front helps the researcher analyze her role in the research. I outline my assumptions here.
Based on the literature on teachers’ attitudes, I assumed that preservice teachers would see their roles as teachers of science content first, and that discussions of issues would be of less importance. As a teacher educator myself, I was also excited to see how the preservice teachers would be surprised and intrigued to think about science in a different way than they have been used to through their schooling in K-12 and college. I knew from the literature and from my own experiences that classroom management would be their main concern and that they might not be ready to really think about the content in a different way. I also assumed that for the senior group, their cooperating teacher’s style might influence the degree to which they implemented STS during student teaching.

Analysis

Data from this study were analyzed inductively (Lincoln & Guba, 1984) to explicate participants’ understanding of STS. I listened to and transcribed the recordings of the class sessions and interviews. Data from class recordings were mainly used to provide a description of how STS was presented in the classroom. After listening to the audio recordings and videotapes, there were many instances where interview themes were confirmed, and others in which interview themes were challenged.

I listened to audiotapes of the interviews several times and then transcribed and coded them for themes (Miles & Huberman, 1994). I came up with the initial themes by listening to the interviews for how the pre-service teachers talked about STS topics in relationship to the interviewer’s questions and to the topics initiated by the teacher candidates themselves. These themes were later reduced and clarified by looking at the
class discussion. The tapes from class discussions and my field notes were used as a reference to connect what the participants were saying in the interview to interactions in the class. As I looked for themes in the interviews, I went back to class discussions to understand what was being said.

I read all the documents produced by the participants several times. I ended up using documents mostly from the senior class. I read their philosophy of teaching documents and coded them according to how they wrote about their goals for teaching science. I compared those themes to the National Science Education Standards discussion of goals for teaching science. I also analyzed the teachers’ surveys to examine how the preservice teachers interpreted their teachers’ advice on how to teach societal issues in science.

A dissertation study group that consisted of one faculty advisor and several doctoral candidates met weekly over the span of several months and listened to samples of the data and confirmed or challenged themes. After initial themes were identified, several subsequent readings of the data were performed and final themes emerged from those readings.

Summary

A naturalistic inquiry informed by Deweyan pragmatism and social constructivism was used to investigate the experiences of preservice teachers in science, technology, and society in their method class and during student teaching. Although I cannot make claims to generalizability of the data, this study has merit on its own to enrich our understanding of novice teachers’ understanding of STS.
CHAPTER IV

FINDINGS

“A text is not a representation . . . of a communicative event, it is that event in its textual realization” (Fabian, 1990, p. 9).

Introduction

This study is a naturalistic inquiry into the experiences of a group of pre-service teachers with Science, Technology and Society approaches during their college classroom and during student teaching. This study is not attempting to answer questions of how best to teach teachers about STS, but to raise issues around the experience of learning how to teach STS. The questions that this study was trying to answer were:

1. How do preservice teachers experience STS as a result of participation in a science methods class?
2. Do pre-service teachers value STS as a result of their experiences?
3. Do pre-service teachers use STS during student teaching, and in what ways?

This chapter is divided into four main sections. The first section describes the context of the two methods classes, which are referred to as the senior class and the junior class. Data from fieldnotes and class recordings were used to construct these descriptions. This context sets the stage to understand how the unit of STS was presented in class, and provides a thick description of the setting. The second section of this chapter presents results of how cooperating teachers responded to survey questions about STS, which provides the lens of the practicing classroom teachers. The third section explores
the profiles of the participants who volunteered to be interviewed (who came from both the senior class and the junior class). These profiles were derived mainly from the interviews but also from my interactions with the participants during class, and are meant to provide an in-depth description of the participants involved in the study. The fourth section presents the overall themes that emerged in response to the three research questions in both classes. Whereas the first two sections are very specific to each context (college classroom, co-operating teachers discourse), the last section is a more holistic synthesis of the themes derived from the research. These different layers of the data are superimposed in order to deepen our understanding of these pre-service teachers’ experiences, and are not meant to attach stable constructs to the participants.

Context: Senior Class

As discussed in Chapter 3, the two groups of participants were taking a similar science methods class due to the restructuring of the secondary education program at the institution where data was collected. The senior class met for the first 5 weeks during the spring semester, twice a week for three hours. During this time the students were expected to be spending at least 6 hours a week at their student teaching school site (where they spent 100 hours of field time during the fall semester). After those 5 weeks, students started student teaching, gradually taking classes over 2 to 3 weeks until they had a full load. The syllabus (Appendix A) defines the purpose of the class as to continue to shape students’ skills as secondary teachers\textsuperscript{12}, with a focus on assessment and science-technology-society curricula in science education. During the spring semester, the class

\footnote{Recall that these students already had a 15-week general secondary methods course and a 15-week science methods course prior to this semester.}
spent two weeks (4 sessions) discussing assessment in science education, then moved on to discuss nature of science, and STS, which spanned 3 sessions. The STS unit was introduced through classroom discussion, readings from “The Golem: What everyone should know about science” (Collins & Pinch, 1993), a video on race, and then application of the concepts through the students creating a WebQuest about an STS issue. The participants also had to survey their cooperating teachers about their views and use of STS, as well as write reflection papers to clarify their own views about teaching STS. I discuss the details of the class presentation of STS. Since the discussion of STS followed the presentation of teaching about the nature of science, and was also linked to it in many ways, I treat them as one coherent unit.

STS and NOS in the Methods Class

The discussion on NOS and STS opened with a quiz from Chiappetta and Koballa (2006), which is the textbook used in class. The students had to answer True or False on statements about the nature of science. Below is a list of these statements:\footnote{For answers and explanations to this quiz, see Chiappetta & Koballa (2006), Science Instruction in the Middle and Secondary Schools (6th Ed), p. 90. Upper Saddle River, NJ: Pearson.}

1. Science is a system of beliefs.
2. Most scientists are men because males are better at scientific thinking.
3. Scientists rely heavily on imagination to carry out their work.
4. Scientists are totally objective in their work.
5. The scientific method is the accepted guide for conducting research.
6. Experiments are carried out to prove cause-and-effect relationships.
7. All scientific ideas are discovered and tested by controlled experiments.
8. A hypothesis is an educated guess.

9. When a theory has been supported by a great deal of scientific evidence, it becomes a law.

10. Scientific ideas can be tentative and can be modified or disproved, but never proved.

11. Technology preceded science in the history of civilization.

12. In time, science can solve most of society’s problems.

Each item in the quiz was discussed in terms of its meaning in relation to the nature of science and also in terms of how to teach that aspect of the nature of science. The quiz prompted many responses from students, and got them interested in the topic. Most of them were surprised at the results, and some items—such as whether technology preceded science in the history of civilization—sparked a lively discussion. The class spent some time discussing science and religion and came to the conclusion that if religion is a system of faith, then science is a system of understanding the natural world. This led to a discussion on evolution and intelligent design and what lines of demarcation are used to differentiate science from non-science.

The discussion turned often to how one would teach students about the nature of science and what strategies would be appropriate, mostly guided by professor’s questions. To provide an example of how to teach about the nature of science, the professor presented the participants with an example of how one teacher explicitly developed and taught an instructional unit on the nature of science in his high school physics class. Even then, the participants were concerned about fitting a discussion about
the nature of science into their curriculum, as they had not seen this kind of teaching in their field observations. The discussion was lively; however, in the end it was clear that the preservice teachers had a hard time visualizing how to fit explicit consideration of the nature of science into their teaching.

The preservice teachers then had to read a chapter from Collins and Pinch (1993), “The Golem.” The book presented a series of scientific experiments to challenge the view that there is one scientific method that all scientists follow that leads to true knowledge.

The description in the book reads:

The Golem presents a view of science as fallible and untidy, a matter of craft rather than logic. To do this it examines a series of experiments, some famous, such as the proofs of relativity theory, and some not so famous. In each case it shows that scientific certainties do not come from experimental method, but from the way ambiguous results were interpreted. To explain science the authors display science. (Collins & Pinch, 1993, p. i)

The preservice teachers read the conclusion of the book which explored the relationship between scientific expertise and public discourse about science. The authors (Collins & Pinch, 1993) claimed that what they tried to do in the book was to “show that there is no logic of scientific discovery. Or, rather, if there is such logic, it is the logic of everyday life” (p. 140). The authors described how scientists and the public react to errors in science (such as space shuttle exploding, Chernobyl) as anomalies, human mistakes, and often find someone to blame for these human errors. They argued that the public separates human fallibility from the enterprise of science. In such a discourse, when these errors occur, it is perceived to be because the science was just not done correctly. The authors claimed that on the contrary:
Human “error” goes right to the heart of science, because the heart is made of human activity. When things go wrong, it is not because human error could have been avoided but because things will always go wrong in any human enterprise. (p. 142)

This view of science as human activity allows us to move away from the view of scientists as all good or all bad; or, in the words of Collins and Pinch, as “gods or charlatans.”

The Golem authors (Collins & Pinch, 1993) also addressed the issue of “science and the citizen,” which is very relevant to science teachers. The authors argued that the public needs to know more about the practices of science (hence the need for such a book!), rather than the content of science in order to make decisions on scientific and technological issues that continue to arise in the political domain. These views opened up a discussion about the goals of science teaching in high schools. The participants in the class with the professor’s guidance continued to affirm that part of their job as science teachers is to educate citizens in this world, so this section of the chapter was conducive to much discussion. The chapter concluded that what students really need to know about science to be informed citizens is not the content of science, but what science is, or “the nature of science” as commonly used in the science education literature and in the methods class.

The book reading allowed for the introduction of many additional questions about the nature of science. The class explored whether science is a special logic, or specialized

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14 On the first day of the methods class, the students were introduced to five historical goals of science education: to help students learn scientific concepts, principles, laws, and general content; to help students learn to use scientific methods of inquiry and process skills; to provide students knowledge for improving their personal lives; to educate a citizenry for participating in democratic decisions that involve science; and to prepare students for careers in science. These goals were often referenced throughout the course as they emerged in discussion.
training; how for-profit scientific research affects scientific work; the influence of human error on the enterprise of science; scientism in our society; how the media uses science arguments in contested topics; and whether there is one scientific method that all scientists follow. The class was revising their ideas of what science is, without necessarily lessening their sense of its value. For example, Professor M. said:

He is going into a dangerous territory of saying that science is just a system of beliefs . . . right, and in some sense it is but in other senses it is not. Because we have to agree that this is the best explanation, but we also have to be willing to change our explanation when we cannot come up with a logical way of talking about science. Ultimately what it comes down to is that science is done by humans. (CR, S, 2-2)

This discussion about the nature of science was important as it related to the class discussion about science-related societal issues. Professor M. stressed multiple times how such issues are often complicated and involve more than expertise in science. The main point that she tried to make was that although knowledge of science may be needed to make decisions on how to respond to societal issues, that knowledge alone is not enough. One also needs to factor in moral, ethical, political, or economic concerns. For example, she said:

It goes culturally against what we expect. We expect to know content. What you really need to know is nature of science to make decisions . . . You need to know something about science; you need to have some understanding of the principles of ecology to figure out if drilling in ANWR is good or bad. But you also need to understand that the only thing science can tell us is about principles of ecology, they cannot tell us how to spend our money, can’t tell us ethical thing to do, because that is not the [scientific] area of expertise. The scientific area of expertise is how the natural world works. So when scientists are giving you advice on economic policy, then they have stepped out their . . . This is the most important thing for you to know. (CR, S, 2-2)

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15 CR: Class Recording; S: Senior class; J: Junior class
The role of expertise in science was also discussed at length. One point the professor was trying to make is that science expertise is very specialized. It is not possible for lay persons to be able to understand all the scientific aspects of an issue. The professor stressed that the participants, as teachers, need to convey to their students which aspects of an issue are answered by science, and which aspects are moral and ethical considerations.

This section illustrated how the participants were introduced to the theme of teaching about the nature of science in science education. The main points of this part of the class that the professor wanted to stress included: (a) whereas there are many common features in science, there is no single step by step scientific method that all the sciences share; (b) scientific knowledge is tentative, but at the same time durable; (c) science relies on empirical evidence; (d) science is done by humans and therefore has creative and subjective elements; (e) science is not the same as technology, although they both impact each other; (f) science is situated in a historical, cultural, and political context; and (g) science cannot answer all questions (McComas, 2004). Furthermore these are elements of the nature of science that science educators agree upon to some extent. This nature of science discussion is important since it illustrates how participants were thinking about the role of science teaching as they explored the topic of STS.

**Race as an STS Issue**

In the next part of class, the students explored the topic of teaching STS in science education. A rationale for teaching STS was linked to the goal of teaching science for citizenship. The class brainstormed topics that can be turned into STS units. As an
example, the class was asked to investigate the issue of whether there is a biological basis for race. They watched a PBS documentary that discusses race. The difference between us is the first in three documentaries gathered in a series titled Race: The Power of an Illusion (California Newsreel, 2003) that explored how the bases for racial classification are social rather than scientific. The main question the video asks is whether race is biological or social. The documentary presents modern arguments from genetics, anthropology, and evolutionary biology to argue that race is not an inherent biological category, but a social invention. The producers described the video in this way:

Everyone can tell a Nubian from a Norwegian, so why not divide people into different races? That’s the question explored in “The Difference Between Us,” the first hour of the series. This episode shows that despite what we’ve always believed, the world’s peoples simply don’t come bundled into distinct biological groups. We begin by following a dozen students, including Black athletes and Asian string players, who sequence and compare their own DNA to see who is more genetically similar. The results surprise the students and the viewer, when they discover their closest genetic matches are as likely to be with people from other “races” as their own. Much of the program is devoted to understanding why. We look at several scientific discoveries that illustrate why humans cannot be subdivided into races and how there isn’t a single characteristic, trait—or even one gene—that can be used to distinguish all members of one race from all members of another. (California Newsreel, 2003)

The video illustrated historical episodes that deal with the eugenics movement, and racism. For example, one case is presented of how “scientific” views about athletic ability of minority groups changed over time. In the early 20th century, some scientists wrote that non-Whites are physically inferior, and doomed to be extinct. This view changed to a common social belief that claims African Americans are better at athletic activities. The point of the video was to illustrate how social ideas about racial inferiority
or superiority influenced the science of the time (and then were historically often reinforced by this same science).

The video was presented as an example of an STS issue in the secondary classroom, but also as an example of how the enterprise of science is essentially social (an idea brought out during the discussion of the nature of science). To follow up on that, the class read Linnaeus' early formulations of racial categories. Linnaeus linked physical attributes to personality traits and mental ability. For example, following the description of physical properties of hair color, hair type, skin color, and so forth, of each race, Linnaeus described the American race as “obstinate, content, free, and regulated by customs;” the African race as “crafty, indolent, negligent, and governed by caprice;” and the European race as “gentle, acute, inventive, and governed by law” (Bennett, 1995, p. 47). The discussion in the methods class pointed to how the cultural background of Linnaeus influenced the science he produced and discussed whether the categories would have looked different, if a Kenyan (or any scientist from a non-European background) came up with them. As an extension, the participants looked at the racial basis for intelligence tests. They read an excerpt by Terman (1916) that discussed how intelligence tests spoke persuasively about the inferiority of “Indians,” “Mexicans,” and “Negroes,” and recommended that children of these groups be segregated into separate classes as they are uneducable. These historical examples were used as examples to illustrate the intersection of science and culture; how culture influences science and how science, in turn, reinforces these social biases.

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16 Linnaeus was a 19th-century Swedish biologist who developed the classification of humans into the following races: American [Native American], European, Asiatic, and African.
The preservice teachers then were asked to think about the issue as teachers. Professor M. distinguished between having a debate and voicing opinion, and a thorough investigation of an issue. Many times teachers ask students to debate an issue, without enough investigation about the issue. Using the video and the readings of Linnaeus and Terman (1916), the class was asked to come up with an overall unit objective that would be used to teach secondary students about race as an STS issue. The preservice teachers in the class were asked to come up with specific points that they wanted their students to learn about the race issue. The class developed an objective to teach the concept that race is not a biological idea to an audience of high school biology class. The class, with the guidance of the professor, came up with the following:

A: all of my students [high school biology class]
B: (bottom line) explain and justify that race is not a biological concept, but a social cultural one
C: knowledge of Mendelian genetics, natural selection, video other resources.
D: (benchmarks, end in mind) make reference to at least two of the following ideas:
   • no single gene or collection of genes is found in everyone in one race or in no one of another race
   • anthropological archeological evidence that all modern people came from same ancestor as opposed to different pre-human ancestors evolving into diff races
   • biological differences that we associate with race (skin color, hair, disease) are best explained by geography not biology.
   • Our idea of racial characteristic has changed over time—best explained by social circumstances rather than biological.) Ex. athletic ability

As the above objective illustrates, the class came to the conclusion that STS issues can be very complex and hard to reduce to measurable objectives. To make the task easier, the

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17 The class was taught to think through teaching objectives using a format known as “ABCD,” for “audience,” “behavior,” “condition,” and “degree.” An ABCD objective supposes to help students flesh out all aspects of planning for instruction (from class recordings).
Preservice teachers were encouraged to separate which questions science can answer in an issue and which questions are moral and ethical. The class discussed several strategies for teaching this objective, such as a mitochondrial DNA lab (which was shown in the video), readings, or discussions. They also discussed which products the students would come up with such as projects, brochures, or presentations.

After practicing looking at an issue, the preservice teachers had to survey their cooperating teachers about their use of STS in the classroom. The responses from the cooperating teachers (discussed below) to the survey questions varied, but they allowed a rich discussion about pedagogical issues surrounding teaching STS. Professor M. used Aikenhead’s (1994c) model of how to infuse STS in curriculum, which was described in the textbook (Chiappetta & Koballa, 2006). The model describes several ways of teaching STS along a continuum from least STS coverage to full STS courses:

1. Motivation by STS: mentioning STS content in order to make a lesson more interesting (this is not usually labeled as STS instruction).
2. Casual infusion of STS content: short study of STS topics attached to the science topic. The STS content does not follow cohesive themes.
3. Purposeful infusion of STS content: a series of STS topics integrated into science topics. Systematic exploration of STS content.
4. Singular discipline through STS content: the science content is organized around STS themes in one science discipline, example ChemCom.
5. Science through STS content: STS is the organizer of science content that is multidisciplinary.
This model served as an organizer to figure out how to introduce STS in the curriculum. The professor stressed that whereas teachers are generally not expected to organize their science curriculum around STS, they are expected to develop well-thought out units around an STS theme, with specific objectives, activities, and assessments for student learning. The model described in class can be labeled “purposeful infusion of STS” according to Aikenhead’s categories. This was also the model described in the Standards for Science Teachers’ Preparation.

Following the discussion on the cooperating teachers’ views about STS, the preservice teachers in the class wrote their reflections on STS and how it fits in the curriculum. Most of the responses focused on relating science to students’ needs and to the society where they live. Also most of the participants chose the end of the spectrum where STS is an add-on, rather than an organizer. The participants raised the question of the extent to which an STS unit can have an action component, where teachers engage students in specific service learning activities. The class also discussed where STS fits in the curriculum. Many participants said that it would be an application or extension of concepts studied in the science class, whereas Professor M. introduced an inductive model where teachers start with the issue and study the content that relates to the issue. The latter approach tends to be more in-depth rather than a casual treatment. The class also came up with a list of things to consider as teachers plan for STS. These considerations included: relevance of the issue to the curriculum and to students’ lives; access to resources such as books, materials, Internet, or transportation; students’
development and their abilities to deal with issues; and teachers’ abilities and skills to design and implement such units.

In summary, the main points that the class covered during the STS component focused on understanding the rationale for teaching STS in high school science classes, the different strategies to implement STS, and the issues that teachers need to consider. The preservice teachers practiced studying an STS issue first then they had to think through the planning process in terms of objectives, activities, and assessments for STS. Next, I present the phase of the class where the preservice teachers had to plan their own STS lessons.

Planning for STS

The next assignment for students in the methods class was to develop a Webquest around an STS topic. A WebQuest is an online inquiry activity where most of the information with which learners work comes from the web (Dodge, 2007). Learners are presented with a specific task to complete given online resources to research. The online resources typically are included within the WebQuest to avoid the problems of asking students to go online and research a topic. The preservice teachers in the class were introduced to examples of WebQuests that deal with STS issues. One WebQuest dealt with cloning and presented students with a role playing scenario to come up with legislation to regulate cloning. The other example dealt with humans’ impact on the earth and asked students to investigate their own impact on the earth and come up with a service project that addresses hunger. These examples were a spring board to discuss

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18 Hello Dolly WebQuest is an excellent example of an STS issue and is available at http://www.pusd.info/projects/dolly/main.htm
pedagogical decisions when planning a WebQuest, such as access to computers, the appropriateness of the task to students’ level, and the availability of accessible online resources, among others. The participants had also to focus on the task that they are asking students to do.

Based on these examples and discussion, the participants had class time to work in groups of two to come up with an ABCD objective for a topic of their choice. Professor M. met with each group during class to answer concerns and guide the preservice teachers. The participants then developed a WebQuest around their topic outside class time and presented them during the last day of class. Table 2 summarizes the topics for the WebQuests.

It is worth noting that the preservice teachers in this study focused on the technical issues around the activity more often than the pedagogical issues. Some participants found the activity novel and appealing to high school students. Others expressed frustrations that they were unable to make the technology work or were spending lots of hours trying to get the technology to work. Overall, during the presentations of the WebQuests, most participants were positive about creating an online activity for students to explore an STS issue or problem.

I presented a description of the experience of these preservice teachers with Nature of Science (NOS) and Science, Technology, Society (STS) during their methods class. I next present how co-operating teachers talked about STS with them.
<table>
<thead>
<tr>
<th>WebQuest</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial Intelligence (AI)</td>
<td>Students role play to be experts on different areas of AI who will be reporting to congress. Students research and present their findings on the following areas: origins of AI, purposes of AI, societal and economic impacts of AI and existing laws or future laws on AI.</td>
</tr>
<tr>
<td>DNA uses</td>
<td>Students investigate the pros and cons of using DNA in the criminal justice system.</td>
</tr>
<tr>
<td>DNA Libraries</td>
<td>Students investigate the pros and cons of having DNA libraries in terms of privacy and first amendment rights.</td>
</tr>
<tr>
<td>Genetically Modified Foods</td>
<td>Students research pros and cons of genetically modified foods in groups and have debate in class.</td>
</tr>
<tr>
<td>Nuclear Energy</td>
<td>Students role play that they are members of a planning committee in a town that is asked to weigh out the benefits and risks of building a nuclear power plant to revitalize the town’s economy. Students research the costs and benefits of such plan and report back to the class in groups.</td>
</tr>
<tr>
<td>Natural Resources Dilemma</td>
<td>Groups of students will select one resource (air, fossil fuels, vegetation, land, and water) to investigate its use (or over-use), and various methods to conserve that resource. Students propose legislation concerning preservation of the selected resource.</td>
</tr>
<tr>
<td>Hantavirus</td>
<td>Students investigate the Hantavirus outbreak in terms of it is transmitted, how it affects people, and how it can be prevented. Students break in groups of epidemiologist from CDC, medical research professional and public health official and research the virus and present it to the community.</td>
</tr>
<tr>
<td>Stem Cell Research</td>
<td>Students are asked to role play as advisors (scientists, ethicists, politicians) to the NIH who will write recommendations of whether stem cell research should be allowed to continue.</td>
</tr>
<tr>
<td>Saving the Rainforest</td>
<td>Students break into teams of experts (environmental ecologist, botanist, entomologist, herpetologist, zoologist, and ornithologist) to investigate the damage to the Rainforest and come up with possible solutions.</td>
</tr>
</tbody>
</table>
Voices From the Field: Co-Operating Teachers’ Advice About Teaching STS

Student teachers are in a situation where they are juggling two worlds, the world of the college classroom and the world of high school classrooms. The section above described how STS unfolded in the methods class. But this is not the only or the more influential aspect of teacher’s formation. There is another world where these participants lived, the field site where they were observing during the first 5 weeks and where they were doing their student teaching. This other site provides a different perspective about teaching. Therefore I present how the methods students’ cooperating teachers responded to classroom surveys about the place of STS in the curriculum. These excerpts are not necessarily a precise snapshot of what happens in the high school classrooms. But they represent pieces of advice that cooperating teachers deemed most important to share with the student teachers.

As part of their field assignments, students in the class were asked to interview their cooperating teacher about their views about teaching social issues in science. This is an interesting story to retell, to contrast what the methods class asks them to do and what their teachers convey through their advice. I am interested in looking at how pre-service teachers hear their classroom teachers talk about STS, which can be inferred from these surveys, and not how the teachers themselves perceived it. The questions that the teachers were responding to are the following:

1. Does your cooperating teacher cover science-related social issues in his or her class (e.g., cloning, stem cell research, acid rain, global warming, etc.)? Why
or why not? What should students know in order to be “scientifically literate” members of society?

2. What advice does your cooperating teacher have on teaching topics like those given above? Are there societal issues that your teacher feels are particularly relevant for your students or your course?

The pre-service teachers interviewed their co-operating teachers and wrote up the responses. I analyzed these documents by looking at three categories (based on the prompts given above): rationale for including (or not including) STS in the curriculum; definition of scientific literacy; and pedagogical advice that the teachers gave to their apprentices. I coded these documents by looking at emergent themes, but also by using the literature.

STS Rationale

The responses to whether cooperating teachers cover STS and why varied with most of them being somewhat positive. Most teachers said that they do cover science related societal issues but with different degrees. Sometimes there was not enough information provided to figure out what the teachers meant by covering societal issues. Overall, it is possible to distinguish between different ways that teachers talked about covering STS:

1. STS is not covered: one teacher said that she did not have time to teach STS since it is not in her curriculum whereas the second teacher said that societal issues are not science, and he tries to avoid them.
2. STS is covered but is not related to the content: One teacher covered some societal issue for a few minutes every Wednesday, but it was not related to the content.

3. STS is a way to make the content relevant to students, but it has to be relevant to the content. Some teachers talked about STS as a way to motivate students and make science applicable to their lives.

4. STS falls within the curriculum and is required, for example, an earth science class that covers issues like global warming, watersheds, pollution, and natural resource conservation, or as a requirement in the state standards on which students are tested.

5. STS is an important goal to teach for its own sake: for example, one teacher covers STS issues in the classroom quite frequently through research projects.

**Scientific Literacy**

How did the teachers talk about scientific literacy with their student teachers? The data suggest that most teachers described scientific literacy in terms of knowing the content and processes of science. As discussed in Chapter 2, scientific literacy has multiple meanings, and the standards definition of scientific literacy can be too vague. However, for the purposes of this analysis, I look at this data in light of the framework of the National Science Education Standards, which span the following categories.

1. Science as inquiry: this standard refers to involving students with inquiry activities through asking questions, planning and conducting experiments, gathering and analyzing data, and thinking critically to find relationships
between evidence and explanations, and finally communicating scientific arguments.

2. Science content: this standard refers to the facts, principles, concepts, laws, and theories in physical science, life science, and earth and space science.

3. Science and technology: this standard refers to the ability of students to understand the linkages and differences between science and technology. Students are expected to identify a problem, design and implement a solution, and evaluate the solution. It also involves the analysis of risks and benefits of multiple solutions to a technological problem.

4. Science in personal and social perspectives: this standard refers to the ability of students to understand and make decisions on personal and social issues.

5. History and nature of science: this standard involves students in the study of science as a human endeavor, through studying the history of science, and the nature of scientific inquiry (see NOS discussion above).

The cooperating teachers spoke broadly about scientific literacy. The two main categories that emerged were: knowing the content of science and knowing the processes of science, with varying emphasis on each category. Some examples of responses that focused on the content of science included:

1. Students should know basic concepts and principles so they can pick up the newspaper and be able to understand what they are reading. Also students need to have enough knowledge to be informed citizens.
2. Knowledge of the current scientific material will aid in the students’ scientific literacy.

3. The basics of science knowledge that will allow them to read an article and listen to a program and be able to interpret it.

4. Being scientifically literate means having a basic knowledge of how things work of chemical, physical, and biological processes.

It is worth noting that some responses link scientific literacy to teaching students to become informed citizens, but the focus is on the concepts of science. In the science education literature, when educators talk about “informed citizens,” they usually mean people being able to make decisions on issues, or understand debates in the media. It seems like for this group of cooperating teachers, informed meant knowing more science.

The other group of teachers focused on scientific literacy in relation to science inquiry or the processes of science. Here are some examples of these responses.

1. Scientific literacy; is the new ideas of science, the new trends, and the old ideas that have been discarded. The single most important factor of SL is the process of science, what science does. Science is the process of asking the questions not answering them.

2. Students should be aware of the scientific method and have a full understanding of all the steps. With the knowledge of these steps, students can then be successful in all they do.

3. Students should understand that science is based on logic and reason, much like the scientific method.
4. Students need to know how to think critically, problem solve, and not to be intimidated by scientific language and issues. We sort of have to teach them how to attack a question and find an answer.

These responses illustrate the link between scientific literacy and science as inquiry, but with different meanings for inquiry. The national science education standards focus on scientific inquiry as going beyond following “a method,” but being able to ask scientific questions, design experiments, draw conclusions, and communicate arguments.

Fewer teachers had a specific focus on informed citizenship, which is linked to the “science in personal and social perspectives” standard. For example, Mary’s and Logan’s teachers said:

1. To be scientifically literate members of society students should have a broad understanding of the basic concepts in science. Knowing and understanding these basic concepts will allow them to comprehend newspaper and magazine articles, appreciate the world around them, and to make informed personal decisions.

2. Being able to solve problems, think critically, and contribute to personal and societal needs based on the scientific background that they received.

These responses illustrate the meanings of scientific literacy that cooperating teachers talked about and conveyed to the preservice teachers in this study. It can be seen from the data that the cooperating teachers associated scientific literacy with knowledge about the content of science, knowledge about the processes of science, and to a lesser extent,
knowledge about issues that affect students’ lives and being able to make decisions on these issues.

*Advice From Expert Teachers*

The question of what advice the teachers would give to the student teachers about teaching STS is an important one. Student teaching is usually a stressful time, and preservice teachers look for these pieces of advice from their cooperating teachers. The responses give us some insights into what these preservice teachers perceived as good practice in teaching STS. Most cooperating teachers said to treat issues with caution, know when to draw a line, stay objective, stick to the facts, and be careful on how you present issues. One cooperating teacher recommended to only discuss issues as they come up: “don’t set aside time specifically for them.” Only two teachers spoke about specific instructional strategies to discuss issues. For example, one cooperating teacher gave the advice of beginning with current events articles, giving students KWL charts, or using case studies, simulations, or videos to discuss the issue. Another cooperating teacher recommended having a plan for handling discussions on the issue and that those discussions need to be well thought out and planned.

On the other hand, two cooperating teachers specifically said to stay away from issues. For example, one teacher said: “When it comes to societal issues, it is important to know the community in which you teach. Some communities are more accepting of content than others.” Some cooperating teachers advised the preservice teachers to stay away from controversy, to protect their job security. For example, Aidan’s cooperating teacher advised him to
Shy away from controversial issues at first. He said that it is better to lay low and not make any noise during your first years of teaching. From there, he said it really depends on the make up of your community and how they would react if you sparked a controversy.

The data from these surveys provide an insight into how the cooperating teachers communicated with the preservice teachers about their views on scientific literacy and teaching STS. Cooperating teachers talked about scientific literacy mainly in terms of focusing on the content of science and the processes of science. To a lesser extent, few teachers discussed scientific literacy in terms of the ability of students to understand and make decisions related to social issues in science. Furthermore, with few exceptions, most of the cooperating teachers were positive about including STS in their science teaching, although the extent to which they covered STS varied. They cited the reasons for teaching STS mainly as to: motivate students, make the science relevant to students’ daily lives, address curricular and state requirements, and prepare students to be informed citizens. It is important to note that these responses were shared in the methods class, so that all the preservice teachers got exposed to the range of answers that cooperating teachers gave. The participants were able to contrast the responses of the teachers to different models of incorporating STS in science education19 (cf. discussion of Aikenhead’s (1994b) categories above), and the link between scientific literacy and STS in the science education literature.

This section described how the senior group was introduced to STS from two perspectives. I first described how the methods class introduced STS. Participants learned

19 These different models are discussed in the description of the class above, using Aikenhead’s (1994c) categories: motivation by STS, casual infusion of STS, purposeful infusion of STS, singular discipline through STS, and science through STS content.
about the “nature of science” in science education and how an understanding of the nature of science is needed to make decisions on societal issues that relate to science. They then explored the rationale for teaching STS, examined different strategies to teach STS, explored an STS issue about the biological basis of race, and finally practiced planning an STS unit through an online activity. I then described the responses of cooperating teachers to how they teach STS. These two perspectives provided a rich description of the experiences of the preservice teachers in STS. The next section describes the experiences of the other group of participants, which is the junior class.

Context: Junior Class

The second group of participants in this study were science education pre-service teachers during their first class of science methods (everyone had a general secondary methods course prior to or concurrent with this class). The class met twice a week for three hours a week for the whole semester (15 weeks). I first describe the class in general, then describe in detail how the STS unit was presented in class. The two classes were somewhat similar in content, but there was a major difference in format. The junior class met twice weekly for the duration of the semester, and they had no field component.

The syllabus (Appendix B) describes the goal of the course as developing students’ pedagogical content knowledge. The class spent two sessions discussing standards for teaching science. Then four sessions were spent on developing students’ understanding of pedagogical content knowledge (PCK). Students were required to pick a content item from the standards, and then try to teach it using different teaching strategies. Misconceptions in science and conceptual change model of teaching spanned
another 3 sessions. Students were required to research an alternative conception in their subject area, design interview questions to get at pupil’s understanding of the topic, and then interview a student and write it up. The next 4 sessions were spent discussing planning, assessment, and specific teaching strategies such as demonstrations. Students came up with discrepant event activities and were supposed to teach them to their peers.

Teaching about the nature of science was introduced through focusing on history of science, which spanned about 3 sessions. STS or teaching “issues” in science, as it was called in class, took about 4 sessions. To show their understanding of teaching about the nature of science, students were required to design a 3-day lesson that addressed the history of science. Finally to address the STS component of the class, students were required to develop a 5-day unit that dealt with an STS issue, and where they could practice their knowledge of teaching (planning, assessment, instructional strategies). The above description was a quick overview of the class. Appendix B shows the sequence of the course and the specific instructions for the assignment. The STS component was one part of the class, and was introduced in conjunction with discussion about the nature of science. The next section describes how the nature of science and STS component of the class unfolded.

Experiencing STS

After spending time discussing history of science, students in the class read the concluding chapter of The Golem (Collins & Pinch, 1993). The discussion centered on how the authors of the book present scientists as experts in the natural world, no more, no
less. Just like plumbers are experts in plumbing, or art experts are in art. One participant suggested that this understanding of science could make it more accessible to kids:

Linn: I really like this last bit about education . . . talked about each kid getting a different degree for [boiling] water and, you know, it is like this discussion that must follow that’s really the science of it . . . Teaching the kids, you know, that it is not always perfect . . .

P.M.: It is not always perfect, but it is not anything goes, it is not like we can just make it up . . . Anyway, so what they’re talking about in the science ed piece there, when students are in a classroom, what you’re really showing them is basically how to talk like a scientist, how to do science, you’re enculturating them into the culture of science, right, giving them an appreciation of how science is done, ok. Other comments about this idea that scientists are just experts in the way that the world works, no more, no less. How does that help you? Do you think that should be something that kids in 7-12 are learning about in science? (Silence) yes or no . . . is that something we want our kids to know about in science? Noah?

Noah: Yes, so they can feel that they can do science as well, instead of like how . . . Like Einstein, like massively intelligent, so kids might feel like, they are not going to be able to do that, so why study science. From the other point of view, bringing science down, they can feel they can understand it and go on with it. (CR, J, 3-22)

Professor M. continued to talk about the book’s position that scientists are not viewed as gods (or charlatans), but as human beings who are experts at what they do, and who can also make mistakes. The discussion then shifted to scientific literacy and why it would be important for kids to understand what science is. The treatment of issues was linked during the discussions to an understanding of the nature of science. The group agreed that in order to understand issues, you have to understand how science works. An illustration of the discussion follows:

Professor M.: Very few people do go into science fields, realistically. So if you realize that, most of your kids . . . you want them to be well rounded citizens, you want them to be productive citizens, so what should a productive citizen know
about science, that is what we mean by a scientifically literate, or scientific literacy. What they should they know?

Ryan: . . . people are going to be voting on science issues and in order to vote on a science issue, it would be very helpful, certainly helpful for the society as a whole . . . that that person knows what science is, and how it is working in that particular area, to vote.

Professor M.: They make an interesting claim about that though [referring to golem], they say most people think that what we should know is more about the facts of science; the content of science. But they are arguing that what people really need to know is what science IS and what it isn’t. The facts you can look up, you can find the facts, but what you need to know is that scientists are experts about how the natural world works. . . . And a lot of times—I think we talked about this with stem cells—we all understand that if there is controversy in science, that is really a sophisticated controversy that is happening at high level, it is not something we can just take a vote on in society, because we are not scientists, we don’t have their expertise . . . That seems to me like a really important for your kids, for your students to know about science. (CR, J, 3-22)

The main points that participants explored in the discussion of the nature of science is that science is a human endeavor, done by scientists who are situated in a cultural and political context. They also learned that science cannot answer all questions, and when dealing with STS issues, they need to separate which questions can be answered by science and which ones are ethical, political, or moral. They discussed that as teachers they need to convey the nature of science adequately to their students.

Following this discussion on how the analysis of issues involves an understanding of the nature of science, the class then examined one particular STS issue: Race. The class watched “Race: the power of an illusion” video (description above). Professor M. directed the discussion to the scientific practices described in the video that justified racism. Professor M. also focused on why it is important to teach about topics such as history of race. Participants answered that their job as science teachers is to prepare
students to be citizens in this world. Professor M. geared the discussion to questions
about teaching of issues: Why would you teach about issues in a science class, and how?

Professor M. (talking about the level of detail of science in popular magazines): And your students as future citizens are going to have to deal with that kind of level of science understanding all the time. As citizens, they are not going to be experts in genetics or in cell biology. They are going to be citizens and they are going to have to remember some key ideas from science. And that is why we are trying to practice this kind of stuff with them. (CR, J, 3-22)

The class explored in-depth how knowing about science is really important to understand issues. This exchange illustrates how participants were willing to view how science and society’s interactions go both ways, not only in historical moments when we got the science wrong (race), but also current issues around the tobacco industry:

P.M.: So why is it important to teach this?

Linn: It goes back to becoming a citizen so that when current concepts come up that they have some tools to look at bias in research, it is like we watched this race video\textsuperscript{20}, and the guy who wrote the biggest paper, with the biggest influence, was a scientist for an insurance agency. It made sense for them from an economic standpoint, not to have to, you know, support or insure, or protect the black race as opposed to the white race because, you know that superiority conflict going on. And that colored his . . . in addition to all the other social things, but also that he was paid for him to be funded.

P.M.: Ok

Linn: So, it gives tools for them. Eventually they are going to have to vote on something, you know, making judgment.

Lisa: Sort of like Philip Morris.

Linn: Right, right.

\textsuperscript{20} This particular incident refers to a report by Prudential Life Insurance statistician (actuary) Frederick L. Hoffman. His report, “Race Traits and Tendencies of the American Negro,” written in 1896, suggested that Native American and Latino groups should not be insured as they are physically weak and bound to become extinct.
After watching the video, the class came up with an ABCD objective to teach students about the idea that race is not a biological concept. This was a practice for them to come up with ways to teach about a social issues, in this case race. This objective was largely teacher guided, and it can be seen that it was similar to the objective the other class came up with. The junior class came up with a more detailed objective, since they had more time to discuss the video.

A: 9th grade biology students
B: explain that race is not a biological concept but rather a social/cultural one
C: given:
   1. Basic understanding of Mendelian genetics
   2. Basic understanding of geography - who lives where and historical changes in that
   3. Natural selection/evolution/population genetics
   4. How new technologies (e.g., DCR, electrophoresis) allow us to obtain the evidence listed below
D: With reference to:
   1. No one gene is found in all members of one race and no one of another race
   2. Our notion of racial characteristics has changed over time and is best explained by societal conditions and circumstances rather than biology. (we used to associate physical weakness with blacks and now we associate athletic ability with that race)
   3. Different societies recognize different races.
   4. Archeological/anthropological evidence that all modern people came from the same ancestors (not separate species).
   5. Biological differences that we associate with race (skin color) are best explained by geography and genetic drift

Focusing on thinking like teachers, Professor M. required the students to come up with activities and matching assessments about race to teach high school students the objective about race above, in groups. After presenting their ideas, the discussion afterwards focused on what you could reasonably expect high school students to be able
to do, what you would need to give them ahead of time, and what the assessment would look like. In their activities, the groups typically focused their instructional strategies on having their students research information and present it. This triggered a discussion in the classroom about the appropriate use of research with high school students, especially with complex issues; Professor M. argued that often, students get little out of an experience like this when it is not scaffolded to help them make sense of what they find through research. The other question that dominated the discussion was whether the activities, assessments, and objectives are aligned. These are all practical considerations, but they also show that the group practiced thinking about STS issues as teachers, in terms of planning, thinking about student developmental readiness, and aligning assessments and instructional strategies with objectives.

The other factor that students brought up is the controversial nature of issues, and the willingness of teachers to deal with them. A comment by Professor M. summarizes these concerns:

Professor M.: OK, so these are interesting conversations that we don’t take the time to have, and in some cases in schools you will be in trouble for having them. So I think it is interesting, one thing about teaching STS issues is that these are risky. If you are going to talk about environmental issues with logging, and most people in the community are loggers, then it is going to be an issue, so you do have to think about this stuff. But you also have to think about the larger purpose of teaching, why are you here. What is the goal of teaching science? And is it to help students understand the facts of science, is it to help students understand the processes of science, is it to help student understand how science aids and assists them in daily life, is to help students understand how science plays in our society and in our societal needs and expectations, is to help students prepare careers in science, so those are the five goals we talked about. It is going to depend on your own values and goals. (CR, J, 4-17)
Similar to the senior class, Aikenhead’s (1994c) model of integrating STS into science was introduced. Professor M. emphasized her expectation that the students plan for a thoughtful unit which (in her way of thinking) was different than merely asking students their opinions about topics. This discussion helped participants think through how to fit STS in their teaching.

The main points of the STS section of the course can be summarized as follows: (a) not all students are going to be scientists, therefore science teachers need to focus on the goal of teaching science for future citizens who will have to understand and make decisions on issues; (b) understanding issues require an understanding of the nature of science and the role of expertise in science; and (c) students need to be guided in their study of issues through purposeful planning that involves clear objectives and aligned activities and assessments.

**Planning for STS**

After going through the experience of looking at an STS issue (Race), the preservice teachers were required to come up with their own STS unit that spans 5 days. The guidelines for the unit are included in Appendix B. The students were developing the units individually. The syllabus directed them to focus on the following questions:

You should focus on helping students understand the issue itself, including its component aspects, issues and questions (Which are the scientific questions? Which are questions of technological application? Which are ethical questions? etc.). You should also guide students through an analysis of the related problem(s), including a consideration of risks, costs, and benefits.

Participants selected a topic, and then tried to come up with an ABCD objective to teach their topic. A considerable amount of time was spent going through each topic
and objective collectively and helping students make it more focused. The class differentiated between issues and problems, through working out the topics at which they arrived. It was said that issues deal with yes/no questions, whereas a problem is more complex and requires a proposed solution (Chiappetta & Koballa, 2006). The topics investigated by students were as follows:

1. Alternative energy: Four units focused on having students investigate several energy sources such as solar, hydroelectric, hydrogen, natural gas, or ethanol and come up with a proposal to select one source they would adopt based on several factors (economic, environmental, efficiency). An additional unit plan focused on investigating personal changes in one’s lifestyle to reduce gasoline consumption such as habits of driving, or choice of car.

2. Nuclear energy: One unit plan focused on having students investigate whether they wanted to build a nuclear power plant in their community and be able to articulate a position and defend it based on research and their own values.

3. Development versus conservation of wetlands: One unit focused on having students investigate whether they want to build a WalMart on a local bog, based on their consideration of the effects on the environment and the economy.

4. GMOs: Two units focused on investigating the positive and negative effects of genetically modified foods on the environment, human health, and economics. One of them looked at outlawing the use of GMOs for production, growth and sale of crops.
5. Cloning: One unit investigated the benefits and drawbacks for using cloning organs for human health.

The first starting point was for the students to figure out whether their topic was an issue or a problem, which would affect how they will present their lessons. The students’ chosen topics ended up focusing on energy efficiency and genetically modified foods, which figured often in the news, and which high school students could easily relate to. The class discussed specific strategies to present their units. The professor kept differentiating between motivation by STS and purposeful infusion of STS which (to the professor) would imply well thought out units. Going through nuclear energy as an example topic, Professor M. stressed that it is inadequate to have students give yes/no answers to a question like, “Should our town build a nuclear power plant?” without serious consideration of the why.

Thinking about the topics you turned in to me on Monday, some of them might work as yes or no question, would be Dan’s: should we build a nuclear power plant in our community. This is a yes/no question. At the end of the 5-day unit, he wants his students to be able to decide either yes we should build the nuclear power plant or no we shouldn’t. And they are going to have a reasoned response to that, right. They can’t just say yeah, I think it will be good or no because; I think it is bad. You have to ask them why. (CR, J, 4-26)

The class discussed how there are multiple questions involved in Dan’s example. They talked about how some questions were scientific, such as where the waste will be disposed of, or the safety of the power plant. Other questions were political, such as how will such a plant affect the community. The other aspects were economic, such as the impact of the power plant on job creations in the community. There was a detailed discussion of how Dan would go about teaching his unit. First, Dan would have to
identify the science questions and help his students understand the science behind those questions. For example, the class might investigate what scientific evidence is available about safety. Then Dan would have to help his students identify the social or economical aspects and rank order what is most important for them: creating jobs for the economy, maintaining safety for the community, or finding a reliable source or energy. After students rank ordered these aspects, they could make a decision. For example, Professor M. said:

If the things at the top of their list are good, as far as nuclear power goes, then they will probably go with it. If the top things on their list are negative, then they will probably say no. But that is what we mean by helping students come to an informed decision. And is it possible in your class that some students will say yes and others will say no on this issue, yeah, absolutely. Because, no one can decide for students how to rank those items. If a student feels that creating jobs is the most important thing and a nuclear power plant, they decide is going to bring in lots of extra jobs . . . then probably they are going to say yes in the end. If a students think that long term environmental impact is most important and they are worried about the safety of burying nuclear waste, then they may end up coming to the conclusion—no . . . and the students have to give a reason for why they would weigh job as most important or why they would weigh safety as most important. Do you see how we guide students through this particular unit? (CR, J, 4-26)

The example above is an illustration of how students were guided through thinking of STS as purposeful lessons, and how to help students separate science questions and political, economic, or moral questions. The discussion moved to talking about how to fit an STS issue within the curriculum, and whether it should come before or after the facts have been explained:

Emily: Do we have to introduce our problem or issue the first day? I want to teach about the different [content] and then give them the problem at the end, because I don’t want them to be biased when they go into the research part. Like, I don’t want them, cause I am doing the whole Wal-Mart thing, I don’t want them to be like I don’t want a Wal-Mart so, they’re not going to listen to anything I have to
say about the wetland or the bog that I want to use. So I want to like have them learn about the things first, and then ok, we have this problem, and then take what you’ve learned on both sides. I don’t want them to pick and choose at the beginning. Are we allowed to do that?

P.M.: That’s a really great question. What a great question of pedagogy and teaching, and how do we do this, right? Because now you are thinking what do you do on day one, versus what do you do on day 5. My advice would be to start with the problem and end with the problem, that would be my advice. And I don’t think you have to worry so much about . . . the students being biased. I think what you have to worry about is that students . . . when they hear information about the environment, or wetlands or habitat destruction, if they are just hearing that for the sake of hearing it, then a lot of times it doesn’t mean anything. But if they are hearing that for the sake of solving a problem with it, then they know what to do with that information. So in other words, it makes sense to sort of give them the problem upfront.

Your question is a good one and I think it would depend on the situation but in general if you want to do an STS issue, what teachers usually do is present a problem upfront and help students understand that they don’t have the resources to answer the question . . . So if you make it on them to justify their answer, then it will be the impetus for them to listen to you explain about ecology, economics, or politics. (CR, J, 4-26)

These examples show how the participants were introduced to teaching STS as a planned activity, which was contrasted with soliciting students’ opinions on issues with no substantial backing. The participants first studied an STS issue as students, then discussed how they would teach STS by working on several examples in class. They also worked through many pedagogical considerations, such as students’ background knowledge, resources available to the teacher, and what type of activities are needed to get students to understand the issue.

These detailed descriptions provide a context for understanding how the participants were introduced to STS teaching and what experiences they went through. It
should be clear from these descriptions that STS was treated in depth, and with a model that follows a purposeful infusion of STS content (Aikenhead, 1994c).

Towards the end of the semester, I asked volunteers from both classes to participate in interviews so they can share their reflections on their STS experiences with me. In order to understand the context of who these participants were, the next section focuses on the participants who were interviewed in terms of their background and understanding of STS.

Profiles of Participants Interviewed

I interviewed the pre-service teachers during the last week of the semester. For the senior group, this was the week following their completion of student teaching. For the junior group, this was the last week of the semester and immediately following their completion of their STS units. This section provides a profile of each participant and a summary of the main points they addressed during the interview. These profiles were constructed based on the interview data and my own interaction during data collection. Each profile is organized around four parts:

1. **Personal profile of participant:** This section describes the background of the participants who volunteered to be interviewed. At the beginning of each interview, I asked each participant to talk about their trajectory to becoming a science teacher. I also interacted with these participants during their class, so this allowed me to construct a description of who they are through the interview, my observations during the field work, and what they shared with me during informal conversations.
2. **Teaching philosophy** (for senior group only): At the end of the semester, these participants were required to submit a written philosophy of science teaching to their methods professor. The interview provides a more spontaneous response to how they see themselves as teachers whereas the written document is certainly a response to what is perceived appropriate to submit to the methods professor. It is important to note, however, that I interviewed these participants during the week where they were presenting their teaching philosophy to their professors, so there could be a lot of overlap between the two.

3. **Student teaching experience (for senior group only)**: I asked the senior group to share with me what their student teaching experience was like and I summarized these findings in each profile.

4. **Meaning of STS for each participant**: This section was synthesized from participants’ responses to the interview questions about how they would explain STS.

These profiles are not meant to be seen as descriptions of the participants’ mental constructs. Instead, they provide in-depth descriptions of their reflections on their experiences with STS during their methods class. I chose to present the data in this way, not to label each individual with a mental state that is stable, but to enrich the understanding of how each individual reflected on their experience, and enacted that reflection during the interview. On a side note, if I had been looking at participants’ mental constructs, I would have probably placed them on a continuum of their STS
understanding (or lack of). The organization of the data by profile of each individual highlights the life experiences that participants bring with them and weave into their narrative. For example, the life experiences of a former chemist in her 40s who is returning back to school for a second career are different than the life experiences of a college student in her early 20s. Similarly, a participant who described himself as religious may associate STS with evolution and controversy, and feel uncomfortable discussing these topics. Hence, the structure of the data exposes the various experiences of the participants as they presented themselves during the interview. In addition, there were differences between the two groups, in terms of the senior group reflecting on their STS experience through the lens of student teaching, and the junior group reflecting mostly on their methods class experiences. Hence this section is organized into the two groups, seniors and juniors.

**Senior Group**

The senior group offers an interesting insight since they just finished student teaching and they could presumably think of teaching science in more practical terms. For some of them, the experience went smoothly, whereas for others, it was a challenge. The interviews occurred the week following student teaching, which was 10 weeks after the methods class discussion on STS. To some extent, the experiences during the methods class seemed somehow far removed. Their answers to the interview questions were influenced largely by how they were thinking about the practical aspects of teaching. The timing of the interview offers a unique point in time to look at how these participants understood STS. Not only did they had the experience of working with
students for an extended period of time, but this is also a time of reflection on student teaching, with some questions asked about what worked and what did not. I was hoping to witness their reflections on how to teach STS, based on their experiences in the methods class, but also with the lens of a teacher who has been in the classroom, and had to go through the process of planning and teaching.

_Laura_

Laura is a White woman in her 40s who returned to school for a second career after staying at home with her two kids for 15 years. “Now that my kids are older,” she said, “it is time for me to do something.” Laura has a degree in chemistry and worked in industrial chemistry for a while. She had some positive teaching experiences and her love of science and love of teaching got her to choose science teaching. During the class, Laura made many remarks about her views of science as a human endeavor, and how her experience working in a science lab gave her a perspective on the awkward relationship between industry and science.

_Philosophy of teaching._ Laura described her teaching philosophy in terms of focusing on the process of investigations, and on connecting science to real life. She wrote that students need to focus on the process of doing science, rather than on the outcome of investigations. Furthermore, she stressed the importance of connecting science to real life, which is consistent with the science education standards. She wrote:

The second component provides meaning to the students by connecting science concepts to real life applications. This component is also critical because it provides illustrations of how science is intertwined with the needs of society as well as how science can impact society.
Student teaching experience. Laura had a difficult student teaching experience, mainly due to her not getting along with her cooperating teacher, but also having some difficult classes (in the sense of classroom management). She referred to the student teaching experience as a stressful one, though she said that she learned how to manage her time, how to multitask, and how not to get angry and not to let the students take advantage of her. She also stressed how she really learned that it is very important to get to know the kids so you can teach them. Laura did not implement STS during student teaching.

STS understanding. Laura said that science and technology affect people without even them taking notice. She also noted that citizens need to look into how much they will allow science and technology to affect their lives. In describing STS, she said:

Science and technology are intertwined. And then both of those are intertwined with society in couple different ways, one in a way that they impact society; the changes that occur because of the increase in knowledge or the betterment of technology and also not just the changes but the issues that are involved like the sides that you can take, should we do this or should we not do this, or how is this going to affect us. So I think there [are] two things, one is without people realizing technology and science affect us. The other piece is, well, how much are we going to let science and technology affect us? So there is decision making there, those are the things I think are the most important. That’s what I took from class.

Laura got excited when I asked her how teaching would look in an STS curriculum:

That, I think is what is going to make this a lot of fun. Because what I saw in student teaching is this: I saw a lot of facts being giving out, I saw students having to struggle with really abstract concepts, and they spent a tremendous amount of time focusing in on these abstract concepts but the kids can never connect these abstract concepts to anything concrete, anything that they can really put their hands around and I have to wonder at the high school level, and this is something I thought about quite excessively this morning. At the high school level, is it
important for kids to be able to memorize and produce the periodic table and the electronic configuration? Or is it more important for them to have a basic knowledge of these things, knowing very well you can look up the periodic table and use that knowledge to apply it to other science topics that they seem never to get to, I mean we’re still doing, they were still doing oxidation states and chemical formulas in March and . . . I mean there is no time to do acid base chemistry and . . . which you can do so many science and technology things with STS things with, there is not a ton of time to do like a thermo, the nuclear chemistry unit that they did was just so tiny that there is not a lot of time to spend on those kind of things and I think the kids . . . what the point of learning these chemical formulas, what the point of learning oxidation states.

Laura talked about making science more relevant to students, but discussing issues for her is not just so students grasp the content better, or so they can get motivated to learn the concepts. She genuinely questioned the value of a content-oriented curriculum, without necessarily using the language of “the goals of science teaching.”

Now do I think that this stuff is important, sure it is a basis but at that level . . . if they are gonna go on to take chemistry in college, they’ll have been introduced to those concepts and those concepts will be drawn out and taken further. But at that level, when you are trying to keep them interested and involved . . . I think it is more important to bring in . . . to do units based around technology and things like a nuclear chemistry unit and base it around nuclear energy and the things that are involved there or an acid base unit where you are talking about acid rain and environmental impact em . . . bring in some of these things together, I don’t know. Do you understand what I am saying?

I am sure all the old time teachers would go: no they have to know how to do electronic configuration, well yeah, but they don’t really need to spend three weeks on them. Do they? I mean especially when you can look them up and as long as I understand what is going on there, that oh that valence electron is what causes reactivity what’s the point of them being able to . . . I don’t know that’s my opinion.

Laura appeared to realize that her vision of teaching through STS was different than what typically happens in the classroom. She, however, described her goals for how to teach science the following year, having secured a job already:
So I think I am going to try to base my chemistry classes around . . . My goal is, I have already thought about it. By Christmas time, they should have the basics of what they need to know about chemistry and then spend the whole other half of year doing units that are based around things that they can put their hands around. That they can get involved with, so I am hoping, I’ll be teaching chemistry next year, and physics. That would be fun.

The time necessary to “get through” a high school chemistry curriculum was not a disturbing issue for Laura, because she was not wedded to emphasizing the content as much. She did talk about using STS and science applications, and having the students figure out content through that. One point worth noting is that Laura had a conflict of personality with her teacher (discussed by her but also by her professors during the exit interview), which made her contrast her own personal teaching style and that of her cooperating teacher:

What I saw was that she drove the basics in, the basics basics basics basics of chemistry and then all the good stuff happen at the end . . . if you’re familiar with chemistry, all the good stuff happen at the end, when you finally can do reactions and then again acid base chemistry, nuclear chemistry, thermodynamics, that’s when all the fun stuff happens. That’s where the application is.

If you spend your whole year, almost 8 months, trying to get kids to name chemicals then . . . you’ve lost them. What I am thinking is, some of that will come as they are doing the bigger picture units, like if you start talking about acid base and you do a unit on acid base and like you do that 3-p thing that I did from last semester, they are gonna have to by default learn the chemical formulas for certain things, for acids and bases. Then you touch on oxidation states, you know what I am saying, integrate it more, instead of pounding all those basics in, in worksheet after worksheet naming chemicals. They’ll eventually get them when they need them. You know when you start needing pieces of information, then you go look them up and use them.

Although she did not implement any STS in her student teaching, she spoke very positively about the prospect of having her own classroom and being able to structure her curriculum around more inquiry oriented units and project based learning. She did not
feel that she had any control over what she taught during student teaching, and she was not comfortable departing from what the teacher was doing. She had specific ideas about what she would do the following year:

What I was thinking of doing, I think spring would be a good time to do nuclear chem., since NewTown is close to the nuclear Power Plant, it might be something they might be interested in. I think I want to do the whole WebQuest and see how it goes . . . I want them to be able to learn to make decision on stuff. I don’t care if they like nuclear chemistry or don’t . . . or if they want a nuclear power plant or what they think about the nuclear power plant, I don’t care about that. What I want them to be able to do is take information and be able to make decisions, based on what they know. To me that’s . . . That’s a life long skill. They may never entertain the idea of nuclear chemistry or physics again, but they will in their entire life have to make decisions based on science stuff, you know important issues.

Overall though, from her comments and her excitement talking about STS, we can see that Laura appears disposed toward viewing science in broader terms. She stressed her willingness to “let go” of covering the content of science, and focus on the process of science, and on issues that affect students and society.

Tom

Tom is a White man in his 20s who spoke passionately about teaching as a way to express himself. He described teaching as a drama, an act, with an opening, a body, and a closing. He equated being a teacher with being on stage, where a performer would get a lot of attention from kids. He said that he tries to have as much fun as possible, being loud and animated, and that kids respond well to that. He talked about following his heart to become a teacher and how his experience with drama helped with that. He said: “Teaching is the way I want to express myself,” and “I feel like I am on stage.”
Philosophy of teaching. In his philosophy of teaching, Tom emphasized again his understanding of teaching as performance, or drama. He focused on a teacher who is animated, who will therefore motivate and interest the students. Tom wrote: “My personal style is one that utilizes drama and animation to gain students’ interest in the subject matter. Students often become more interested and trusting when they feel that a teacher is enthusiastic about the material they are instructing.”

Tom’s comments suggest that he places a lot of value on the teacher as a central motivating factor for students, rather than relying on issues or topics to engage students’ enthusiasm. Without observing the classes he taught, it is unclear whether Tom regularly employs a teacher-centered pedagogical style. However, he clearly saw the successful teacher as one who was funny and animated. In terms of his goals for teaching science, Tom focused on the traditional goal of teaching content and process in science education, with his focus shifting more towards process: “science as whole revolves around discovering the world in which we live in, this is heavily rooted in the Scientific processes—i.e., the scientific method.” He also casually mentioned teaching science for active citizenship, when he wrote that students need to know content in order to function in our society: “Knowledge of the main principles of science will in fact empower the students to be active members in our society.”

Student teaching experience. Tom referred to his student teaching experience as a great experience. He talked about being fortunate to have worked with an understanding cooperating teacher, who gave help and support but also gave Tom some “space” to develop his own style. Tom also was very relaxed during the interview because he
already had a job. Tom said that he did not implement STS teaching during his student teaching, but he mentioned that he tried to relate current events on the news to his teaching, commenting on relevant topics in the manner his cooperating teacher used (although not to the extent that the teacher did it). He talked about discussing stem cell research in class with his students, but he said the students in general were apathetic and did not really listen. He brought a newspaper article that discussed stem cell research and he wanted his students to discuss it. He recalled that two students got into a heated debate about stem cell research and religion which made Tom uncomfortable enough to feel like he had to stop the students’ dialogue. He said that he did not intend for his “mini discussion on stem cell to turn into a heated debate.”

*STS understanding.* Tom started the interview trying to recall what was meant by “STS” during the methods class discussions. He talked about scientific literacy and preparing students for real life. During the interview, it was clear that Tom was trying to make sense of his own understanding of STS, even when at times it seemed conflicting. He worried about the controversial nature of the issues in STS and how it could cost him his job. He compared STS to “walking on eggshells.” Overall, Tom emphasized using current events to discuss issues.

Trying to take the news . . . the advances in medicine, the . . . political arena and integrated into the classroom and using it to make them be (pause) I guess proficient citizens . . . I mean it’s out of the . . . you’re taking what you learn in the book and kind of bringing in how society is playing upon it . . . evolution is a tricky subject and you have to talk about it in science and there’s lots of different things going on in society about those debates and you can integrate that in the classroom but you have to be careful about that I guess but I think that it is a vital part of the science curriculum not just that evolution the whole STS: you want to make sure that the students are able to be citizens when they leave and I think this is one of the ways that you can do it by integrating the science and the technology
into the classroom everyday. . . . Not everyday, I would say once a week or twice a week, or when these big topics come up in the news I think that you should draw upon them even if it is not going directly with your curriculum.

Tom had job security on his mind as he thought of implementing STS. He repeated several times that a seasoned teacher might be able to deal with the problems with STS but not a new teacher.

Tom: So I guess I will play it safe. I don’t think that’s wrong. I think that’s ok. Playing the game so I can stay to be a seasoned teacher . . . (laughs), so they don’t kick me out.

NM: Do you feel like you can get kicked out?

Tom: Oh absolutely, I think if you rub the wrong person the wrong way or the right person the wrong way, that has a little bit of authority, they can definitely cause you a lot of havoc that you don’t want to get into as a beginning teacher.

NM: Is that from a specific experience?

Tom: That’s from reading the news . . . you hear often time about teachers who get into these situations where they have talked about a controversial topic, sometimes they’re off the wall, anyone with common sense would know that, but other times, it is one parent who got upset and took it as far as they could and then that person is without a job. So I think I am hesitant but I am cautious from entering these kind of situations, but I want to be fully aware of the risks I take as I touch these topics that are so controversial.

Tom mentioned at the end of the interview that he used the WebQuest during student teaching, in contrast to his earlier statement that he did not engage the students in an STS lesson during student teaching. Tom’s student teaching placement was in a physics and chemistry classroom, but during the 10-week experience he arranged to teach a unit in a biology classroom in order to get more experience. Because he would be teaching a separate unit with a new group of students, Tom felt that using his WebQuest (which was on a biology-related topic) made sense. His reflection on this teaching
experience focused on the pedagogical incorporation of instructional technology by having students research materials online:

It was definitely an appreciated change . . . than a normal curriculum, and I would like to devise a new one. They liked not having to listen to me for a while. They liked independent research that is exciting. Because I tried to jazz it up as much as I could. It was the technology that they liked.

Tom talked enthusiastically about using technology in the classroom, such as having students make presentations using Power Point® or designing WebQuests. The value Tom placed on instructional technology was further in evidence when he talked about how showing his WebQuest in a job interview helped him become more marketable:

It worked really great in the interview . . . they liked that I did stuff like that. They were really impressed that I had the ability to do that. They may not even have the technology to do that, but knowing that I can do that, made me more marketable. It certainly impressed them that I had an understanding of technology.

It seems like for Tom, the WebQuest was separate from STS and more about instructional technology.

*Emma*

Emma is a White woman in her early 20s. She did not participate much during the class discussions and was brief in her responses to the interview questions compared to the other participants. She talked about having good experiences in junior high and high school which led her to want to be a teacher.

*Student teaching experience.* Emma spoke very positively of her student teaching experience. It went very smoothly, except for a few difficult classroom management-related situations. According to Emma, student teaching was not as stressful or
overwhelming as professors or other people warned it could be. The teacher had the curriculum set and ready and she had to follow what the teacher wanted. She still was able to do few things here and there, but her plans were mostly set by the cooperating teacher.

*Philosophy of teaching.* Emma stressed a focus on inquiry in her written philosophy of teaching. She wanted to teach students to “think like scientists” and she felt she could accomplish that through inquiry-based activities. She wrote that “if students can do inquiry and be able to communicate and explain what they have discovered or experienced, then science education has achieved its goals.”

*STS understanding.* Emma talked about using STS only when it fits into the curriculum. It would be a way to get the students interested in the topic they were studying. She did not implement STS during student teaching because the curriculum was cramped and they were preparing students for the state graduation test. “I would have done it if I had time,” she said. She talked about how important it is for students to be knowledgeable citizens. She talked about how her ninth grade students were bored easily and how an STS issue might get them more interested. She stressed however that any potential STS topic had to tie into the curriculum and that she would have to have time for it.

I would definitely only use it if it fits with the concept I was teaching. I wouldn’t just blow out of the air and say hey let’s learn about this. So I think that would be the only that I would use it. If I really find it is interesting to them and they can really get something out of it and it ties into what we are doing in the classroom.
Randy

Randy is a White male in his early 20s. Randy started studying architecture, but did not have a love for it. He recalled a high school teacher that opened his eyes to science and got him interested in science. “I never really thought of myself as a teacher but taking physics college classes got me into thinking about becoming a physics teacher.” He liked physics and wanted to teach it. He did his student teaching in an urban school, in a physical science classroom. He tried to teach concepts that are considered appropriate for the 12th grade curriculum to freshmen students: “It was quite difficult, but I tried to make things as simple as possible.” He thought it worked out well.

Philosophy of teaching. Randy focused his teaching philosophy on teaching main concepts in science, while motivating students by relating this content to their personal lives and societal issues around them. He wrote: “In my classroom, I make content as relevant to students’ lives and societal issues as possible. By establishing this connection, students’ interests and motivations are heightened and a higher quality of learning takes place.”

STS understanding. Randy thought of STS as a way to make the content more interesting and to bring technology into the classroom. In his interview, he linked STS to interesting events on the news or articles in magazines. However he did not implement STS in his student teaching due to lack of time and his feeling that the students were not mature enough. As a new teacher, he said he would be overwhelmed to try something like STS. He talked about STS as linking science to real life for his students, like providing a news article that he could discuss at the beginning or end of class. At the end
of the interview though, he mentioned that if a teacher looks hard enough, there is an STS issue in any topic. He said that we owe it to the students to introduce it to them.

Often time I heard students say why am I learning this, why is it relevant, so I always try to tie in news articles and what is going on in the world and make it more relevant. I think once students find it more relevant, they become more interested in the topics and then they want to learn more. A good example . . . there was a news article on Yahoo about black holes, probably about a month ago, and I decided to . . . print it off and I talked to class about it. It was a fairly interesting topic, and I kind of simplified it, so the students could understand it more and as soon as I started talking about it, you could see kids who usually slept in class, they did kind of pay attention, so it was kind of more interesting to them than the book.

It was somewhat unclear why Randy chose to talk about an article that discusses black holes as an example of STS. When asked about it, he mentioned how this related to their energy unit, and how tapping the energy from black holes might solve societal needs for energy.

Maria

Maria is a White woman in her 20s who spoke passionately and very positively about student teaching. She said that she found her niche in teaching, which erased all the doubts and frustrations she had. “I just feel comfortable,” she explained. She started college thinking about counseling, but she had many interactions with adolescents that led her to want to teach them. She related well to the high school age group.

I did have a high school physics teacher that had so much fun . . . I remembered him as I looked into what I wanted to major in. I wanted to be with kids and have impact on their lives . . . I like science.

She mentioned that her family members have backgrounds in math and science; her mom works in research, one brother is a doctor, and another brother works in computer science.
Philosophy of teaching. Maria wrote in her teaching philosophy that her goal for her science classroom is focused on teaching science for students’ personal needs. As she discussed later in the interview, this came about as she observed how important it was during student teaching to make science relevant. She wrote:

My goal for my science classroom is that students understand how science relates to their personal needs. When students see how science interacts in their personal lives an interest is formed. This interest can be the catalyst for an individual student to discover other important aspects of science such as the principles, processes, and the nature of science.

Of all of the interviewees, Maria was the most able to use the vocabulary of the methods class in talking about her teaching. She discussed teaching in terms of pedagogical goals aligned with the standards. She listed science as content, science as process, science for personal and societal needs, and science for career preparation as possible emphases for teaching science, just as the historical goals of science education were discussed in the methods class.

Student teaching experience. Maria talked about how going through the teaching experience changed how she views her goals for teaching science. She started student teaching with a primary goal of teaching process skills; however, interacting with the students made her realize that her goal for teaching science was to address science in personal needs, and she felt that STS fits in that category. She used the specific language of standards, planning, and assessment. Her cooperating teacher also valued teaching science processes, which might have influenced her views as well: “to him the single most important factor of scientific literacy is the process of science, what science does.
Science is a process of asking the questions, not answering them, says my CT” (Field Assignment 2).

STS understanding. Maria talked about STS as the interactions between science, technology, and society. She said that she does not fully understand what it means yet, but it is something that she values and wants to learn and think more about. Her main goal for teaching science is to relate it to students’ personal needs, and she sees STS as a way to bring science to students’ lives, especially when it has to do with issues that are happening in their communities or affecting them. Maria was the only participant who talked about implementing STS during student teaching as a planned lesson. This was probably due to the guidance of her cooperating teacher on approaching the topic she was to teach. She taught a unit on biological diversity, and she asked her students to pick a biome and identify an issue that impacted that biome (deforestation, desertification, etc.). One of the requirements for students was to identify how technology has impacted the issue. The deliberate planning suggested her attempt at integrating an exploration of how science and technology impacted society into her science classroom. She described the experience:

I did my last two weeks I did a biology unit on biological interactions, and so I had 7 groups and each group had a different biome and I had all these requirements for them to fulfill, and one of my requirement on their rubric was environmental issue or endangered species. And one of my goals for that unit was to have them explain and express how technology impacted that issue, like what problems were being done to help solve that issue and so . . . when they turned in their project, a lot of them tried to explain technology, I saw that it really did not register like what I wanted from them like for example endangered species they talked about like elephant tusks, that those are really high on the market, and so some students tried to mix in the technology of how guns have adapt to like prey on, you know they are starting to getting the idea of mixing human machines and things like that with issue and another one they talked about deforestation and
how machinery have developed perhaps to cut down more trees at a quicker rate things like that, but their research, their background, is kind of what I told them to look into but they just took my word for it and they did not really back their word with research, I found this article about how machinery developed and stuff, so they weren’t really putting the two ideas completely together like I would want to them to do. They started to understand that technology can cause problems like deforestation or desertification, like another one was bald eagle, using pesticides and stuff, so If I would have done it again, I would have spent more time on, since I didn’t have time to do this, using kind of scaffolding, what it means to have an STS issue, how society, what is science and what is not science. What are the facts and opinion . . .? Maybe do a group work activity and pass out worksheet and talk among themselves. Even like have time for me to lecture, talking a whole class period to talk about that. Because it was really a hit and miss thing because we wanted to get through the chapter and the content before I was done student teaching. So that was my trial and error thing for doing STS.

Maria talked about how she wanted students to learn how science and technology are interdependent, but also learn about the context of science. She acknowledged that her knowledge is incomplete, and she still has a lot to learn about teaching. Although she saw teaching the nature of science and STS as something that is required of her to do (otherwise, they would not be learning about it in college), she also saw it as a possible way to organize her science teaching (eventually).

I know more about the focus of everything. It will be, as I am learning more about STS it would be easier and easier to come up with a general plan of how I want activities to flow and after implementing it different years that I teach, I think it will become easier and easier because I have expectations. Expectations to hold my students to, because with the biome project I didn’t know what to expect from freshmen or sophomores once I put that into practice, I’ll have an expectation to hold students to from previous years, from knowledge that I gained.

Junior Group

The junior group had different experiences during the methods class. Although the content was somewhat similar in both classes, this group had more time discussing STS, and practicing ways of teaching issues. The interviews also occurred the week
following their STS presentations, so it was fresher in their mind. On the other hand, this group of preservice teacher had very few experiences in the classroom, except for five weeks of observation in an urban setting during their general principles of teaching class.

Lisa

Lisa is a White woman in her 20s. Lisa comes from a family of educators: Both parents are teachers. She said she always knew she would become a teacher, and as a student, she loved math. An AP biology class in high school got her interested in crop genetics and she started college as a biotechnology major. After two years, she realized that teaching was what she wanted to do and she really loves science. She talked about communicating this love of science to students so they could like it, too. Lisa mentioned in class that she worked in a soybean lab, so she decided to do her STS unit on GMOs. Her experience with biotechnology came up several times during the class and during the interview. During the exit interview with her methods professor, she had a very good grasp of what the professor meant by “nature of science” and she had mentioned taking some philosophy of science classes. The two science education professors were impressed with her ability to reflect upon the nature of science.

STS understanding. Lisa discussed STS in terms of motivating students, but also in terms of understanding the nature of science. She worried that students hear many stories about science in the media, and she felt that they need to be able to understand what these stories mean. In her interview, she said:

There are a lot of misconceptions about the nature of science, that when society is talking about scientific issues, they are not using science the way it should be, or they are not understanding the science behind it . . . There is . . . I had an example, well like new stories, when you talk about diets, red wine is good for you, red
wine is bad for you, grapes are good for you, and basically I think it is important that students understand that they are hearing part of the story so that’s another thing where pop culture is integrated into . . . what’s good about red wine is [anti-oxidants], so grapes, tomatoes, are good for you, not just red wine, there is more of the story than what’s being presented to them, so I think it is part of nature of science and STS and general science example. Or dark chocolate, because [anti-oxidants] are high in dark chocolate.

Lisa is one participant who talked about science as just another example of human knowledge, and discussed the possibility of integrating multiple subjects in high school. She talked about how it is hard to integrate issues, because of subject departmentalization in the schools:

There is so much history in science, and em . . . current events are so tied up you cannot separate them. Like, I would have no problem talking about history because it is important that we understand what happened so we can understand what is happening right now. And em, they’re all human studies. You can’t separate, take something and like, you can’t . . . They are all forms of knowledge and you can’t just take them apart. You’d have to . . . and it is really important to make the more connections you make with students, and their minds, with other things, it is easier for them to understand it and it is easier for them to remember. Making sure connections are made. Those aha moments, when you realize the connections between something, it really helps . . . your understanding; you basically want a big aha at the end of the year.

Lisa was also very attentive to students’ needs, and making the issues relevant to them. For example, she felt that talking about crop genetics might be most relevant for rural students, who would have some background with the concepts based on their life experience.

Mark

Mark is White man in his early 20s and has never pictured himself as a science teacher in high school; he really never liked science in high school. He started out as a pre-med student and he started liking science when he took science classes in college.
Not wanting to go through years of med school, he ended up being in the science education program. Mark talked about really liking to work with kids because of all the possibilities that work could entail. He saw his role as teacher to inspire students, and be a good role model for them. He also described himself as religious and as having some problems with the scientific theories that conflict with religion, such as evolution.

**STS understanding.** Mark talked about STS as the study of how science affects society. He mentioned several issues in society that are affected by science such as energy or cloning. He focused on how teaching science is not just content (to a large extent it is, he said), but also the effects of science on society. He did not recall seeing any issues being discussed in high school science classes, which he attributes to teachers’ fear of conflict. He talked about being uncomfortable dealing with issues that can cause controversy.

I just think there are many regulations in school. I think many teachers try to avoid conflict at all cost it is just a hassle to them. I know some of them don’t deal with stuff like that but if you get something like cloning . . . it all depends on how you present the material too. Because if you don’t present it in a way that you’re leading the students to if you’re just presenting the science concepts; but when it comes down to playing god, teachers avoid that, teachers don’t see how to teach that in a way, parents will get upset or something so I think it is in the way you present it.

Furthermore, Mark said that he would structure his lesson plans in a way to avoid conflict, so he would not have a debate about something like cloning. Mark linked teaching issues to a good understanding of the context of science. He felt that this framework would allow him to focus on the science of issues. He felt that if students understand the difference between science and beliefs, then he could focus his attention on discussing science and technology and not on ethical or moral issues. However, he
noted: “I really hope I don’t have to deal with this stuff. I am really not big on biology. I sort of want to teach chemistry or physics.”

*Linn*

Linn is a White woman in her 40s. After graduating from high school, Linn worked for 20 years and then decided to go back to school. She wanted to major in physics or physics and chemistry but the higher math course requirements scared her. Time was also an issue since she has a family. In Linn’s words, “I always had a bent for teaching and person after person would tell me that I am such a good teacher, that I should go into teaching.” She described her previous work experiences in training employees at a hospital to use new computer programs as an example of how she was good at explaining things.

Her decision to go into teaching was a practical one. She really wanted to go into medicine, but being a single mom with four kids, could not dedicate the time and the money for it. She was not very excited about going into education, but being able to work while going to school was an incentive. “It all kind of just fell that way, you know.” Her long term goals are to get a doctorate in physics and teach at the college level. Linn felt that an education degree would give her a good foundation in teaching, since most college professors are not taught how to teach. She commented that “it is a crime that science professors don’t have to take one education class.”

*STS understanding.* Linn saw her role as educating people on the scientific aspect of issues. She felt that people get distracted with political agendas and they do not understand the science behind issues such as stem cell research:
Kids should be able to understand how to sort these things out, especially when the media and the politicians take an interest in promoting it. To me it is almost like a red flag. When it gets blown up in the media, there is usually a bias that’s motivating a portion of it, and the whole story isn’t being told, and it is our job to tell the rest of the story.

Linn focused on her role as a teacher to educate citizens, which was a theme mentioned in class several times. She described it:

The big picture is hopefully (although statistics say otherwise) hopefully 100% of our students will become voters and will become at least 75 percent parents, and that is a whole lot more than those who will go on to college. One hundred percent of them will be citizens in some nation in the world, they need to know not just to hear it but to say maybe there is something more to this story, because all what I keep hearing is this, what is the flip side we need to teach kids how to think not assume they know how to do it. Think deep critical thoughts using Bloom’s taxonomy get into these real evaluation type thought processes, those don’t come naturally you have to kind of learn how to use them and exercise them.

She also saw science content and issues as complementing each other:

The content relates to the issues and the issues relate to the content. I mean if I was a biology teacher and I did not teach about stem cell research, I would say shame on me. If I was a physics teacher and never asked about if they’d heard about them, it being an important issue, I’d say ok, how to relate that to physics and say ok, stem cells, it’s part of fluids, and try to make a connection.

These individual profiles provide a description of how each participant talked about his or her understanding of STS during the interview. The answers ranged from questioning the value of content-laden curriculum and being very excited about introducing STS, to others who thought STS is valuable, if there is time to do it and it fits in the curriculum. These profiles provide a context to better understand who the participants are and how they talked about STS during the interview. I present a summary of these profiles in Tables 3 and 4.
Table 3

**Summary of Participant Profiles—Senior Class**

<table>
<thead>
<tr>
<th>Participant</th>
<th>Demographic Information</th>
<th>Descriptive Statements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laura</td>
<td>White woman, 40s</td>
<td>“There is no sense in drilling students with so much content. They can look up the content when they need it. It is important that students understand the process of scientific investigations.”</td>
</tr>
<tr>
<td>Tom</td>
<td>White man, 20s</td>
<td>“Teaching is the way I want to express myself,” and when I teach “I feel like I am on stage.” I like to entertain students.</td>
</tr>
<tr>
<td>Emma</td>
<td>White woman, 20s</td>
<td>“I want to teach students to think like scientists.”</td>
</tr>
<tr>
<td>Randy</td>
<td>White man, 20s</td>
<td>“In my classroom, I make content as relevant to students’ lives and societal issues as possible. By establishing this connection, students’ interests and motivations are heightened and a higher quality of learning takes place.”</td>
</tr>
<tr>
<td>Maria</td>
<td>White woman, 20s</td>
<td>“My goal for my science classroom is that students understand how science relates to their personal needs.”</td>
</tr>
</tbody>
</table>

Table 4

**Summary of Participant Profiles—Junior Class**

<table>
<thead>
<tr>
<th>Participant</th>
<th>Demographic Information</th>
<th>Descriptive Quotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lisa</td>
<td>White woman, 20s</td>
<td>“It is important to make connections between science, and other subjects (history), but also with students’ lives. When students make connections, they learn.”</td>
</tr>
<tr>
<td>Mark</td>
<td>White man, 20s</td>
<td>“I really hope I don’t have to deal with this stuff. I am really not big on biology. I sort of want to teach chemistry or physics.”</td>
</tr>
<tr>
<td>Linn</td>
<td>White woman, 40s</td>
<td>“The content relates to the issues and the issues relate to the content. I mean if I was a biology teacher and I did not teach about stem cell research, I would say shame on me.”</td>
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</table>
Discussion

Although this study was undertaken with an appreciation that different contexts might give rise to different student understandings (and so, for example, students might talk one way about STS in methods class and another way about it in the interview), it is interesting to note that participants used similar language to describe their understanding of STS in the senior methods class surveys, and three months later, during the interview. For example, Randy wrote in his methods class survey response that “science, technology, and society teaching incorporates the use of technology to teach science to students, while relating science to society that the students live in.” During the interview, Randy described STS as using technology in the science classroom, and also tying science to social life, by bringing in news articles that relate science to what is happening in the world. He provided an example of doing STS during student teaching by using an “energy leg” that shows students transformation of energy by using technology. He also described how he brought in an article about black holes to class, as a way to bring in current news articles about science. The way that Randy described his use of STS illustrates that he could be confusing STS to mean anything that has to do with technology and that relates news articles about science to students’ daily life. This was also evident through the interview, which took place several months after class instruction. But Randy also used very similar language during the methods class when STS was discussed.

Maria talked about STS during the interview as one of the several goals to teach science. This was also evident in her class survey. She wrote:
STS teaching is showing students how science is intertwined into technology and society. There is a relationship among the three; some would say it’s an interdependent relationship. This teaching is important b/c it targets some of those social and personal goals, and career goals.

Maria continued to talk about her teaching in terms of what goals she wanted to accomplish.

Emma had a focus on content during the interview. She saw that STS should be done when it benefits the content being studied. This was also evident in the class survey, where she wrote:

STS is teaching relevant and societal issues that involve some form of science; shows the significance of the facts or concepts learned in the classroom . . . I see STS fitting into the curriculum where it is appropriate. If you are teaching some topic, and you know of a specific societal issue that is related to that topic, then that would be a great time to fit STS in. once again, it would show the students the relevance of what they are learning.

This suggests that Emma focuses on content as her main goal, and STS as supporting materials to show students that science is relevant.

As I discussed in chapter 3, the interview was not meant to uncover the participants’ conceptions of STS, but to look at how they were reflecting on their experience. It is a performance through talk (Fabian, 1990), rather than a representation of stable beliefs.

The next section attempts to get at a more general description of how these students’ understanding of STS unfolded during the classroom conversations and interviews, and to some extent, students’ written survey responses. Although themes emerged from the interview participants responses, classroom data were also used to confirm the themes. Therefore, other participants’ names appear in the discussion of the
themes, and were not included in the profiles above. These participants are Aidan, Ben, Brandon, and Dillon, and they were students in the senior class.

Research Questions, Revisited

Research Question 1: How Do Preservice Teachers Understand STS as a Result of Participation in a Science Methods Class?

This section describes pre-service teachers’ understanding of STS. Using multiple data sources such as classroom discussions, interviews, and documents, I attempted to create a collage of how this understanding developed during the class. Major themes emerged from the analysis. First, many participants adopted a perspective that STS is equivalent with current events, whereas fewer of them thought of it as a curricular approach. Second, there was a clear association between nature of science and STS. Third, STS was conceived as controversy. The fourth theme that I discuss is how STS is seen by the participants as an assignment in a college class rather than a possible choice for teaching.

STS as Current Events

Although the pre-service teachers in the study could articulate their understanding of STS and talk about the value of teaching from an STS approach, most of the participants thought of STS as an “add-on,” rather than as a fundamental goal for science teaching. They talked about STS as a way to make science relevant to students and get them motivated to be in the science classroom. The methods class discussion addressed the difference between bringing up issues just to get students motivated (Motivation by
STS content) and a purposeful planning of an STS unit (Purposeful infusion of STS content). An example of that distinction during class follows:

Looking over those papers, your teachers say that they do something with STS like we had mentioned last week; that they use current events. I just want to point out that it doesn’t have to be current events. It could be historical events in the framework of STS. A lot of them gave you the advice that it should be relevant, that you shouldn’t go off topic and things like that, so. I think the way that a lot of teachers get off topic is by not being clear about what is the point of teaching this, right? It is sort of bring it up because it is interesting; you think it might motivate kids, then a lot of time you don’t get focused on what’s the purpose of the STS unit. Ok. You still need to think through objectives, you still need to think through what is the point, why are we doing this, it does definitely conform to the standards both at the state level and at the national level, teaching about issues in science and society. (CR, 2-7)

The view of STS as a motivator to students was also expressed during class surveys about students’ definitions of STS. Most participants said that STS teaching is important because it makes science relevant to their lives. Here are some examples:

- Emma: STS teaching—teaching relevant societal issues that involve some form of science; shows the significance of the facts and concepts learned in the classroom.

- Dillon: STS teaching—drawing from the world around you and relating concepts to real life. Using current events, human interests and advancements in society to teach concepts in science.

This theme of STS-as-current events was further reinforced during the interviews. Many participants in this study talked about STS during the interviews as the “extra, cool stuff” that can keep students motivated, while the teacher tries to meet the major goal, which is to teach the content of science. Most participants who were interviewed discussed talking about STS issues here and there during teaching, with content coverage
coming first. Only one participant questioned the value of focusing science teaching on content when science educators try to achieve “scientific literacy for all.” Except for Laura, most of the participants did not talk about STS as a valuable goal to teach by itself. This is probably due to the associations they made when talking about STS in class as reference to current events, but also how the issues that are STS in nature tend to be covered on the news. For example, Emma said that her ninth graders are bored easily and STS issues would get their attention and “spark their interest” to learn the content. This is an example of how STS is viewed as a way to motivate students using current events. For Emma, content is the main goal. When I asked Emma how she would teach STS, she stressed that it is very important that issues tie in with the content she is covering. If she can find a place for it in the curriculum, she would be willing to incorporate things that are on the news “that make something pop in my head.” Other participants expressed similar tendencies to associate STS with current events. Here are some examples of how the participants articulated this during the interview:

I talked about things that were relevant like my cooperating teacher throws in you know wherever. It is very cool like I read the newspaper about this new drug or this study that’s going on and I tried to do that like I would try to read up to keep current with the newspapers and the news and just throw it in every once in a while like I read about this new stem cell research or I read about this new drug for Alzheimer’s and kind of get their feel for it. (Tom, interview)

It depends on who is in my class and where I am teaching but I think, I know the issues will come up throughout the year and actually I think, I would wait to see what issues come up. And if not, I will develop something. All of it has to do with what issues are on the news, what students are seeing in the news, like if there is a big development in cloning, we might do an STS unit on cloning so that they understand what they are hearing on the news, so they can take all of the stuff that is being thrown at them and talk about it. (Lisa, interview)
This emphasis on STS as a way to make science relevant to students’ lives and get them motivated confuses STS with current events. Making references to current events is not necessarily STS, and can lead to misunderstandings. For example, Randy associated current news events with STS, even when these news events were only discussing new advances in technology and not raising issues around the role of technology in changing our society. When I asked Randy about how he would explain STS, he said:

Tying what you learn in the classroom to society which I am really big on. Students say why am I learning this, why is it relevant, so I try to tie in news articles and what’s going on in the world. When they find it more relevant, they want to learn more . . . I am big on reading news like CNN, I get a lot of my science news this way, anything that pops up, you can take 10 minutes to talk about it in the beginning or end of class. You got some real issues that student can see what’s going on in real life. (Randy, interview)

These associations between STS and current events are not peculiar to this group of teachers. The literature discusses how teachers often think of STS as the little boxes in the textbooks (Laurence et al., 2000). However, these references to current events to motivate students are not considered STS (Aikenhead, 1994c). Although this approach is easy to implement, and no one would argue against the importance of making science relevant to students, it often confuses science with technology, and fails to extend the analysis to society (Ziman, 1994).

Not only did the participants associate STS mistakenly with current events, they oftentimes had misunderstandings about the issues, which suggests that teacher candidates need more experience investigating issues as students. For example, during the methods class, the issue of global warming came up. Many students said that it is debatable whether global warming is due to human factors:
P.M.: Is global warming contested in the scientific community?

Laura: Yes

P.M.: Is it?

Laura: There are people on both sides, yeah.

P.M.: Not a lot.

Aidan: (barely audible)

P.M.: What?

Aidan: It is contested in the political arena.

P.M.: It is contested in the political arena, right?

Brandon: They are also saying that it is shifting . . . it is a natural process.

Laura  (talking at the same time): I mean I cannot imagine . . .

P.M.: That used to be the case, but a few years ago, I don’t know, the national academy actually did a huge report, with scientists around the entire world, and there is consensus in the scientific community, em, that we are causing, that human activity is causing global warming. Now there is not consensus about what the impact is going to be, what the results are going to be, but . . . Yes there are always going to be natural causes for fluctuations in the earth temperature, but there is consensus in the scientific community that human activity is causing global warming.

Brandon: They were saying there’s palm trees underneath north pole, stuff like that.

P.M.: Oh

Student: There could be plates . . .

P.M.: Do you understand the issue though? The issue is, if we ask the question, is the earth warming up, that’s just a matter of observing, taking temperature data. Yes we know the answer to that question. But then the next question is why the earth is heating up? Is the earth heating up because of the green house gases we’ve been releasing in the atmosphere because of industrialization? And there were some scientists who say, no it’s just a natural thing, fluctuation, and others
say yes, it is because of human activity. And that used to be contested, it is not contested anymore. There is certainly an element of science that contests it, but it is a very small fraction, and it is typically the scientists who are paid by industry.

Laura: I still thought that there are still some . . .

P.M.: Not much, but that is sort of recent. But the other thing that we don’t know is: we don’t know how to predict what is going to happen as a result of this.

One factor that might be contributing to this view of STS as current events is the view that content coverage should precede discussions about issues. In that perspective, STS belongs in the classroom after the concepts have been explored. For example, during the senior class, Professor M. asked about where STS would fit in the curriculum. One student responded: “I think that it belongs after the ideas and concepts. They cannot see how they are connected if they don’t understand the foundations” (Brianna, CR, 2-7). The junior class had some more time discussing the issue of where STS belongs in the curriculum. After choosing a topic for their unit, they spent considerable time going through each topic and analyzing the objectives for that unit. Students were concerned that they needed to cover too much content before they got into an issue, and Professor M. discussed how it could be desirable to present the problem first (see section: context: junior class). There are challenges in the science education research literature to the idea that more content knowledge leads to better analysis of issues (Kolstoe, 2000); nonetheless, the participants in this study felt they needed to cover content first to be able to get to issues. Furthermore, this concern for covering content often relegates issues to being marginally discussed. With so much content to cover, not enough time can be devoted to issues unless the view of curriculum changes.
Since these misunderstanding of STS as current events are documented in the literature, it is worth asking why these pre-service teachers are not viewing STS as a curricular choice after having the methods experiences. One reason could be that the pre-service teachers themselves have not had enough experience studying STS issues, so they are bound to think of them as discussing issues that come up through casual contact with the media. They might have experienced instances in their own high school years or when observing in the field when teachers mention issues to get students motivated. As science students, these participants are rarely exposed to in-depth treatment of issues. As teachers, they have rarely seen it implemented in schools. The other question that is worth investigating is whether teachers have enough control of their curriculum to be able to reconceive it.

STS as Curriculum Orientation

Although most participants talked about STS as current events, not all of them did. Laura and Maria are two participants that thought of STS as a way to organize their curriculum. Laura found in STS a hook to think about what is valuable to teach her students. Although she did not specifically talk about goals for science teaching, she clearly had a strong preference to organizing her curriculum around STS issues. The profile of Laura offers insight into how a new teacher internalizes the value of teaching STS. She said:

What I saw in student teaching is this: I saw a lot of facts being given out, I saw students having to struggle with really abstract concepts . . . but the kids can never connect these abstract concepts to anything concrete, anything that they can really put their hands around. And I have to wonder at the high school level . . . is it important for kids to be able to memorize and produce the periodic table and the electronic configuration? Or is it more important for them to have a basic
knowledge of these things, knowing very well you can look up the periodic table and use that knowledge to apply it to other science topics that they seem never to get to? . . . What’s the point of learning these chemical formulas, what’s the point of learning oxidation states? But at that level, when you are trying to keep them interested and involved, I think it is more important to…do units based around technology and things like, a nuclear chemistry unit and, base it around nuclear energy and the things that are involved there; or an acid base unit where you are talking about acid rain and environmental impact.

This participant saw herself as able to implement STS, because it is a curricular decision a teacher has to make, one that takes into account what to teach, the value of what is being taught and how to structure the curriculum to make it meaningful to students. Unlike other participants who were thinking of STS as an add-on where it fits, she was able to talk about the curriculum in a way that indicated that she perceives having enough control to decide what she wanted to teach, and not necessarily follow the textbook. Unlike the other participants, she did not see herself wedded to the content in the textbook or pressured to cover all the chapters. The content was more fluid, and integrated:

If you spend your whole year, almost 8 months, trying to get kids to name chemicals then . . . [with excited voice] you’ve lost them. What I am thinking is, some of that will come as they are doing the bigger picture units, like if you start talking about acid base and you do a unit on acid base and like you do that 3-P thing that I did from last semester, they are gonna have to by default learn the chemical formulas for certain things, for acids and bases. Then you touch on oxidation states . . . integrate it more, instead of pounding all those basics in, in worksheet after worksheet naming chemicals. They’ll eventually get them when they need them. You know when you start needing pieces of information, then you go look them up and use them.

Not only was this participant able to view STS as a curriculum orientation, but she was well aware of the difference between casual infusion of STS (Aikenhead, 1994c) and planning a curriculum around important issues. Although at the beginning of her
methods class she talked about her cooperating teacher using STS, after going through the experience, she was able to articulate that her teacher’s approach does not really count as doing STS.

All she does is at the beginning of every class she talks about something, like she talked about recycling the other day. I guess it is great that she brings up that stuff up. The problem is, I am not sure if she is doing it to waste time, or to . . . I mean she brought the issue of what the recycling label mean and how many bottles are recycled every year, she read this article to the kids and they talked about it so she is trying to promote recycling in her classroom, and I think it is awesome. So that’s how those look like. So picture this, she gets up and reads an article that she founds in such or such magazine and then they move on to whatever physics topic of the day . . . She didn’t relate it to the topic they were studying, that’s what I did not see much of. None of those things were connected to what she was doing in class, I started to say, I am not sure if I understand the whole picture here. Do I think it is wrong, no, do I think current events are important, yes, but I think . . . that when do you bring it all in and intertwine it, make it make sense, make it apply to what you are doing, then I think it is more useful information.

Even though most teachers cite lack of time as a factor for not implementing STS (DeBoer, 1991), for this participant, time was not an issue. Implementing STS in her case is not adding more content to her curriculum but changing her approach to how to present the science content. She talked of having control over what is being taught:

You know, these cook book labs, they get to the point where if you do a hundred of them, even the kids get to the point where they don’t know what they’re doing . . . I saw that a lot, lab after lab just to keep them busy for two periods. A lot of times they go, didn’t we do that already? (laughs) And you need to pick and choose which labs to do, then you get all that extra time. They had two double periods a week; (in a very excited voice) think about the inquiry that you could be doing during two double periods a week! They don’t have to be doing labs, they can be doing a big project a week with two 80 minutes slots, that’s huge for inquiry, instead of doing ten labs on hydrates, so I don’t know.

Maria is another participant who also talked about STS as a goal for teaching science (see profile). She specifically talked about the different standards in the NSES and said that her main goal for teaching science was to teach science for personal and
societal needs. It was her way of making the science relevant to students, but not necessarily in the service of content. The student teaching experience allowed her to view students’ needs as the most important ones for teachers to consider, rather than the structure of the disciplines.

These examples illustrate a possible connection between teachers’ enthusiasm for STS and their conceptions of it as a curriculum orientation. It is interesting to note that the student who was most positive about STS and saw it as a curriculum orientation was also a non-traditional former scientist pursuing a second career in teaching. Although the data is anecdotal, it might be fruitful to investigate a developmental appropriateness for introducing STS to teachers. Is it developmentally appropriate to expect pre-service teachers to use STS teaching in the classroom? Or, should STS teaching be an expectation for teachers who have already gotten “their houses in order,” so to speak; those teachers who are comfortable with the science content and the managerial aspects of teaching enough to think about their goals for science teaching and learning in somewhat broader terms?

STS as Controversy

The third theme that emerged from the data was the association between STS and controversy. This association of STS with controversy appeared during the methods class, the interviews, and through cooperating teachers’ advice. During the senior method class, and after discussing where STS belongs in the curriculum, Laura asked: “Does it have to be issues that are controversial? I mean, can STS be anything that is science and technology and its uses in society, it could be for a positive thing?” (CR, S, 2-7). This
association between STS and controversy could be due to the fact that the topic discussed as an example of STS during the methods class was the issue of race, which can be viewed as a very controversial topic. Professor M. talked about Laura’s question as a misconception and that many STS topics are not controversial.

This theme was also prevalent during the interviews. There were strong associations between STS and controversy, especially when it comes to issues that deal with religion. In one interview, Randy said, “Whenever I think of STS the first thing that usually comes to mind is controversy . . . topics . . . So I have to kind of be careful with what I do.” Mark’s interview also illustrates this link between STS and controversy, which manifests itself with references to the fear and avoidance of conflict:

A lot of teachers just don’t want to deal with it. Again I don’t want to deal with it, but students need to know about these issues. If I am going to teach cloning, I want to do it in a way to avoid conflict. I know what is not always going to happen. I mean I can try to avoid conflict, that’s all what I can do. No one wants to deal with conflict. I think that’s why teachers avoid these kind of issues.

I just think there are many regulations in school. I think many teachers try to avoid conflict at all cost; it is just a hassle to them. I know some of them don’t deal with stuff like that but if you get something like cloning . . . it all depends on how you present the material too. Because if you don’t present it in a way that you’re leading the students to if you’re just presenting the science concepts but when it comes down to playing god, teachers avoid that, teachers don’t see how to teach that in a way, parents will get upset or something so I think it is in the way you present it.

The fear of conflict is perceived to be in the culture of the schools:

A lot of teachers just don’t want to deal with that, they got pressure from parents, pressure from school system, all these factor in their lives, they don’t want to deal with it they would rather just teach science concepts, I’ll be ok if I teach science concepts, what’s structured in the book.; whatever. And I think there is a lot of pressure out there. (Mark, Interview)
This fear of controversy is related to job security for some participants. Talking about teaching evolution, Tom said:

I think this is more of a seasoned teacher approach. As a novice teacher I think I would try to stay clear of anything that debatable. I mean as showing the video that is talking about religion openly in the debate of evolution. I would probably stick straight to the facts of what science can define and what science can’t define. Everyone else may be right but all I can tell is about what science can define. That’s where my realm of profession is, realm of study is. So I guess I will play it safe. I don’t think that’s wrong. I think that’s ok. Playing the game so I can stay to be a seasoned teacher.

Other participants seemed uncomfortable with any topic that had some kind of perceived overlap with religion, such as abortion, stem cell research, or cloning. This association of STS with controversy is also linked to how the participants talk about STS being easier to implement in biology rather than physical sciences. In the junior class, many topics that were investigated were related to energy and resources, yet the participants in the interviews still linked STS to biology. Mark, for example, did his methods class unit on alternative energy resources, yet he mentioned during the interview that it is hard to think of topics in physics that you can do STS with, whereas issues in biology (such as cloning, stem cell or evolution) always came to mind. These kinds of issues frighten teachers, because of their link to religion. Mark said that he hopes he does not have to teach biology so he will not have to deal with that.

This concern with controversy shows up also in the surveys conducted with cooperating teachers. When teachers are asked about covering STS issues, they often hear
controversy. For example, Dillon’s teacher asked her to stay away from issues that are emotionally charged, such as intelligent design. Aiden’s teacher advised him:

   to shy away from controversial issues at first. He said that it is better to lay low and not make any noise during your first years of teaching. From there, he said it really depends on the make up of your community and how they would react if you sparked a controversy.

   Although many STS issues are not as controversial, and students can engage with in-depth treatment without upsetting anyone, it is often the case that teachers hear controversy when they hear STS.

   It is worth noting that some participants found comfort in sticking to the science aspect of issues. Both Tom and Mark talked about how they can discuss issues and avoid conflict by focusing on the scientific aspects of issues, such as talking about the science of cloning, without getting into the ethics of whether scientists should be doing cloning. However, this is problematic. Although the methods class (and the standards) stressed that teachers need to separate the science questions from the ethical questions, it did not ask to avoid ethical or moral issues. If teachers are saying that they value discussing issues so that their students can grow to be responsible citizens, then later say “let’s stick to the science,” are they really addressing “issues”? Oftentimes, the science of issues is not debatable. The moral and ethical questions are. As citizens, students will have to deal with the ethical implications of issues, and not the science of issues. Therefore, it is questionable to what extent teachers can treat issues without addressing ethical and moral questions (Blades, 2006; Kolstoe, 2000).

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21 These examples are from participants in the class, and not necessarily those who were interviewed; Hence the names that appear may be different that those discussed in the section on profiles.
This fear of controversy is also supported in other studies. McGinnis and Simmons (1999) reported that teachers perceive the most relevant topics to students as too controversial to teach. Even though the suggestion was made during methods class discussions that STS topics need not be controversial ones, this association between STS and controversy makes it more difficult for pre-service teachers to decide to implement STS. Most participants find themselves uncomfortable dealing with controversial issues, especially as beginning teachers and thinking that their job security might suffer in the process.

STS and Nature of Science

One theme that came out of the interviews is that participants talked about teaching STS in the context of understanding the nature of science. This is not surprising, knowing that the methods class focused on discussing history and nature of science before talking about teaching from an STS approach. During the class sessions on STS, the discussion focused on how one cannot study societal issues related to science, without a good understanding of the nature of science. Most of the participants were able to articulate that connection between the nature of science and discussing STS issues. They talked about how an understanding of the nature of science is essential to making decisions on STS issues:

There are a lot of misconceptions about the nature of science, that when society is talking about scientific issues, they are not using science the way it should be, or they are not understanding the science behind it . . . when you talk about diets, red wine is good for you, red wine is bad for you . . . and basically I think it is important that students understand that they are hearing part of the story . . . what’s good about red wine is [antioxidants], so grapes, tomatoes, are good for you, not just red wine, there is more of the story than what’s being presented to them, so I think it is part of nature of science and STS. (Lisa, interview)
This connection between nature of science and STS plays itself in different ways. For some students, it seemed like talking about the nature of science gave them a framework to discuss STS issues and made them much more comfortable to discuss issues that might be controversial, especially when it came to religious beliefs. One example is Mark, who was uncomfortable discussing any issues that relate to religion, because of his own religious beliefs. Thinking of discussing issues in reference to the nature of science gave him a structure to rely on:

I would probably present the science concepts, maybe I will present . . . I wouldn’t touch on subjects where some people think you’re playing god. That again comes in the nature of science and what science is what science isn’t. If your students have a good background in NOS, it plays a large role on what they’re going to believe and how you’re going to teach it. If they have a good background you can say those are beliefs, these are science evidence and the difference between science and belief. If they understand that concept, I think it avoids a lot of the conflict . . . If I am going to teach cloning, I want to do it in a way to avoid conflict. I know what is not always going to happen. I mean I can try to avoid conflict, that’s all what I can do. No one wants to deal with conflict. I think that’s why teachers avoid these kinds of issues.

Whereas some participants thought of the nature of science discussion as a safety net to avoid conflicts, others pushed the links between science and society to question bias in science, and the influence of profit. Scientists are increasingly working in industry rather than universities. In such an environment, science is expected to produce useful knowledge (Hurd, 2000). In the class discussion about the special logic of science, Logan said:

I think a lot of people think about science, and I don’t know how much exactly it ties in with the logic thing, but SO much of science is for profit. And so much of experimentation is based on profit. So if it is like special logic, or normal logic, all that logic is geared towards making money. And a lot of times it is the most important thing for scientists. They set up their experiments. Just to make money. And they gear everything towards that profit. (CR, S, 2-2)
Laura, working previously in a research lab, was also very well aware of this link. This is evident during class discussion, during the interview, and in her writing. She talked about no matter how you view your data, scientists always have bias. She suggested having students role play to see how bias affects scientific results.

It seems encouraging that these participants are linking the treatment of issues to a good understanding of the nature of science. This is increasingly being recognized in the literature (Zeidler, Sadler, Simmons, & Howes, 2005). However, for some participants, there was a naïve assumption that you can separate the moral and ethical from STS and stick only to considering the science.

STS as a College Assignment

Although STS plays out in different ways during class discussions and the interviews, for the most part, STS was understood by the participants in this study as an assignment for a methods class. In many instances, the senior group would interchangeably talk about STS and WebQuests. For example, when asked about how he addressed the NSTA standard “issues” during student teaching, one of the participant mentioned that he did get a chance to implement his “WebQuest” when his students were taking the state graduation test that week. He had some time that he did not know how to fill, so he decided that it would be neat to do his WebQuest. He then explained how he would like to do more WebQuests in the future to address issues. Also other participants would talk about their WebQuest when asked about teaching STS issues. Another participant discussed his worries about the time it would take him to construct WebQuests in the future if he had to implement STS in his teaching. However, this is not
the case for all of the pre-service teachers, as a few others did see themselves teaching
STS outside of this context. Although this is not surprising, given that this group learned
about STS in the context of having to construct a WebQuest, it might be useful to
investigate how their understanding might change had they been required to implement
STS during student teaching.

In both classes, many practical issues arise around finishing an assignment rather
than around thinking of STS as a curricular approach. For example, in the senior class,
choosing the WebQuest as an assignment directed students’ attention toward the
technology and less toward curriculum organization. But there is more involved in a
classroom assignment, such as meeting the professor’s expectations, working with a
group, and finishing on time. For the methods students, it becomes a matter of
negotiating the interplay between figuring out how to plan a unit as teachers and
answering to the professor’s expectations for them as students. Maria addressed these
concerns during the interview:

Laura and I were just trying to figure out a focus. We realize how important it was
to bring it down to one simple focus instead of go search on this website or go
search on that website so, try to, it was difficult to know what do we want them to
see. What really is the objective here, what really is the point? Answering some of
the questions that you are asking now. Like what role does STS play, try to
struggle with learning it ourselves and then bringing it together and then working
with all the technology with FrontPage and uploading the pictures, so once we got
our focus in, what we wanted to do besides the technology and uploading, it ran
smoothly for the planning thing. Once we both let go of like, it is also difficult
working with somebody, you think one thing, and they think another thing; once
we both like let go of our strong opinions about something, we really didn’t have
any strong opinions, but once we both said, all right let’s just work on this. We
just, it was much easier once we got our objectives written down.
It is not surprising that many practical concerns come up as teacher candidates work through their college assignments about STS. The question that science educators need to explore further is how we can make STS as a possible choice for them to implement in the classroom and not merely an assignment for a college classroom.

*Research Question 2: Do Pre-Service Teachers Value STS as a Result of Their Experiences?*

All of the participants who were interviewed stressed the importance of discussing social issues with their students. They had a positive view of the obligation they would have as science teachers to discuss social issues in their classes. The discourse in the methods classroom centered on NSTA’s standards for preparation of science teachers, which include discussing science-related societal issues. This positive view is expressed in how they talk about the value of teaching students to be able to understand news articles or to vote on issues in the future. Their way of talking can be traced to classroom discussion about the importance of preparing citizens to be able to understand, converse, and make decisions on social issues that relate to science. This is evident in the quotations used in the class description section.

During the interviews and in class discussions, pre-service teachers used the “appropriate” language to talk about STS. They talked about “teaching for informed citizenship,” and “making sure our students can vote on issues in the future.” These quotations from Mark (junior), and Emma (senior) exemplify what most of the participants were saying:

I know we are not going to have a lot of scientists in class but we have students who need to make decisions on stuff in the future. And that’s what they’re going
to vote on, what they’re going to see in the news, and they are going to have to make intelligent decisions based on, you know, the science side and their personal belief. (Mark, interview)

Just let the kids know what’s out there. Make them aware, instead of always just using those textbooks, and doing these labs in the classroom. Let them use issues, let them be aware of the world around them and how it affects them. And usually these issues do affect [them] in one way shape or form and the fact of the matter, as citizens, you have to vote on these kind of issues and things like that. So I think making them aware of their surroundings and what is going on in the world, I think is very important. I mean, right now, most of them are not at the age to vote, but as they grow older, at least they will be informed knowledgeable citizens about what is going on. If they hear something on the news, they can be like, oh, they can follow that and understand it, at least they’ve heard of it somewhere. So I think most importantly to make them informed knowledgeable citizens. School is not just about being locked up in a classroom and learning the textbook or what the state standards tell you have to know to pass the test. I think these real life issues have an impact on students and are more interesting they can relate to it, something real that happened; not just something they are reading out of a book. (Emma, interview)

The pre-service teachers stated that the public is generally lacking a good understanding of science, and saw it as part of their job as science teachers to make students aware of how to analyze an STS issue, and how to separate the science from the non-science aspects of these issues.

However, the question of whether participants value STS or not was apparently not enough to lead to changes in their teaching. As was clear from the interview results, pre-service teachers are comfortable talking about the value of teaching “issues” in the classroom. A more interesting question is whether they go beyond valuing and actually implement it, which brings us to the third question in this study.
Research Question 3: Do Pre-Service Teachers Use STS During Student Teaching, and in What Ways?

The third question that this study attempted to answer is whether pre-service teachers are willing to implement STS during their student teaching experience. Data for this question came only from the senior group since the junior group was not in the field yet. I have used fieldnotes from the methods class exit interviews and interview data\textsuperscript{22} to come up with these results. At the end of the student teaching semester, each pre-service teacher met with the two methods faculty members. I was present at these meetings as a graduate assistant, but also as a researcher.

During these exit interviews, students were asked to share pieces from their professional portfolio that show their understanding of the standards for science teacher preparation. They were also asked about student teaching, how the job search was going, and to share comments about the semester in general. In discussing the “issues standard,” they were asked if they implemented any STS issues during student teaching. The categories of the portfolio follow the standards for the preparation of science teachers, and they include:

1. Content
2. Nature of Science
3. Inquiry
4. Issues
5. General Skills of Teaching

\textsuperscript{22} Exit interviews refer to final presentation that preservice teachers go through at the end of their student teaching. The term interview refers to the interviews I conducted as part of the research.
6. Curriculum
7. Science in the community
8. Assessment
9. Safety and welfare
10. Professional Growth

Of the 18 who were student teaching, few students implemented the “issues standard.” Based on the exit interview, two participants said that they used the WebQuest they developed during their methods class.

In the first case, Aiden said excitedly that he used his WebQuest during teaching. However, it was not connected to the lessons he was teaching. The WebQuest he developed with another classmate addressed artificial intelligence and robotics, which is not a topic typically covered in high school. Aiden was placed in a class that was preparing to take the state graduation test, so he used his WebQuest as filler between test preparation classes. He said that he had 20 minutes between classes, and figured out that using the WebQuest as time filler was a good idea. As he put it, the students like to use computers anyway.

In the second case, Ben described how he used his WebQuest on genetically modified grains in a student teaching unit on biotechnology. Since studying how biotechnology affects society is one of the state standards that gets tested on the state graduation test, the WebQuest had a place and was used to support the content. I did not have enough information on how this specific implementation went, because Ben did not volunteer to be interviewed.
A third participant talked about implementing STS without referencing the WebQuest. This participant linked teaching “issues” to her goals of teaching science. Out of 18 students who were student teaching, Maria was the only participant who talked about trying to incorporate teaching issues in her lessons, as a planned activity with specific objectives that the teacher wanted to accomplish, rather than throwing out random topics for class discussion here and there:

My last two weeks I did a biology unit on biological interactions and one of my requirements on their rubric was environmental issue or endangered species. . . . and one of my goals for that unit was to have them explain and express how technology impacted that issue . . . . I wanted them to see that how technology and science are interdependent. I think that is a big thing, and I wanted them to understand the nature of science, context of science. . . . Because it was really a hit and miss thing because we wanted to get through the chapter and the content before I was done student teaching. . . . If I would have done it again, I would have Spend more time on, since I didn’t have time to do this, using kind of scaffolding, what it means to have an STS issue, how society, what is science and what is not science. (Maria, Interview)

One reason that these participants did not use STS might be attributed to the special circumstances of student teaching. Most pre-service teachers feel that they do not have enough freedom to implement their own agenda. So it is not surprising that most of the participants did not choose to implement STS during student teaching, or implemented it superficially. In many cases student teaching becomes mainly an issue of managing the classroom and various expectations from the cooperating teacher, university supervisor, and professors. Being in charge and having good classroom management skills often becomes the “bottom-line” barometer of success. As Britzman (1991) observed:

Issues of pedagogy do not enter into a student’s view of the teacher’s work. Rather, the teacher’s skills are reduced to custodial moments: the ability to enforce
school rules, impart textbook knowledge, grade student papers, and manage classroom discipline appears to be the sum total of the teacher’s work. (p. 4)

In such an environment, STS did not seem like a viable option, a possibility to be explored yet.

Student teaching might also be a space where these participants are not fully in charge. In fact, Emma mentioned that she was following a set curriculum from which she could not deviate. However, these constraints do not just disappear once teachers have their own classrooms. In many instances, pressures to cover content and control the students remain the same.

On the other hand, it is also interesting to look at how student teaching shapes the participants’ teaching selves (Britzman, 1991) and “opens the possibilities for creative pedagogies” (p. 2). This was clearly the case for Laura, who came out of student teaching with deep questions about the value of the content-laden curriculum offered in schools. How much of this orientation was due to Laura’s personal inclination to question the curriculum or to the tension that existed between Laura and her cooperating teacher (as described by the methods professor through personal conversation) is unclear. This is also clear for Maria, who said that she started student teaching with a focus on the processes of science and changed her perspective to focus on “personal and social perspectives.” Her interactions with the high school students made her put their interests above the interest of the subject matter.

Because starting out this semester, my goal for science education—which is important—was process, that students will learn process skills, to me that’s the most important. And then the least important to me was science for personal needs. I had my reasons for that. But the coming through student teaching, I realize that my philosophy for now my goal for science education is the complete
opposite, to teach students like how science affect their personal needs. Because I see how that’s how I teach to people, is I relate to them. And so I saw in my instructions, in my assessment, that I had a lot of analogies and life examples. And to make the students understand how science interacted in their lives. So just because that’s how I saw in my style in my instruction, and I saw how students get more engaged when they see like how . . . the gas laws, I did an analogies and demonstrations on like what really is the hot air balloon, what law does it relate to, little things like that they can relate to.

As far as STS being my main goal it’s not my main goal at this time but it is up there in the second or third goal. I think that it is something important to hit throughout units if I can find like something like issues with technology issues or with society issues within what I am teaching, I think it would be very important to address any time throughout the year, just talking about it one time a year doesn’t give it enough credit. I think you can also use STS to bring science into their personal life too. So maybe some issue that is happening right at their community or everything, you can kind of intermix those two goals. (Maria, Interview)

Maria described her cooperating teacher as very supportive and a great role model. It is important to keep in mind that student teaching is a special case where student teachers are trying to negotiate space. It might not be a space where teachers are in control, but it is interesting to look at whether these pre-service teachers take their methods class experiences and transfer them to the field. Further research is needed to look at how the experience of learning about STS carries over to new teaching situations.

On a side note, I had the opportunity to see the junior group one year after data was collected. They were taking a student teaching seminar during their student teaching semester and I was the instructor for that class. I did not collect data during that semester since participants were overwhelmed with the experience, and I felt that I needed to focus on my job as their instructor rather than as a researcher. However, I have anecdotal evidence of what happened during student teaching from interacting with them for the whole semester. The senior group in my study was not required to implement STS.
However, the group I taught was required to implement an “issues component” in a unit during student teaching. This was mainly done to satisfy NSTA requirements for accreditation purposes (for the teacher education program). From my experience with that class, the students overall still treated the “issues” component as an assignment to be submitted to me, rather than a useful way of looking at curriculum. Their focus was mainly on how to manage the students, how not to cry in front of them, how not to lose the classroom, and so forth.

Summary

This chapter described the experiences of pre-service teachers with STS approaches in their methods class. Through the stories that the participants told, I tried to describe the tension between what is provided in the methods class and what they see in their field placement. These stories illustrate the disconnect between the space of the methods class and the space of the classroom. Lortie observed that by the time students enter a teacher education program, they have “spent approximately thirteen thousand hours observing teachers” (in Britzman, 1991, p. 3). For this reason and many others, the STS assignment gets locked in that space of college classroom. Although most of these teachers are able to talk about the value of teaching STS, the data suggest they are not likely to implement it.
CHAPTER V
DISCUSSION AND IMPLICATIONS

“Life is about worthwhile experience; education should be, too”
(Wong & Pugh, 2001, p. 335).

This study explored the experiences of two groups of preservice secondary science teachers, at different points in their teacher preparation programs, with Science, Technology, and Society (STS) approaches. The questions that this study asked were:

1. How do preservice teachers understand STS as a result of participation in a science methods class?

2. Do pre-service teachers value STS as a result of their experiences?

3. Do pre-service teachers use STS during student teaching, and in what ways?

I begin the chapter by summarizing the main points that emerged from the study, and then discuss implications for research and teaching. I examine the current paradigm that guides the research on teachers’ beliefs about STS, mainly constructivism and conceptual change, and then draw on Deweyan Pragmatism (Wong & Pugh, 2001) as a theoretical framework to understand how teachers make sense of STS. Finally, I discuss implications for science teacher education, and the STS field.

Summary of the Study

Chapter 2 discussed the different aspects of scientific literacy and how they relate to a rationale for teaching students about science, technology, and society interactions. Science and technology public policy issues, such as environmental concerns and
bioethical issues, continue to be debated in our society. In order for the public to participate in the democratic process and make decisions on these science and technology issues, it needs to be scientifically literate. But what kind of science do people need to know in order to make such decisions? Collins and Pinch (1993) argued that the public does not need to know the content of science to make decisions. Rather, they need to know how science, as a social enterprise, works: they need to know the role of social factors in experimental work, the influence of funding agencies and politicians on scientists, and the impact of the media on experts and on the public.

Furthermore, this argument for “informed citizenship” is affirmed in education policy documents at the K-12 level. Reform documents in science education assert the need to prepare students to be responsible citizens (AAAS, 1989; NRC, 1996). Scientific literacy for all implies a science curriculum that engages students in meaningful investigations of issues that affect them personally and that affect our society. The Science, Technology, and Society (STS) movement in science education offers a framework for such a scientific literacy.

Although there are competing discourses about what it means for someone to be scientifically literate, the rationale for teaching STS has been established in the literature (Solomon & Aikenhead, 1994; Bybee, 1993; Yager, 1996b) and is supported in the national reform standards. However, science teaching in schools continues to be content-oriented. Many reasons can be cited for the lack of incorporating STS curricula is school science, but teachers remain the key agent for change. Bybee (1991, 1993) suggested that there is a practice-policy gap and that teachers need to buy into the reform if change is to
happen. Hence, researchers have turned to looking at teachers’ role in implementing STS-like curricula in schools.

One way researchers have been focusing on teachers is through investigating teachers’ beliefs about implementing STS in their teaching (Lumpe et al., 1998; Mitchener & Anderson, 1989; Rubba & Harkness, 1993). These studies suggest that teachers do not implement STS issues for the most part. Teachers often cite lack of time, lack of resources, or lack of rigor (DeBoer, 1991). Many teachers do not perceive STS curricular materials to be rigorous enough, since the content of science is not the focus of the instruction. Multiple studies attempted to link a need to change teachers’ beliefs about STS to solving the problem of implementation. However, very few studies looked at how teachers experience what STS means as a curricular approach.

Since teachers often learn about STS in preservice teacher education classes, there is a need to investigate how they experience STS in that context. This study attempted to fill that gap, by focusing on how preservice teachers experience STS when they are first learning about the approach, but also by critically examining the discourse about teachers’ beliefs in the literature.

The results of this study suggest that pre-service teachers discussed their understanding of STS: (a) as an add-on to the science curriculum, with few exceptions who considered STS as a curriculum organizer; (b) as controversy; (c) as a component of the larger discussion about the nature of science (NOS); and (d) as a college course assignment. These different ways of talking about STS can be attributed to the participants’ experiences in the methods class to some extent, but also to their
experiences observing classrooms, or more generally, to influences of discussions in media outlets. Most participants discussed STS in terms of current events that can be used to motivate students to learn content, and not as fully developed units that teach students how to understand the issues and how to make informed decisions. There were few exceptions to this tendency, as several participants were able to articulate the need for students to practice in-depth treatment of issues. Participants also were worried about the controversial nature of issues, and felt unprepared or unwilling as new teachers to deal with controversy. In addition, participants were able to situate an understanding of issues, within the larger context of understanding the nature of science. This finding is in line with recommendations from science educators that students need to understand the nature of science to make decisions on STS issues. However, for most participants, STS remained situated in the context of a college classroom, as very few of them attempted to fully implement an STS issue during student teaching.

Furthermore, the results suggest that preservice teachers valued teaching STS issues, without their ‘beliefs’ affecting what they taught during student teaching. Although pre-service teachers were able to use the appropriate language (that of the standards, or the language of the discussion in their methods class) to describe STS, and that they talked about the importance of teaching from an STS approach, during their student teaching most of them did not implement STS to the degree recommended in the NSTA standards for science teacher preparation. There were also differences among participants in the study in terms of how their perspectives about STS influence their teaching. One participant, Laura, talked passionately about rethinking the content of
science teaching, but the constraints of student teaching did not allow her to put her views to practice. Another participant (Maria) tried to incorporate STS themes into one of her units on ecology, but one has to wonder whether the topic at hand allowed for discussing issues, and not necessarily the participant’s views. Other participants discussed how they incorporated their STS WebQuests as time-fillers, or to impress others with their use of technology.

These results suggest that we need to rethink this link between teachers’ beliefs about the value of STS and their practice. Research that focuses on teachers’ beliefs about STS often proposes recommendations to changing these beliefs. It is assumed that if we can only “fix” the teachers’ beliefs, we can resolve the problem of implementation. Instead, this study seeks to look critically at the assumptions in the literature about teachers’ beliefs driving their decisions about implementing STS. Rather than being prescriptive, I am adopting the view that social science is “a practical intellectual activity, aimed at clarifying the problems, risks and possibilities we face as humans and societies, and at contributing to social and political praxis” (Flyvbjerg, 2001, p. 4). I also draw on Eisner’s (2002) notion that research in education does not provide us with knowledge that is able to explain or predict (Episteme) but with knowledge that enables the development of wise practical knowledge (Phronesis). Thinking of knowledge as Episteme implies that research needs to come up with prescriptions for teachers to use in the classroom. Thinking of knowledge as Phronesis, research seeks to document the particular so we have a broader repertoire of cases to draw from to make classroom decisions (Eisner).
Initial Assumptions and Reflections

This study was undertaken from a naturalistic inquiry perspective; hence it evolved through the process of research. I began the study with the intention of focusing on the junior group, mainly because they had more time to explore STS. I assumed that the seniors would be focusing on getting through student teaching, and might not be interested in volunteering for my research project, or consider STS as an option to inform their teaching. During the data collection process, I found that the stories the seniors were telling provided a rich discussion about how STS can become a possibility. The language that many of them used suggested that they were very comfortable with the goal of teaching science for social responsibility. I think the experiences that the senior group had, and their involvement in student teaching, opened up a rich discussion about what is possible in the classroom. For the junior class, the experiences they had during the semester were more focused on getting an assignment done for a college classroom— which I am not suggesting is trivial—rather than thinking about their goals for teaching science when they have their own classroom. Furthermore, the rapport I established with the senior group was stronger, and allowed for a trusting relationship, which resulted in more participants sharing their experiences with me.

I also began the research process with the intention of focusing on the interviews, as a data collection method that provides a space for the participants to talk about their understanding on their own terms. But as I assumed the role of participant observer in the methods class, I found many instances of rich discussions and meaning making about STS. I ended up relying on the audio and video recordings to construct a description of
how STS unfolded during the experiences of the classroom. Furthermore, the presentations of the senior group following student teaching became very informative as many participants discussed how they used STS (or the NSTA Standard ‘Issues’ as they referred to it) in the high school classroom. Using a Deweyan perspective, I focused on what the experience meant for the participants, not as a way to label their beliefs as faulty or lacking, but as a way to describe how they acted out their understanding in different contexts, such as the class discussions, the interview, or their writing about STS.

Implications for Research

This study was undertaken from a Deweyan perspective that focuses on the holistic nature of experience, and also on meaning making as interaction rather than a cognitive process (Garrison, 1994; Wong & Pugh, 2001). In this section, I elaborate on how this perspective allows us to look at the research with teachers’ role in STS with a different lens.

As discussed in chapter 4, most of the participants in this study were positive about the value of teaching science for social citizenship. But these values did not translate into implementation, which challenges the assumption that changing teachers’ beliefs would change their practice. This focus on changing teachers’ beliefs seems to be derived from (cognitive) constructivism as a theoretical framework to doing research in science education. Although some alternatives have been suggested with a focus on the social aspects of learning science (Brickhouse, 2001; Lemke, 2001), in the area of research on teachers’ use of science, technology, and society, there is a commitment in the literature to a constructivist approach that focuses on teachers’ values and beliefs. For
example Rubba (1991) argued that teachers need to change their beliefs and values about the goals of teaching science before they can develop and implement STS materials. Rubba coached this process as a conceptual change model, where teachers have to examine their beliefs, confront logical inconsistencies in those beliefs, and then construct more suitable set of beliefs and teaching practices.

The model that Rubba (1991) suggested is very similar to the conceptual change model in science education where students are presented with discrepant events that would lead them to confront their inaccurate conceptions so they are able to change them. However, as research shows, “students neither changed their conceptions as anticipated nor sought to reduce logical inconsistencies as expected” (Wong & Pugh, 2001, p. 333). This is also reinforced in studies that suggest that people do not necessarily use reason alone when deciding on issues (Oulton, Dillon, & Grace, 2004). Learning involves more than rational components (Lemke, 2001) and human beings are not merely cognitive beings (Wong & Pugh, 2001).

Furthermore, in terms of teacher decision making, this commitment to constructivism leads to thinking of beliefs driving practice. This view often leads researchers to assume that teachers first need to form a cognitive opinion/value about STS before they can use it. However, this view that we necessarily form theories about the world before we can act in it is misplaced; we come to know the world as a result of (and in tandem with) our actions in it, rather than the reverse (Greiffenhagen & Sherman, 2008). Similarly Dewey’s philosophy rejected cognitive structures that are separate from action (Garrison, 1994). In other words, teachers come to know teaching as a result of
their practices/actions in different contexts, and not the opposite. They do not form a
type in their ‘minds’ about teaching that consequently drive their teaching practices.
Oftentimes, practical consideration rather than stable beliefs drive teachers’ decisions.

The other thing that is at play here is that the focus on changing beliefs makes it
seem like these beliefs are stable. Once we change them in the methods class, teachers
carry them in the classroom, which is a problematic assumption. From a Deweyan
perspective, an experience can only be thought of in the moment, in the interaction
(Garrison, 1994; Wong & Pugh, 2001); hence teachers should not be seen as “carrying”
beliefs with them from situation to situation. Therefore, we can talk about experiences
with STS when they are discussing the race video in class, or when asked to reflect on it
in an interview, or when they interact with students in their student teaching. But there is
no sense in talking about teachers’ beliefs, or values about STS in general. It is not
something that they can think about independent of context.

Finally, the literature that deals with teachers’ beliefs places the burden of
implementing STS with individual teacher cognition and ignores the larger systemic
pressures that teachers face. The problem of implementation becomes one of mere
convincing the teachers of trying something new and “fixing” their beliefs (May, 1992).
But teachers have many constraints on them, especially in the culture of testing and
accountability that is common to our schools. One can ask whether a lack of
implementation of STS issues is due to teachers’ resistance to the approach or more
appropriately, the pressures of testing and standards and the realities of everyday life of
teachers in general.
An Alternative to Constructivism: STS as a Way of Being

An alternative way of looking at the problem of STS implementation is through the use of a Deweyan model described by Wong and Pugh (2001) as a framework to understand and think about teaching STS. In contrast to constructivism’s focus on cognition, Dewey focused on action in the world; which Wong and Pugh summarized in the following passage:

Although cognitive perspectives emphasize thinking, Dewey emphasized something else, something we call “being.” One’s being is constituted not only by cognition, but also in action. Dewey’s emphasis on being, rather than cognition, reveals an epistemological stance that locates meaning neither in the mind of the learner nor in the surrounding environment. Instead, meaning is a transactive phenomenon: it exists only in the situation created in interaction between person and world. (Wong & Pugh, 2001, p. 324)

This shift in perspective from looking at teachers’ cognition/beliefs, to looking at action in the world, allows us to focus on practice rather than on beliefs. As opposed to asking how to rationally change teachers’ beliefs, we can examine the kind of experiences that preservice teachers find valuable in terms of rethinking the practices of teaching science. For example, the participants in the junior group who took ecology classes were very enthusiastic when talking about their experiences investigating ecological problems and were able to talk about these experiences in terms of their skills as teachers to implement the NSTA standard “Issues.” These college experiences were valuable, not because they addressed their beliefs, but because they provided valuable experiences, or ways of interacting, that made such investigations possible. Wong and Pugh (2001) wrote that “according to Dewey, the central goal of education is to help students lead lives rich in worthwhile experiences” (p. 319). Although science educators have taken experience to
mean anything but rote learning, a worthwhile experience for Dewey is more intense, it allows “a sense of the possible, an anticipation of how things might come together” (p. 320).

Furthermore, Wong and Pugh (2001) suggested that science education from a Deweyan perspective aims at having students experience ideas rather than construct conceptual representations of concepts. Similarly we can think of teachers in the methods class as having experiences with ways of being a teacher rather than construct conceptual representation of teaching. In this framework, we can think of the class as giving those teachers ways of being in the world rather than changing their conceptions about goals of teaching.

Implications for Future Research

Researchers who draw on constructivism as a theoretical framework focus on teachers having stable conceptions about STS. This presumes a stable cognitive state that is not useful. Researchers who are dealing with the implementation of STS as a conceptual change model ask how to best change teachers’ beliefs. Adopting a Deweyan framework leads us to ask different questions. In a pragmatic philosophy, it is not what’s in the teacher’s mind that is worth investigating. Rather, it is in action in the world.

“Pragmatism . . . situates meaning in the idea’s consequences, in its possibilities” (Wong & Pugh, 2001, p. 323). This is a departure from a constructivist prospective that focuses on teachers’ conceptual schemes, which is not useful in relation to what actually happens

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23 Although I did not have access to teachers’ actions during student teaching in this study, I considered the interview to be a space to document participants’ reflections on their actions. These reflections were not meant to probe participants inner cognitive space, but were looked at as action through language.
in the classroom. Hence, following a pragmatic philosophy we can ask: how can methods
classes create opportunities for new teachers to experience STS in a way that opens up
new possibilities? Instead of asking how I can change teachers’ beliefs, I am asking what
possibilities—ways of being a teacher—we can offer them so that STS is in their
repertoire of choices to draw from when they are making curricular decisions. Research
in this framework then can document successful cases for others to draw upon and use in
their decision making.

Furthermore, this model can be implemented in looking at the experiences of
middle or high school students with STS. Research can seek to document the practice of
doing STS in that context. We can examine what issues inspire students, and document
the struggles and successes of teachers during those experiences.

In terms of research methodology, getting at teachers’ or students’ “actions”
suggests a different methodology than getting at “beliefs.” Naturalistic inquiry methods
(such as observation and open ended interviewing) that focus on participants’ interactions
can be more helpful in increasing our understanding of successful STS experiences than
methods such as surveys. As stated earlier, the purpose of the research from that
perspective is to document the particular, so we increase our repertoire of choices
(Eisner, 2002).

Implications for Teacher Education

Since teaching social issues in science is one of NSTA’s teacher preparation
standards, we can assume that teaching about “Issues” happens in science methods
classes during pre-service teacher preparation. What implications can we draw from this
study for science teacher educators? Focusing on educative experiences, several implications from this study for teacher educators can be drawn. I discuss these implications, focusing on the role of context in learning about STS, the fear of controversy, and some possibilities for teacher education that emerged from this study.

**Context of Learning About STS**

The role of the context of learning about STS is very important and often overlooked. When pre-service teachers have no experiences with STS in their own high school years, in science college classes, or in observing in the field, they come to think of STS as an assignment for a methods class, separate from the actual teaching that happens in the field. What they see in the schools influences their teaching much more than their methods class, which is not surprising given that learning to teach is an apprenticeship of observation (Britzman, 1991; Lortie, 1975).

This does not imply that the methods class had no influence on pre-service teachers. Although before taking the methods class, participants did not have the tools to describe what STS is and why it should be taught; the class gave them those tools, without necessarily having impact on what happens when they go out to teach. For some of those students, STS became synonymous with a WebQuest, not a curricular approach to teaching science. When students see teaching science as decontextualized facts in their field experiences, they will likely come to view their own teaching in a similar way. Context is very important when it comes to how pre-service teachers learn STS. When it is embedded in the methods class, it becomes this assignment they have to do, while what they see in the field seems to exert more of an influence over how they teach.
This is also supported by other research. Meyer and James (2002) found that pre-service teachers who were introduced to STS as a collaborative project with social studies teachers, linked STS to collaboration with a social studies teacher when surveyed three year later. The authors observed:

The most surprising discovery was that teachers believed they have to work with a social studies teacher to implement STS in the classroom . . . From the responses of the teachers, they did not understand that you could implement STS in your science class without working with a social studies teacher. (p. 14)

This finding will not be so surprising if we think of the role of context in teacher’s learning. The participants in Meyer and James’ (2002) study were associating STS with a specific context, that of collaborating with a social studies teacher in the methods class. They have not seen it implemented in a different context and that is why it is not surprising that they felt this is the only way to implement STS. Similarly in this study, many of the pre-service teachers thought they had to do a WebQuest if they decided to teach STS.

This role of context in learning to teach STS brings up the question of whether it is adequate to keep focusing on teachers’ beliefs as the problem. As illustrated in this study, the pre-service teachers expressed that they see their role as teaching students to become informed citizens in our society. This conforms well to the vision of science education expressed in many reform documents. These views were expressed during the class, in their teaching philosophy, and during the interviews. Would requiring students to do STS during student teaching make it a possibility? Or would it still be a requirement for college classes that can soon be forgotten when one exits the teacher education
program? More research needs to be done in that area, keeping in mind that student teaching contexts may not be conducive to such approaches.

**Teachers and Controversy**

STS issues often involve dealing with controversial topics, and oftentimes, teachers are uncomfortable with controversy and conflict. Therefore, there needs to be an explicit way of presenting preservice teachers with strategies that help them deal with controversy. Schools are institutions that traditionally avoid conflict (Apple, 1979) and as teacher educators, we need to prepare teachers to deal with controversy within that school culture. It might be helpful to have an explicit discussion about controversy, where it belongs in the curriculum, and how to deal with it in the classroom. There is a literature on strategies for dealing with controversial issues in the classroom such as having students role-play the different stakeholders in issues (Geddis, 1991), but not enough discussion on how to prepare teachers for that. Furthermore, very little research has been done on the way teachers deal with controversial issues (Gayford, 2002). Oulton et al. (2004) suggested that teachers and students need to understand the nature of controversial issues so they have a meaningful discussion with STS issues. This has implications for teacher education classes which need to prepare preservice teachers to deal with controversial issues.

**Possibilities**

Some possibilities emerged from this study for teacher educators to consider in teaching about STS. Preservice teachers in this study were able to articulate the usefulness of their experiences with STS during their college science classes. This
suggests that requiring pre-service teachers to take science courses that are STS oriented can provide them with experiences that they can draw from when they are in their classrooms. It might be unreasonable to expect teachers to structure their science teaching around STS issues, when their science preparation in college classes focus on the structure of the disciplines. The more experiences that teachers have with STS in different contexts (e.g., college science courses, observing teachers, and science methods courses), the more likely they are to consider the possibility of implementing STS. More research can be done to document how these science experiences can influence teachers’ use of STS.

Furthermore, it seemed in this study that talking about STS within the discussion on the nature of science was very helpful to students. Participants were very comfortable talking about issues in the context of the “nature of science” discussion. This suggests that situating STS within the larger “nature of science” discussion might provide teachers with more comprehensive ways of dealing with issues while recognizing that solutions to issues cannot be sought by recourse to reason alone (Oulton et al., 2004).

The other factor that needs to be examined in teacher preparation is whether the learning of STS is a developmental process. Can we expect new teachers to adopt an STS orientation or is this something they will be more likely to implement once they have gained experience in the classroom, and classroom management seizes to be the defining issue of student teaching? We can probably start the conversation during pre-service teaching but there is a need to revisit teaching STS during in-service classes, when

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24 A similar argument is made regarding how it is important for teachers to experience “inquiry” in their college science classrooms, in order to implement “inquiry” with their students.
teachers are ready to think about new ways of conceptualizing their curriculum. This type of in-service is mostly crucial for cooperating teachers who can discourage their student teachers from trying units that focus on STS (Scharmann et al., 1997). The placement of our pre-service teachers with teachers who support STS might be a very important factor in providing them rich experiences with STS in the classroom.

Implications for the Science, Technology and Society Field

Yager (1996a) affirmed that the STS movement embodies the aspects of the reform in science education, which focus on inquiry. Similarly, the NSES discuss how students can be engaged in inquiry through an STS topic. However, as discussed in chapter 2, there is a tension between the language of the reform documents that call for ‘scientific literacy’ for citizenship while stressing a content-oriented curriculum. This tension also played out in this study in the sense that the participants were able to talk about general goals of ‘literacy for all’ while still focusing on content (which was exemplified by stressing they have to get all the content in before they do issues). Furthermore, some pre-service teachers in this study talked simultaneously about how they value ‘scientific literacy for all’ but that they also wanted to stress the science of ‘Issues.’ It is not clear that knowing more science would lead to better decision making (Bell & Lederman, 2003; Kolstoe, 2000), which leads us to ask: to what extent should we re-examine the centrality of content in STS issues?

The lens of Deweyan experience might be valuable in conceiving of STS in this regard. This lens offers a perspective to view STS as a holistic experience, and not separate it into teaching content versus teaching values. Some critics (Shamos, 1995)
affirmed that students cannot make decisions on issues due to the complexity that they require. But this focus on rational factors in making decisions ignores the larger aspects of the experience. We can teach students to examine their values and feelings about issues, and make decisions based on that, and not necessarily based on one right answer.

The lens of experience as Dewey outlined it shifts the focus from teaching concepts to engaging students with ideas (Wong & Pugh, 2001). Wong and Pugh discussed a subtle and specific meaning for ideas: “Ideas are something that seize students and transforms them” (p. 325). Unlike describing learning as conceptual representations, Wong and Pugh described learning as an unfolding drama: students are excited about an idea, anticipating the possibilities it offers, and acting on it. I would like to apply this model to STS issues. Assuming that the topic is of interest to students, STS topics have the potential to be experienced as ideas that inspire students by engaging their thinking, feeling, and action.

It is important to note that this perspective of worthwhile experiences transcends science education and suggests an integrated curriculum that focuses on students needs as a starting point (Beane, 1993). The subject matter cannot precede the needs of students. Dewey (1938/1997) wrote:

What avail is it to win prescribed amounts of information about geography and history [or science], to win the ability to read and write, if in the process the individual loses his own soul: loses his appreciation of things worth while, of the values to which these things are relative; if he loses desire to apply what he has learned and, above all, loses the ability to extract meaning from his future experiences as they occur? (p. 49)

Science, technology, and society curricula have the potential to become integrated curricula that start with students needs’ and contribute to their education in a
science/technology culture, through worthwhile experiences. Hurd (2000) advocated a lived curriculum as one that engages students in making decisions on societal problems that are embedded in science and technology. Hurd suggested replacing the discipline bound curriculum with one that integrates “science and technology and the social sciences into a core of integrated curriculum oriented toward everyday life and human affairs” (p. 6). A lived curriculum attempts at involving students in personal experiences around core themes in human affairs, such as “health and wellness, stabilizing the global environment, new energy resources, the quality of life, and the world of work” (p. 6). Hurd discussed how a traditional discipline-specific curriculum is inadequate to answer these human questions. An integrated curriculum can allow students to study science and technology not as subjects, but as major components of our culture.

Summary

We have recognized that teachers are the key element to implementing STS in the classroom (Bybee, 1991; DeBoer, 1991) and the literature suggests that pre-service and in-service courses need to address teachers’ values and beliefs (Aikenhead, 1984; Rubba, 1991). Research has been conducted with the assumption that changing teachers’ beliefs would solve the problem of implementation. This framework assumes a separation between cognition and action and that a change in cognition will result in a change in actions. Furthermore, this perspective tends to put the blame for lack of success of STS on teachers, when they are not always in control of their curriculum (May, 1992). In this chapter, I drew on the findings from this study to make the case that practical considerations rather than stable beliefs often drive teachers’ decision making in terms of
adopting an STS curriculum. Following Dewey’s focus on being rather than thinking, what happens in the pre-service classroom is not necessarily a new way of thinking, but a new way of being in the world. Rather than looking at how teachers change their views about teaching STS, this study looked at how the class offers a space for being a teacher that is different from what they are accustomed to. This chapter explored the possibilities if we challenge this dichotomy between cognition and action and the consequent focus on thinking and beliefs and suggested an alternative approach that Dewey calls “being.”

Teachers can understand and value STS, yet go back and teach the content-only chapters in the textbooks. The problem does not lie in their beliefs, but in a lack of experiences that they can take with them. Can we reasonably expect teachers to implement STS as a curriculum orientation rather than the little boxes in the textbook (Lawrence et al., 2001), when the standards themselves treat issues as an add-on? Are we expecting too much of teachers when they are not in control of the curriculum and when the curriculum is compartmentalized into separate subjects? When teachers do not implement STS to the extent that policy in science education is suggesting, it is not due to their beliefs or attitudes, as much as to the constraints of standards, testing practices, and their own experiences with school science as students and observers.

In sum, it may be time to question the connection between teachers’ beliefs and their decisions to implement (or not implement) STS. Lawrence et al. (2001) asked whether constructivism as a theoretical framework is enough when a lot of the work in STS is based on community. Taking a Deweyan approach of giving teachers ways of
“being” rather than focusing solely on cognition may be a way to continue this conversation.
APPENDICES
APPENDIX A

EXCERPTS FROM SENIOR CLASS SYLLABUS
Course Goals
In this course, you will continue to develop your skills as beginning secondary science teachers. We will examine various topics in secondary science teaching not previously emphasized in your fall method class. In particular, we will focus on assessment, technology, and Science-Technology-Society curricula in science education. In addition, we will engage in practical preparation for and work toward a seamless transition into student teaching, which begins at the end of the fifth week of this course.

Course Objectives
In this course, students will be expected to complete daily in-class and out-of-class assignments. Students are expected to participate in class and in field settings in a timely and professional manner and to be well-prepared for all class sessions. Students are expected to contribute thoughtfully to class discussions and activities. Students are expected to demonstrate understanding of assessment strategies, technology use in instruction, and STS curricula through development of an instructional technology product. Students are expected to revise and refine their philosophies of science education throughout the course.

Course Evaluation
Your performance in this course will be evaluated in the following manner:
1. Participation and Preparation (20 points)
   You are expected to come to class prepared and to participate in class activities and discussions. The success of this class will largely depend on student participation. In-class assignments can generally not be made up, and homework assignments are generally given in class. Absences should be absolutely necessary and should be prearranged with the instructor. In case of emergency, please notify the instructor as soon as possible. Missing class for any reason will result in less than full credit in this evaluation category.

2. In-Class Activities (20 points)
   Each day we meet, we will complete various graded activities designed to help you practice the skills you need to become a competent, reflective professional. These activities will be graded and scaled to be worth 20% of your final grade in the course.

3. Field Assignments (20 points)
   Each week (Thursday’s class), you will be given an assignment to complete at your field setting (student teaching site). Field Assignments (four total) will be due in

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25 Names of university, course name, course number, instructor name and contact information, and dates have been removed to protect participants’ privacy.
class on the following Tuesday. These assignments will be graded and will be scaled to be worth 20% of your final grade in the course.

4. Class Topics Project (20 points)
You will demonstrate your competence in the topics covered in this course (assessment, technology, and STS curricula) by designing and producing either a WebQuest or an Instructional Video that incorporates required elements covered in class.

5. Philosophy Development and Exit Interview (20 points)
This semester, you will continue to develop your personal philosophy of science education. You will submit a revised philosophy statement that demonstrates your understanding of secondary science teaching. Your statement will be presented at an individual exit interview to be held during final exam week.

Textbooks:

Optional:


Grading Scale: 93-100% = A; 90-92% = A-/B+; 84-89% = B; 80-83% = B-/C+; 74-79% = C; 70-73% = C-/D+; 64-69% = D; 60-63% = D-; below 60% = F. Borderline grades are determined by student’s participation and attendance (timely).

STUDENTS WITH DISABILITIES: In accordance with university policy, if you have a documented disability and require accommodations to obtain equal access in this course, please contact the instructor at the beginning of the semester or when given an assignment for which an accommodation is required.
Science Methods II - Senior Class  
Spring: T& Th, 11:00 am to 2:00 pm

T  Theme: Introduction to the course       HW:
Th Theme: Assessment       HW:

Field Assignment: Assessment Survey

T  Theme: Assessment       HW:
Th  Theme: Assessment/NOS       HW:

Field Assignment: Technology Survey

T  Theme: STS issues and controversies       HW:
Th  Theme: STS lesson components       HW:

Field Assignment: Student Teaching Lesson Plans

T  Theme: STS/Technology/Demos       HW:
Th  Theme: Demos Microteaching       HW:

Field Assignment: Student Teaching Schedule Plan

T  Theme: Sci Field: COSI Day at Local School       HW:
Th  Theme: Student presentations; Summing Up and Looking Ahead

EXAM WEEK
Time, day, and meeting place to be scheduled
Science Methods II—Senior Class  
Field Assignment 2

STS and Technology Survey

1. Does your cooperating teacher cover science-related societal issues in his/her class (e.g., cloning, stem cell research, acid rain, global warming, etc.)? Why or why not? What should students know in order to be “scientifically literate” members of society?

2. What advice does your cooperating teacher have on teaching topics like those given above? Are there societal issues that your teacher feels are particularly relevant for your students or your course?

3. List and describe the technology available to you in your classroom and school. Use the following format:

<table>
<thead>
<tr>
<th>Item</th>
<th>Typically used for</th>
<th>Can be used for</th>
<th>Working? Y/N</th>
</tr>
</thead>
</table>

Include communications technologies (computers, VCRs, etc.) as well as science technologies (microscopes; probes; meters; etc.).

4. Ask your cooperating teacher about any official policies regarding technology use that you should know about. For example, how do you sign up to use the computer lab? If you share equipment with other science teachers, how do you decide who is able to use it on what days/times? What are your responsibilities when you use school-based equipment? Is ‘tech support’ available in your school? Do parents sign consent forms to allow students to use the Internet? Are there students in your class who have not given permission for using the Internet? Etc.

5. Find out: What is your teacher’s view of using technology in secondary education? How should it be used? When? For what purpose? What are the caveats or cautions? What are the benefits? Then share your views on these questions, either from the perspective of a teacher, or a student, depending on your experience.
One of your graded assignments for this course is to submit a revised philosophy statement that considers the topics covered in this class. Here are the details of the requirements:

This philosophy statement should be thoughtful and concise. Ideally, it will be a 1 to 2 page statement that summarizes your outlook on various aspects of science education. This is the same philosophy statement that should be placed at the beginning of your professional portfolio (see the Inquiry IV requirements). You should expect that a principal or other potential employer would read your philosophy statement with some care.

Your philosophy statement should address the following topics:

The Goals of Science Education
   e.g., The Nature of Science; science content; Processes/Methods; Societal issues; personal needs; careers; “Scientific Literacy”
   What should students be learning in science class, and why?

Science Teaching and Learning
   e.g., Instructional Methods; Assessment; learning environment; Teacher-Student relationship
   What is your teaching style? How is it connected to your knowledge of student learning? What is your philosophy of assessment? What is your ideal learning community?

Professional Responsibilities
   e.g., To students, parents, colleagues, school, community; to the profession; to yourself
   What is your role as a science teaching professional? How do you hope to contribute to the community of secondary teachers and more specifically, science teachers?
Science Methods II—Senior Class  
Assignment Guidelines  

Class Topics Project (20 points)

For this assignment, you will demonstrate your understanding of various topics covered in class through the development of instructional material. Working with a partner, you will need to develop either a WebQuest or Instructional Video/Powerpoint presentation for use in a 7-12 science classroom (hopefully, YOUR 7-12 science classroom!).

The Quest should center on a Science, Technology, Society theme. Decide on an STS story that you want to convey to your students, and decide what the learning goals and objectives should be. The time spent on an activity like this is variable; you could picture and develop something like a two-day, in-class kind of activity; or, the Quest could be part of a longer-term ongoing project that students refer to every week or every other week throughout the grading period.

In general, a WebQuest is designed so that students are given a problem or a task, and they must explore resources gathered and linked through the Quest in order to complete their “mission.” Often, students get to role-play as part of the WebQuest. Students can take on various roles either as individuals or as part of cooperative teams. For lots of good information on designing WebQuests as teaching tools, see the site at San Diego State University:  
http://webquest.sdsu.edu

This assignment is worth 20 points. There are five areas of evaluation, and each will be scores 0-4, according to the following scale:

4 = exemplary  
3 = satisfactory  
2 = developing  
1 = misunderstood  
0 = missing

The five areas for evaluation are:

1. The WebQuest has at least two clearly written learning objectives (measurable, observable).

2. Formative and (authentic) summative assessment measures are included as part of the WebQuest and are aligned with the learning objectives given in (1).

3. Summative assessment is a quality example of authentic assessment.

4. The STS issue is supported with sound, accurate, and overall unbiased (from a scientific point of view) information.

5. Media presentation is well-organized, attractively presented, free of mechanical errors, and functional.
Personal Philosophy and Exit Interview (20 points)

Throughout your experiences in this course and during student teaching, you should be coming to terms with your own personal philosophy of science education. A description of the requirements for the philosophy has already been provided to you.

This assignment will be graded as follows:

Philosophy topic 1: The goals of science education, 5 points
Philosophy topic 2: Science teaching and learning, 5 points
Philosophy topic 3: Professional responsibilities, 5 points

For each of these categories, points will be awarded as follows:

5 points: exemplary, which means that you have thoughtfully and concisely integrated ideas from your experiences into a coherent statement of your beliefs
4 points: satisfactory, which means that you have generally clarified and justified your beliefs, but some points are unclear or inconsistent
3 points: developing, which means that you have given statements that contradict each other or that you have left out a major point
2 points: some misunderstanding, which means that you either left out several major portions of the topic to be discussed or could not articulate your beliefs in a clear way
1 point: serious misunderstanding, which means that you left out several major portions of the topic and that you could not articulate your beliefs in a clear way
0 points: not submitted

The last five points will be awarded according to: mechanics of the written paper (spelling, grammar, punctuation, etc.); overall coherence and organization of the philosophy; and your ability to be poised and articulate during the exit interview.
APPENDIX B

EXCERPTS FROM SYLLABUS: JUNIOR CLASS
Appendix B
Excerpts of Syllabus
Methods I - Junior Class

Course Description
Goals, methodology and resources for effective teaching of science to adolescents and young adults.

Course Goals
The readings, discussions and assignments for this course are designed to guide several aspects of your development as a secondary science teacher. The course is meant to help you build a sense of current professional knowledge in science education (including standards for science teacher preparation and for science students’ content knowledge). The coursework will allow for practice with and reflection on various methods for planning and teaching science to secondary students, and for assessing student learning in science. Finally, you should begin to nurture the competencies you will need to develop effective pedagogical content knowledge and to become a reflective practitioner of science education.

The Specific Objectives include:

1. Students will attend all class meetings and will be ready to begin at the designated time. Students will, in a timely manner, complete all reading and written assignments designated during the course. Students will participate in all class discussions and activities enthusiastically and in a way that reflects appropriate preparation.

2. Students will design and present multi-modal activities for developing conceptual understanding among secondary-level science students.

3. Students will engage with the science education professional literature and individual learners in order to design research-based assessment and instructional strategies for effective science teaching.

4. Students will consider the elements of effective demonstrations in science class and will plan and perform such demonstrations.

5. Students will demonstrate understanding of the history and nature of science through a reflective essay and design and presentation of a set of lessons on a historical episode in science.

26 Names of university, course name, course number, instructor name and contact information, and dates have been removed to protect participants’ privacy.
6. Students will explore effective methods for teaching about science-related societal issues in secondary-level classes and will design a mini-unit on an STS topic.

7. Students will reflectively evaluate their own performance as an emerging teaching professional and by identifying strengths and weaknesses and setting goals for individual growth. Students will develop skills for participating in a community of professionals by listening to and providing constructive feedback for their peers.

Your Graded Responsibilities include:

I. In-Class Activities and Participation (10%). *Attendance for this course is required.* The success of our course will depend upon the active participation of all individuals. If you must miss a class, please make every attempt to notify the instructor beforehand, and you are responsible to catch up on news and assignments you might have missed. Class absences will result in loss of points in this category. Lack of participation or inappropriate participation will also affect your grade in this category. For purposes of assessment in this category, you will be expected to maintain a class notebook. The notebook may be turned in at the end of the course to provide evidence of thoughtful participation if you expect to be on the borderline for your course grade.

II. Activities to Develop Pedagogical Content Knowledge (10%). Details and a rubric are appended to this syllabus.

III. Researching and Planning for Student Conceptions (10%). Details and a rubric are appended to this syllabus.

IV. Science Demonstration Microteaching (10%). Details and a rubric are appended to this syllabus.

V. NOS Reflection Paper (10%). You will turn in a written reflection on class discussion topics; details will be given in class.

VI. Telling the Story of Science 3-lesson Plan (15%). Details and a rubric are appended to this syllabus.

VII. STS one-week mini-unit (20%). Details and a rubric are appended to this syllabus.

VIII. Personal Portfolio Review (15%). Details and a rubric are appended to this syllabus. *Due Finals Week*

*Grading Scale:* 93-100% = A; 90-92% = A-/B+; 84-89% = B; 80-83% = B-/C+; 74-79% = C; 70-73% = C-/D+; 64-69% = D; 60-63% = D-; below 60% = F. Borderline grades are determined by student’s participation and attendance (timely).
Note: Major assignment due dates are given in the course schedule and/or announced in class, and it is your responsibility to be aware of this schedule and complete your work in accordance with these dates. Class sessions are designed around the assumption that students have completed the assignments. Late work may not receive full credit.

Students with Disabilities:
University policy 3342-3-18 requires that students with disabilities be provided reasonable accommodations to ensure their equal access to course content. If you have a documented disability and require accommodations, please contact the instructor at the beginning of the semester to make arrangements for necessary classroom adjustments.

Registration:
University policy requires students to be registered in order to attend classes. Anyone who is not officially enrolled by the second week of classes is not eligible for course credit or a grade in the class. Students may not enroll in a class after the registration period unless there is documented proof of a University error.
## Methods I - Junior Class
Tentative Schedule of Topics and Assignments:

<table>
<thead>
<tr>
<th>Session</th>
<th>Topic</th>
<th>Assignments</th>
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<tbody>
<tr>
<td>1</td>
<td>Course Introduction; Housekeeping; What is Science Teaching? Scientific Literacy</td>
<td><a href="http://www.nsta.org">www.nsta.org</a> Standards for Tchr Prep (1)</td>
</tr>
<tr>
<td>2</td>
<td>Science Teaching Standards, Portfolio</td>
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<tr>
<td>3</td>
<td>Pedagogical Content Knowledge</td>
<td></td>
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<tr>
<td>4</td>
<td>PCK activities</td>
<td></td>
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<tr>
<td>5</td>
<td>Comparing Teaching &amp; Content Standards</td>
<td></td>
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<tr>
<td>6</td>
<td>PCK presentations</td>
<td>PCK ACTIVITIES DUE</td>
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<tr>
<td>7</td>
<td>Student Conceptions (PUP)</td>
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<td>8</td>
<td>Conc. Change/Language in Science</td>
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<td>9</td>
<td>Conc. Change/Language in Science</td>
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<tr>
<td>10</td>
<td>Purpose, Planning, Instr., Mgmt., Assessment</td>
<td>STU CONCEPT. DUE</td>
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<td>11</td>
<td>Demonstrations in Sci Class</td>
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<tr>
<td>12</td>
<td>Demonstration Microteaching</td>
<td>DEMO PRES. DUE</td>
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<td>13</td>
<td>Assessment in Sci Class</td>
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<td>14</td>
<td>Kuhn &amp; Whig History</td>
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<td>15</td>
<td>NOS</td>
<td></td>
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<td>16</td>
<td>Evolution is an NOS issue</td>
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<td>17</td>
<td>Sci controversy in society</td>
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<td>18</td>
<td>Issues in Sci</td>
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<tr>
<td>19</td>
<td>Issues in Sci</td>
<td>SCI STORY PRES. DUE</td>
</tr>
<tr>
<td>Date</td>
<td>Activity</td>
<td>Due Date</td>
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<tr>
<td>20</td>
<td>Research and Planning</td>
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<tr>
<td>21</td>
<td>Research and Planning</td>
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<tr>
<td>22</td>
<td>&quot;Telling the story of Science&quot; Presentations</td>
<td>SCI STORY PRES. DUE</td>
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<tr>
<td>23</td>
<td>&quot;Telling the story of Science&quot; Presentations</td>
<td></td>
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<tr>
<td>24</td>
<td>STS issues analysis and instructional strategies</td>
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<td>25</td>
<td>STS issues analysis and instructional strategies</td>
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<td>TBA</td>
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<td>27</td>
<td>Summing up &amp; Looking Ahead</td>
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<tr>
<td>28</td>
<td>STS Presentations</td>
<td>STS MINI-UNIT DUE</td>
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<td>29</td>
<td>STS Presentations</td>
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<tr>
<td></td>
<td>Final Individual Portfolio Interview</td>
<td>PORTFOLIO DUE</td>
</tr>
</tbody>
</table>
Methods I—Junior Class
“Telling the Story of Science”

**Task:** You are to plan a 3-day lesson that addresses some aspect of the history of science. Although you should use the Brody and Brody book as background, you are not limited to this source of information. You will write lesson plans for three days (assume 45-minute class periods). Over the three days, your plans should focus on covering 1-4 objectives appropriate for students in grades 7-12 science classes. You should focus on helping students understand why the event was significant in the history of science. You should also be careful not to produce a “Whig history,” as we talked about in class.

**What to turn in to me:** Be prepared to turn in your lesson plans on [DATE].

**Grading Specifications:** This assignment is worth 15% of your grade in the course. I will use a 15-point scale, as follows

<table>
<thead>
<tr>
<th>Item</th>
<th>Exemplary</th>
<th>Satisfactory</th>
<th>Developing</th>
<th>Misunderstood</th>
<th>Missing</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABCD objectives (2 pts)</td>
<td>Complete, clearly written, match plan</td>
<td></td>
<td></td>
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<tr>
<td>Lesson plan components (2 pts)</td>
<td>Objective, materials, procedure, assessment present and clear</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Lesson plan alignment (2 pts)</td>
<td>Materials, procedure &amp; assessment follow logically from objective</td>
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<tr>
<td>Historical Significance (3 pts)</td>
<td>Accurate; easy-to-understand and follow; not simplistically heroic; reference to scientific puzzle /problem</td>
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</tr>
<tr>
<td>Historical Context (3 pts)</td>
<td>Accurate; provides background for scientific contribution; no ‘Whig’ history</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific concept(s) (3 pts)</td>
<td>Accurate, easy-to-understand and follow; clear; logical</td>
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<td></td>
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</tbody>
</table>
Methods I—Junior Class
STS Mini-Unit

Task: You are to plan a(n) (mini) instructional unit that addresses some Science, Technology, Society (STS) theme. You will write lesson plans for five days (assume 45-minute class periods). Over the five days, your plans should focus on covering 1-4 objectives appropriate for students in grades 7-12 science classes. You should focus on helping students understand the issue itself, including its component aspects, issues and questions (Which are the scientific questions? Which are questions of technological application? Which are ethical questions? etc.) You should also guide students through an analysis of the related problem(s), including a consideration of risks, costs, and benefits.

What to turn in to me: Be prepared to turn in your lesson plans on [date].

Grading Specifications: This assignment is worth 20% of your grade in the course. I will use a 15-point scale, as follows:

I will be looking at the following elements of your lesson plans:
ABCD objective written correctly (2 pts)
Lesson plans contain at least: objective, materials, procedure, assessment (2 pts)
Materials, procedures, and assessments are aligned with objectives (2 pts)

I will be looking for the following in the development of concepts and ideas in your plans:
The lessons help students clarify the kinds of questions/issues that make up the problem (3 pts)
The lessons help students accurately understand the scientific concepts (3 pts)
The lessons help students accurately understand the social and/or technological issues (4 pts)
The lesson model good problem-solving skills, including considerations of alternative solutions and cost-risk-benefit analysis (4 pts)

Points in each category will be awarded along a scale as follows:
(No credit) misunderstanding developing satisfactory exemplary
REFERENCES
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and learning: A project of the National Science Teachers Association (pp. 45-93).

New York: Macmillan.


