Chapter 16
Enacting a Socioscientific Issues Classroom: Transformative Transformations

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> The first semester, I was constantly frustrated because the students seemed to be incapable of understanding Nature of science (NOS), the relevance of Socioscientific Issues (SSI) in their daily lives, and the value of evidence-based argumentation. Actually, my first impression was that this was an exceptionally unintelligent group…though I often doubted my teaching ability, as the problem was global throughout six classes. (High School Teacher's Reflections of First Half of First Quarter)

Sociomoral discourse, argumentation, and debate are necessary elements in a socioscientific issues-centered classroom. While these factors are fundamental in realizing a socioscientific issues (SSI) curriculum, related pedagogical factors, such as a commitment to inquiry, enacting opportunities for the cultivation of character, and conceptualizing the role of the nature of science (NOS) are consistent with progressive views of science teaching and scientific literacy (Sadler & Zeidler, 2009; Zeidler & Sadler, 2010). Further, classroom research has demonstrated that a fully enacted SSI approach to science education becomes a transformative process for participating students and their teacher. Successful transformation occurs when the teacher-centered approach shifts to a student-centered classroom and the science curriculum becomes issues-driven. Further, the results of this shift may be said to be transformative when students' discovery of scientific concepts emerges out of socioscientific issues.

Introduction of novel pedagogy is often met with resistance from experienced teachers, as well as students who have become comfortable with classroom and instructional expectations. The unique dynamics of SSI-based instruction requires establishment of new relationships among teachers, students, and researchers, a series of transitions likely to impinge on established classroom social norms that can

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be both subtle and overwhelming. The social norms consist, in part, of implicit and explicit expectations established about the roles of the teacher and the students in that classroom. Frequently, we discover that such norms are firmly established after years of entrenched teacher-centered instruction. Historically, the education initiatives and changes to classroom norms have been structurally superficial in nature, where a new pedagogical approach may be implemented, yet students remain dependent on the teacher for instruction regarding the method of learning and which information has value. In contrast, an SSI curriculum provides for fundamental and deep structural changes that reorganize those norms at a core level of social networking and understanding. In the former case, one may think about how to rearrange desks and chairs or initiate a "new teaching strategy" without much thought to the deeper core structures of the classroom. In this case, there would certainly be changes in the classroom and between student-teacher interactions. We could speak about that experience as having undergone a certain type of transformation that was not necessarily transformative, in that the introduction of those new elements merely represented changes in surface features of normative and structural relationships. By contrast, if a teacher and his or her students experience pedagogical changes in ways that alter the *fundamental nature* of social discourse and community, we should understand that the experiences bringing about this deeper shift in epistemic beliefs are different in kind, and may properly be said to be *transformative*.

Many contemporary educative experiences consist only of transforming surface level characteristics of the classroom setting. It has become commonplace to find examples of reform in education that addresses only surface structure issues (e.g., high stakes testing, redistricting, the No Child Left Behind mandates and the like). Comprehending the shift from traditional classroom practice to an SSI framework requires an understanding of the distinction between the pedestrian transformation from new surface structure reform mantras and deep structure transformative practice—the latter represents fundamental normative shifts in core pedagogical expectations on the part of teachers and a sense of empowerment in terms of assuming responsibility for learning on the part of students. Our approach with SSI is an instantiation of progressive education, a concept that necessitates transformative shifts in how we understand science education and science teaching.

The purpose of this chapter is to present a description of a comprehensive research project that used a SSI framework to dramatically alter a high school level science curriculum and implemented the necessary pedagogical practices that transformed the teacher and his students from actors within a very traditional classroom context to participants in a progressive educational setting. It is our claim, that this accomplishment was based upon the transformative nature of a robust SSI approach that facilitated deep structural changes necessary to accept and understand the complexities of developing a progressive science teaching curriculum. We initiated this project to explore issues and challenges associated with the implementation of an SSI-driven curriculum. Specifically, the two primary objectives of this chapter are to: (1) Describe the conceptual design and implementation of a year-long SSI-driven course and (2) Outline a framework for SSI instruction, with suggestions and caveats that emerged from the design-based research associated with this implementation.

Pedagogy and Deep Structure Reality

> My mood as an educator has improved. Once I realized what needed to be accomplished, the projects progressed easily, rapidly, and with a great deal of enjoyment for the class and me. It should be noted that part of the differences was the result of my decision to put the projector, computer and transparencies to rest. The technology was beautiful and well organized, but exceptionally impersonal. When I rolled the white board to the front of the class and drew pictures and wrote down what the class was saying, they became involved in their own education. (Teacher's Reflections at the End of the First Quarter)

As we suggested above, many reform attempts to impact the educative experiences of our children consist of transforming surface level characteristics of the school setting. In understanding the shift from traditional classroom practice to the SSI framework, it is important to note the distinction between transformations that occur in classroom practice and transformative practices—the latter represents deep structural shifts both in teacher pedagogy and students' conceptual understanding of subject matter and reflective thinking. Figure 16.1 illustrates the contrast between two far ends of a continuum of instructional paradigms: traditional methods of instruction on the one hand, and progressive instruction on the other. We view our approach of SSI as an instantiation of progressive education—an approach that necessitates transformative mind-shifts in how we think about science education. The SSI framework we propose, necessitates deep restructuring—and recreating pedagogical reality in science education if we wish to arrive at the outcomes (autonomy, responsibility, etc.) often associated with progressive education.

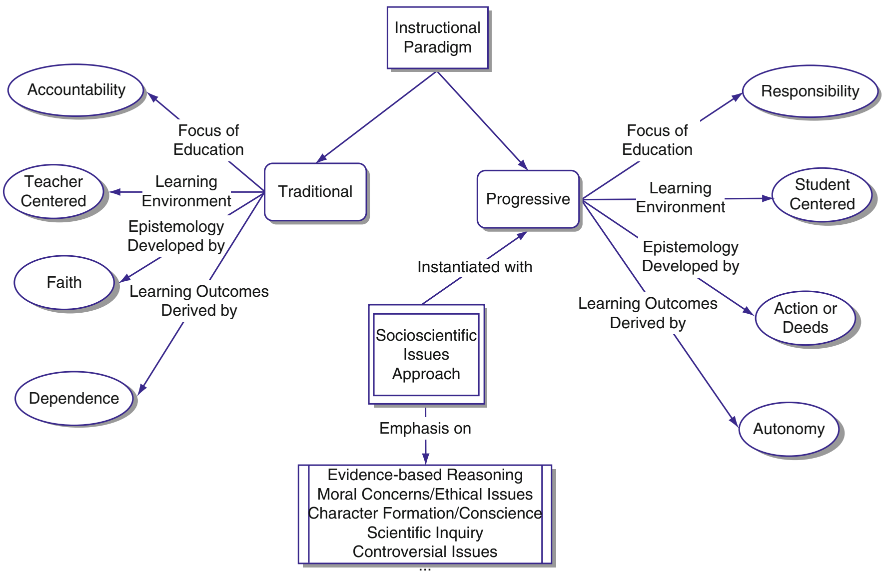


Fig. 16.1 Continuum contrast of instructional paradigms

The progressive venture has its historical roots in the experientialists (e.g., Jean Rousseau (1712–1778); Friedrich Froebel (1782–1852); John Dewey (1859–1952)), who viewed education as an individual (student)-centered social process where epistemic meaning is derived from the collective meanings of shared social experiences (actions and deeds) where autonomous thinking emerges as a natural outcome. This stands in stark contrast to a traditional approach, influenced by the thinking of social behaviorists (e.g., Johann Herbart (1776–1841); Wilhelm Wundt (1832–1920); Edward Thorndike (1874–1949)), which is dominated by a teacher-centric emphasis that focuses on mastery of prescribed bodies of fixed and discrete knowledge. Such an approach tends to produce in students, a dependence on the teacher where, in the extreme form, epistemic meaning is an act of faith. In this case, students are taught in an autocratic fashion, where text and authority produce unreflective students and inflexible knowledge that appears immutable. Hence, whereas the traditional approach develops knowledge and beliefs associated with the justification of that knowledge, through dogma or nonevidential (faith) methods, SSI begins with evidence-based reasoning, and challenges the normative assumptions of the knowledge claims students hold. Emphasis is placed on engaging students in the activity of scientific inquiry, and connecting that inquiry to contextualized social-scientific issues. In prioritizing personal and collective responsibility as an outcome of progressive philosophy, the cultivation of conscience through the formation of character is achieved by students engaging in discourse and making decisions about various moral problems (Zeidler & Sadler, 2008). It is important to emphasize that the final epistemological claims students hold are less important than the means by which they were developed. Under our SSI framework, students ought to be able to provide evidence-based justification for a position and exhibit an openness to reflect on that position in light of new evidence.

Project Goals and Setting

The project was initiated when a high school anatomy and physiology teacher (the second author) approached two science education researchers with established track records related to research and teaching of SSI (the first and third authors). The teacher had recently begun a graduate program in science education and was interested in the intersections of SSI, NOS, and the teaching of science content. He wanted to conduct a longitudinal experiment with his classes to understand how SSI could be leveraged to promote student learning of NOS and science content. The researchers enthusiastically agreed to partner with the teacher. The first author assumed the role of project director. He worked with the teacher on a weekly (sometimes daily) basis, visited the classroom frequently (to monitor curriculum implementation, serve as a resource and mentor for the teacher, and model selected lessons), and coordinated a group of graduate students who collected various forms of data. The third author served in a consulting role for both the teacher and the project director. All three authors collaborated on the design of the year-long curriculum and the development of specific learning activities within the curriculum. The three also maintained frequent communications (via phone, email, and face-to-face visits) to work through implementation challenges and research issues as they arose.

Teacher–Researcher Relationships

Finding a teacher with the fortitude to commit to a longitudinal intervention incorporating SSI, NOS, argumentation, and a dose of reflective judgment into their classroom for one academic year is no doubt a rarity. Such a teacher must be comfortable with his content and teaching abilities and demonstrate an unwavering commitment to inquiry into his own teaching practices and results. Labaree (2003) notes many of the unique challenges of teacher-as-researcher. Both teachers and researchers tend to conceptualize their roles as transformational, but the targets of their efforts are somewhat different. Teachers are personally invested in the lives of their students and work to transform those lives. Researchers typically seek more global effects: they work to improve education systems, curricula, and/or theory by creating better understanding of teaching, learning, and learning environments. Ultimately, these goals are complementary, but in the immediacy of an intervention study, the variable perspectives can create challenges for teachers trying to help their students learn and researchers trying to understand how students learn. Table 16.1 reveals some of the key issues that arose regarding the tension between the teacher and the researchers, and the ultimate resolution of those issues in the context of the current project. Because of the high degree of professionalism and mutual respect between the teacher and researchers, problems were brought to light and discussed with candor and humor. All three authors were very closely involved with not only the research but also curriculum design and implementation.

Because planning SSI units was done in concert with the teacher, we were able to question one another about the meaning and intent of particular investigations without undermining anyone's sense of ownership or professionalism. At times, where there may have existed a disconnect between the researchers' vision of how the various components of SSI were to be implemented relative to design features of the study, and the teacher's concern for immediate observable outcomes, we were able to have spirited discussions and come to a consensual resolution, much like we expected from the students who underwent this SSI curriculum. As the academic year unfolded, as suggested by the subtext of Table 16.1, we experienced transformations that were, indeed, transformative in nature. Perhaps the best way to describe how we fundamentally changed our understanding of working through various issues that arose is to suggest that all of us continually experienced a succession of mini-epiphanies about what constituted critical issues in the context of the research design and in the context of the real needs for the teacher and his students, and were able to negotiate and achieve common understanding and resolution as issues arose.

Table 16.1 Teacher-researcher action research issues and resolutions

Context	Critical issue	Teacher perspective	Researcher perspective	Resolution
The researchers ask the teacher to administer several pretreatment assessments	Appropriateness of the assessment instruments.	Students will not perform well on the assessments. "The nonhonors students have little chance to no ability of understanding the questions nor the type of answer they are expected to provide… They have a long way to go in the area of cognitive ability or skills."	The point of the project is to assess the extent to which a curricular intervention can promote the skills assessed by these instruments. Low scores on the pretreatment assessment are useful data points.	Administer the assessments with protocols informed by the teacher for instances in which students do not understand an item.
At the beginning of the project, the teacher uses a newspaper article to stimulate discussion and writing assignment for all students.	Communication between the teacher and researchers regarding the nature of each treatment group.	A news article of interest and relevance is available, so it should be shared with all students. The "experimental" classes will receive explicit instruction on argumentation later. "Yesterday, on the front page of the St. Pete Times was an article entitled, 'In stem cell debate, truth lies between the lines.' Michael Reagan …was quoted as referring to embryonic stem cell research, 'junk science.' I take issue with his uniformed opinion and had 150 copies prepared for the classes to read and evaluate."	Topics related to socio-scientific issues and/or argumentation should not be specifically addressed with the "comparison" classes. Presenting the article blurs the distinction between the "comparison" and "treatment" classes.	The Teacher and Researchers discuss the nature of each treatment. They take steps to enhance communication among all parties especially with regard to classroom activities.
The researchers produced a classroom activity related to course content,	Development of materials that address issues	The activity uses inaccurate information to support one side of the controversial issue. Students	The extent to which information is deemed inaccurate is heavily influenced by one's	The Teacher and Researchers compromised to

which is an area of the teacher's expertise, and argumentation themes, which is an area of the researchers' expertise. The activity attempted to point out two sides of a controversial issue.	mportant for course content as well as research themes.	would likely make inappropriate conclusions "My concern is that the risk/benefits are not equal and would prejudice most open-minded individuals."	perspective. When considering SSI, individuals are exposed to contradictory information, and the activity provides a real demonstration.	produce a draft acceptable to all parties.
The teacher asked students to explore NOS characteristics in the context of scientific theories. He became very frustrated with the products that were not nearly as well developed as had been expected.	Student learning.	Students should be learning, and it is very discouraging when they do not reveal anticipated gains. "I believed that they would be able to describe the topics using NOS as an historical basis and for the varied current theories that are still tentative and changing with cultural and technological influences…The essays reflect that they still do not get what the f**k NOS is all about and they are unable to understand how science could exist outside of the statements printed in their texts."	Improving student understanding of NOS themes is a seminal goal of the project. Data suggesting that students are not achieving this goal are every bit as important as positive results.	The Researchers are able to stay relatively detached from the situation; whereas, the Teacher maintains a much greater personal investment in the success of his students. Follow-up NOS activities coupled with more explicit instruction produces more encouraging results. In this case, one of the researchers modeled further NOS inquiry for the teacher.

Settings and Context

Since the focus of this chapter is on the pedagogical aspects relevant to the teaching of SSI, we omit certain methodological features that can be found elsewhere (e.g., Zeidler, Sadler, Applebaum, & Callahan, 2009) and concentrate on providing a brief overview of the learning treatment. The study involved a full academic school year that enabled the teacher to observe and monitor growth in students' perspectives of characteristics of science, scientific inquiry, and the relevance of science to daily decision—making through debates, argumentation, class discussions, small group and individual projects.

Participants were from four intact classes of the eleventh and twelfth grade students (typically ages 16–18) from a large suburban public high school in Florida. Two classes were honors and two classes were nonhonors anatomy and physiology sections. Each class had between 29 and 31 students. One honors and one nonhonors class were assigned as a comparison group while the two remaining classes became the treatment group sections. It is important to note that all sections (including those constituting the comparison group) were to have explicit emphasis on NOS constructs. Our rationale to include NOS in all groups stems from our belief that while SSI can elucidate features of NOS (Zeidler, Walker, Ackett, & Simmons, 2002), NOS in and of itself is a central component to teaching all science. Additionally, any changes in students' ability to use SSI-contextualized evidence-based reasoning could better be attributed to the interaction of NOS with SSI, rather than NOS alone. The teacher, who holds terminal degrees, taught all sections to control for variation in teacher attributes. Observations by researchers and extensive weekly journals helped to guide instructional decisions. An overview of the pedagogical approaches used with the two groups (i.e., comparison and treatment) is presented in Table 16.2.

We found Kolstø's (2001) general framework of eight "content transcending" themes quite useful in guiding the scientific dimensions of contextualized SSI instruction. While we have described these themes in previous research (Zeidler et al., 2009), it is important to restate them here: (1) Science-in-the-making and the role of consensus in science; (2) science as one of several social domains; (3) descriptive and normative statements; (4) demands for underpinning evidence; (5) scientific models as context-bound; (6) scientific evidence; (7) suspension of belief; and (8) scrutinizing science-related knowledge claims. These themes provided a template that served as a pedagogical mind-set for the researchers, and especially for the classroom instructor. Therefore, we were mindful that both the SSI modules and the pedagogy incorporate elements of one or more of these themes, as they provided guidance for developing important scientific habits of mind. For example, during discussions, debates, or advancing oral position narratives, the teacher would constantly question students' positions and demand that they provide supporting evidence for their claims. Statements like "I heard that…" or "My friend told me…" were forever banned from the students' vocabulary. He went further to challenge the veracity of the evidence students provided. It was interesting to observe how students eventually began to adopt these criteria

Table 16.2 Pedagogical framework for SSI study

	Comparison group	Treatment group
Approach	Traditional Approach: content topics follow textbook chapter topics.	Socio-scientific Issues Approach: content-related course topics embedded with SSI.
Teaching methods	Lecture, lab, discussion of content-related concepts, worksheets, predesigned lab activities.	Focus on argumentation and discourse, small group activities, role-play, and student research into SSI. Limited lectures and traditional labs.
Nature of science	Explicit activities and connections are made.	Explicit activities and connections are made.
Intended outcomes	Mastery of structure, function, and pathology of anatomical systems; more sophisticated views of NOS.	Improved critical thinking and decision-making particularly in the context of SSI; engagement in scientific discourses; sociomoral development; content mastery; more sophisticated views of NOS.
Classes	2 classes: 1 regular and 1 honors	2 classes: 1 regular and 1 honors

in reviewing their own work and when questioning one another. He provided opportunities for authentic inquiry investigations so students could engage in the activity of science, not as a fixed body of information, but as a process where people construct knowledge through collective understanding and examination of evidence. Avoiding dogma was achieved by encouraging the notion that students may question authority and think about the social perspectives under which knowledge claims were advanced. The work of Keefer (2003), Ratcliffe (1997), and Pedretti (2003) also informed our thinking in terms of ensuring the conditions necessary to focus on argumentation and discourse.

We were further influenced by features related to the Reflective Judgment Model and its use in classrooms such as the use of evidence-based reasoning, consideration of the role of authority, understanding the relationship between the role of knowledge and the status of epistemic beliefs (Baxter Magolda, 1999; Kegan, 1994; King & Baxter Magolda, 1996; King & Kitchener, 1994, 2002, 2004). The congruence between these factors and the type and quality of reasoning and discussion within the SSI framework are synergistic. In practice, the following strategies proved to be useful guideposts:

1. Show respect for students' assumptions, regardless of the developmental stage(s) they exhibit. Their assumptions are genuine, sincere reflections of their ways of making meaning, and are steps in a developmental progression. If students perceive disrespect or lack of emotional support, they may be less willing to engage in challenging discussions or to take the intellectual and personal risks required for development.
2. Discuss controversial, ill-structured issues with students throughout their educational activities, and make available resources that show the factual basis and lines of reasoning for several perspectives.

3. Create many opportunities for students to analyze others' points of view for their evidentiary adequacy and to develop and defend their own points of view about controversial issues.
4. Teach students strategies for systematically gathering data, assessing the relevance of the data, evaluating data sources, and making interpretive judgments based on the available data.
5. Help students explicitly address issues of uncertainty in judgment-making and to examine their assumptions about knowledge and how it is gained (King & Kitchener, 2002, p. 55).

The units chosen for the SSI Project were designed to move students toward deeper understandings of scientific concepts and their application to SSI. The issues were carefully selected in a manner that aligned students' interests with the course content embedded in the SSI, challenge core beliefs, and apply new content knowledge to the appropriate scientific context in a manner that was personally relevant and meaningful. The treatment(s) was intentionally designed to consistently challenge deeply held core values by offering opportunities to confront and defend or reject new information. The curriculum included multiple activities that required participants to evaluate claims, analyze evidence and their sources, come to a decision on a personal position, make moral decisions, and present the information within a group of peers to negotiate a consensus opinion. Each SSI unit required between 3 and 7 days; however, content was reinforced and reiterated on multiple occasions. Topics ranged from organ transplant allocation, the safety of marijuana and fluoridated water, the morality of stem cell research and euthanasia, quality of life issues, fast food consumption, and other contemporary subjects that were socially relevant. The learning opportunities were carefully crafted so as to highlight the idea that scientific knowledge is theory-laden and socially and culturally constructed.

Teacher Transformation in a SSI World

> Most importantly, each section began with a discussion or project of some SSI that they [students] resolved in groups of four, and then presented to the class… the content knowledge was extracted from these discussions, mostly from questions they had to clarify certain issues. They were using NOS references without realizing it and they have become aware of the relevance of science in their daily decision-making …. mostly, they learned that scientific knowledge is evolving and some of the empirical information is distinct for different groups of people. (Teacher's Reflections during the Second Quarter)

Intervention

The SSI project was developed and designed to feature an issues-driven curriculum. Activities and investigations were intended to provide personal experiences that are individually relevant and socially shared, while promoting enduring reasoning and decision-making skills. The goal for each unit was for the teacher to create opportunities for students to discover and acquire scientific content knowledge from an investigation of an SSI context. The motivating goal of the ten SSI units was to create activities that strategically directed students to essential subject matter content and concepts of anatomy and physiology. (Please refer to Appendix 1 to view all ten units). It should be noted that while the subject matter is narrowly defined, the contemporary application and moral implications of each unit could broadly connect to students' daily decision-making.

In preparation for the design of individual units, we developed a design framework to help inform this work. We used the design framework to explicitly highlight common elements to be introduced across all of the SSI based units, including the evolution of subject matter awareness and comprehension through contextual examination of corresponding social issues. This framework is presented in the outline below. We used this framework as a basic sequence for planning and implementing instructional activities but this list does not necessarily prescribe a fixed sequence. This issue highlights an important caveat to the presentation of the outline: following a prescribed sequence of steps is no path to assured success with SSI. It does take a flexible and insightful teacher to take advantage of opportunities when they arise and orchestrate these many components in creative ways to mesh with the moment, context, and students. The outline below provides a template of a typical SSI unit.

Development of an SSI Unit

1. Topic/Subject Matter Introduction
   a. Magazine headlines, articles, and advertisements
   b. YouTube video presentation of controversy associated with subject matter
   c. Photographs
   d. Models
   e. Other media formats
2. Challenging Core Beliefs
   a. Contentious questions that "attacks" commonly held beliefs
   b. Challenging "Common knowledge" of subject matter
   c. Misconceptions
3. Formal Instruction
   a. Anatomy
   b. Physiology
   c. Related science information
4. Group Activity
   a. Development of related, but unconventional topic/subject matter questions
   b. Individual investigation of data and evidence

   c. Small group negotiation of evidence
   d. Group presentation of consensus understanding

5. Develop Contextual Questions

   a. Fundamental science concepts of subject matter
   b. Defeating misconceptions
   c. Contemporary claims regarding subject matter

6. Class Discussion

   a. Evidence reliability of contemporary issues
   b. Importance of specific knowledge for informal decision-making

7. Teacher Reiteration of Content/Subject Matter

   a. Essential learning of subject matter content
   b. Purpose and relevance of specific knowledge
   c. Application of content knowledge
   d. Negotiating contemporary issues

8. Knowledge and Reasoning Assessments

   a. Group presentations
   b. Posters
   c. Argumentation/debate activities
   d. Paper production of selected topics
   e. Written tests of subject matter

A contextual example of the development of a particular SSI unit is provided to demonstrate how an SSI lesson plan for learning the digestive system for an anatomy and physiology course can be achieved. Specifically, investigation of popular diet plans and outrageous claims of weight loss from consuming exotic fruit (acai berries), taking diet pills, or wearing patches and creams can introduce specialized subject matter and engage a classroom of high school students to enthusiastically investigate esoteric science concepts. When confronted with Internet and tabloid advertisements that proclaim, “Lose weight without diet or exercise!”, “Lose weight permanently! Never diet again!” “Lose weight no matter how much you eat of your favorite foods!” or “Block the absorption of fat, carbs, or calories!” students were challenged to utilize knowledge, reasoning, and argumentation skills obtained in science classrooms to decipher physiological facts from science fiction. Following the template for a typical SSI unit is a detailed example to provide clarity to this unique pedagogy.

1. Topic Introduction: magazine articles, advertisements, and headlines; 5 min YouTube video of subject matter controversy, photographs, models, or media format.

   The development of a representative SSI lesson plan began with subject/topic introduction, engaging students with interesting demonstrations of recent magazine or newspaper headlines, articles, and advertisements. Visual presentations of subject matter controversy, such as YouTube and other Internet, photographs, models and other methods of capturing adolescent attention were used. We have realized that "more is better" when providing sufficient stimulus to encourage all students to become interested and engaged in learning new subject matter. Our introduction of science concepts, using contemporary issues related to the digestive system included photographs of teenage and adult obesity and inquiry about the absence of pictures of an overweight elderly population. Determining student knowledge and "pre-conceptions" of the subject matter was determined by posing non-threatening inquiry, such as how to relate individual diet, and health, and the potential side effects of a fatty diet besides excess weight. The number of students involved in discussions and the conversation volume of the classroom is a reasonable method of determining the quality of the topic introduction.

2. Challenge Core Beliefs with Contentious Questions.

   A fundamental element of negotiating scientific issues is the extraction of content knowledge from the controversial context. In this regard, a focus on the "learning" of anatomy and physiology was adjusted to consider contentious SSI contexts related to the digestive system. Specifically, controversial questions were written on the white board for students to evaluate and reference during their continuing investigation and argumentation. The debatable claims were intended to challenge bias and misconceptions that form the basis for many core beliefs. Typical and customary questions included: "If someone deliberately consumes food they know is both harmful to their health and detrimental their future well-being, is that choice an immoral decision?" or "Should high fat foods be taxed, since their consumption affects health care costs for the general population?" or "Since more people die of heart disease than drug overdose, should fried foods be considered an endangerment to the community and therefore illegal?" The moral implications of the questions challenged students' core beliefs and the varying responses enabled us to develop group activities, based upon "uninformed" responses.

3. Formal Instruction

   We recognized that formal instruction of anatomy and physiology of the digestive system (in this example) was necessary to provide students with a fundamental vocabulary of relevant structures and functions, which enabled better comprehension of information obtained through individual investigation. The anatomical structures of the digestive system and pathway of food movement were demonstrated, with PowerPoint photographs and drawings of related organs, tissues, and cells. Students were reminded of the complementary relationship between structure and function, while tracing the peristaltic passage of food from the mouth to the anus. While it is beyond the scope of this chapter to include all of the instruction regarding mechanical and chemical digestion, peristalsis, absorption, and excretion, it should be noted that students need to be "reminded" that formal science knowledge and application is a necessary adjunct to intelligent argumentation and negotiation of evidence and data reliability and validity. Students discovered that simple food selection requires sophisticated knowledge of the digestive system. However, new knowledge was now anchored in more meaningful contexts so students could create conceptual understandings and better transfer concepts to novel situations.

4. Construct Group Investigations and Presentations

   Because SSI instruction requires student engagement and commitment to active discovery, individual and socially shared group activities must be utilized. Our construction of the activities included multi-tiered projects involving individual investigation, evaluation of validity and reliability of evidence, group negotiation of verifiable data, creation of knowledge displays and presentation materials, and group presentations. Reintroduction and presentation of contentious popular claims related to the digestive system was stressed, to stimulate student interest. Typical group activities included:

   a. Group #1: Why are my biceps small and my butt so big?
   b. Group #2: How can I lose weight without dieting or exercising?
   c. Group #3: Are my bad dietary habits an eating disorder?
   d. Group #4: What are good, better and best diets?
   e. Group #5: Why does older generally mean fatter?

   The rationale for individual investigation and small group negotiation activities is based upon the recognized importance of developing and practicing skills related to evidence evaluation for reliability and accuracy. Science is ultimately an exercise in generating and testing new understandings particularly in light of misconceptions; therefore, group presentations were not intended to be amusing demonstrations, but synthesized instruction of the science related to the claims made and corresponding to the question posed.

5. Develop Contextual Questions Directed Toward Content and Concept Discovery.

   Subsequent to formal instruction, students were reintroduced to SSI, using less controversial, contextual inquiry, directly related to recent scientific instruction. Students are encouraged to investigate formal and practical aspects of the subject, with overtones of personal relevance. The formality of information is intended to promote inquiry of concepts and misconceptions. Contextual questions included:

   - How can you break down your cheeseburger into a molecular size so that 37 trillion body cells can receive nutrients to survive (make ATP)?
   - What is the difference between digestion and indigestion?
   - Why does alcohol and medication rapidly enter the cardiovascular system?
   - How do food molecules enter the cardiovascular system?
   - What are the differences between carbohydrates, protein and fats?
   - What is a calorie and how many do I need?

   The primary intention of questions like these was to encourage students to apply their informal reasoning skills and utilize their newly acquired knowledge to resolve contentious issues, evaluate evidence reliability and make informed decisions.

6. Class Discussion, Argumentation and Debate

   An established method for promoting reasoning skills and winnowing concepts and misconceptions is argumentation around debatable themes. Further, a significant component of SSI curriculum is realizing that decision-making is a moral exercise and a reflection of individual character. For high school students, the topic of morality connotes perceptions of personal behavior. For this reason, it was imperative that formal instruction included an opportunity for students to better understand that community living standards and relationships are based upon contemporary understanding of moral attitudes. Providing students with contentious issues that confront moral dilemmas is an important part of the acquisition of formal knowledge. Teachers can find excellent sources of ethical controversy in newspapers, on television, and conversations with their students. SSI activities should encourage students to develop personal understanding and informed opinions based upon reliable evidence. The cumulative purpose and goal of these activities is student maturation, character development and skillful negotiation of ethical dilemmas, as well as formal knowledge of the digestive system.

   In a designed digestive system-SSI activity, several topical issues were presented as the topic for argumentation and debate. In the midst of our implementation, the case of Terri Schiavo became headline news in our area, and we used the case as a center-piece of debates and discussions within the digestive system unit. In 1990, Schiavo collapsed and fell into a persistent vegetative state for 15 years. It was hypothesized that the initial condition was precipitated by a severe eating disorder that included frequent use of diet pills. The case gained national prominence when Shaivo's husband petitioned the court for permission to remove her feeding tube. Shaivo's parents strongly opposed this action and a legal and ethical battle ensued that involved the state and national supreme courts and the President of the United States. Ultimately, Schaivo's feeding tube was removed and she died. The patient's initial physical condition, her end of life condition and the pathology of her deteriorating digestive, cardiovascular and nervous systems provided a rich and compelling context for students to discuss physiological functions and connecting science to real-life events. Other topics that could be used in a similar fashion include:

   - Diets for Sale: Nutri-System, Jenny Craig, Weight Watchers, etc.
   - The Fast Food Highway to Cardiovascular Disease
   - Fat Tax for Unhealthy Foods
   - Health Care Penalties for Obesity
   - Involuntary Camps for Overweight Children

   Students explored these topics (and others relevant to the other curricular topics) through investigations of media, Internet resources and interview activities. SSI curriculum provides opportunities for enhancing scientific literacy, with students translating their understanding of SSI subject matter to research and position papers. Historically, students have demonstrated an ability to learn and "store" large quantities of scientific information, yet struggle to apply conceptual understanding to random claims, stated with authority. Internet search engines provide an easy access to vast amounts of information and concepts that may or may not be valid. It is the further purpose of utilizing an SSI program of study that students are encouraged to learn and develop skills that will facilitate intelligent and prudent application of knowledge.

7. Teacher: Final Instruction and Clarification of Concepts

   At the completion of the SSI/subject matter unit, the teacher acted as a moderator to revisit topics and clarify concepts, so students could confirm the understanding that science is innately organized and can be meaningful when understood in relation to the perception of their universe. The unit is best summarized by explaining that knowledge of the digestive system, and organ systems in general, cannot be understood in isolation, but as pieces of an incomplete biologic puzzle. In a perfect classroom setting, teachers will continue to discuss the elements of the section as other subjects are introduced.

8. Knowledge and Reasoning Assessments of Anatomy, Physiology and SSI related to the Digestive System

   Public and private schools rely on number and letter grading systems to measure student ability, and SSI instruction and curriculum encourages practical and conceptual understanding of science in the "real world." In these contexts, measurement of empirical knowledge is standard. Student presentations, arguments, posters and evidence provided rich insights into student understandings—but assessment of these products can be subjective. Written examinations can be arguably objective, but neither traditional or performance assessments provide complete insight into a student's ability to develop comprehensive understandings of subject matter. We made a concerted effort to utilize process and product assessments, which included evaluating quality of evidence used to defend opinions, the depth of understanding demonstrated in investigative papers, and student ability to recognize the inherent value of considering opposing opinions. While individual perception is difficult to assess, student evaluation should include a measure of their awareness that content knowledge and reliable evidence are fundamental building blocks in formulating well-measured stances. The definitive final examination occurred when students were confronted with controversial socioscientific issues that required understanding of empirical information and the skills of informal, moral reasoning.

Points of Consideration

Because SSI instruction often introduces issues with a moral dilemma, conflicting evidence, as well as multiple sources of evidence, teachers are expected to evaluate claims regarding the students' sources of information. Adaptation to this new approach requires the teachers to transform their perception about being a singular source of knowledge and encourages students to make individual decisions, even when personal beliefs are mistaken for scientific concepts. Recent studies have demonstrated that when SSI is presented in science pedagogy, students can handle conflicting evidence by drawing upon past experiences and combining them with new information, to explain actions in a scientific context (Driver, Leach, Millar, & Scott, 1996; Driver, Newton, & Osborne, 2000; Kolstø, 2001, 2006; Sadler, 2004; (Sadler, Klosterman, & Topcu, Chapter 21, this volume); Zeidler & Keefer, 2003; Zeidler & Sadler, 2008; Zeidler, Sadler, Simmons, & Howes, 2005; Zeidler et al., 2009).

Perhaps even more important is recognizing the significance of the transformative nature of classroom climate and culture. Under the SSI canopy, classroom management includes developing a relationship of trust where the students gain confidence in their ability to learn important science concepts. Creating a relationship of trust with students is necessary when using designed activities that investigate personal use of cigarettes, alcohol consumption, recreational drugs, and steroid abuse. The advantage of using this format was the ability to adjust the themes to accommodate both the academic abilities and interests of the students as well as the different science disciplines.

Using issues-based curriculum, teachers are compelled to reveal explicit nature of science connections by demonstrating that scientific knowledge is not absolute but forms as a result of social knowledge construction from argumentation and discourse. These new goals require deep epistemological conceptual shifts so teachers can transform their pedagogical orientation from being purveyors of scientific knowledge to moderators and mediators of a classroom culture that mirrors society in which students are challenged to make informed scientific decisions and exercise moral reasoning.

And Now for Something Completely Different

> They are having fun in class, taking notes without encouragement…. and best of all, their test grades are exceptionally good. Their ability to remember esoteric information has increased because the information makes sense to them. I constantly remind them that the earth is flat and that images are projected into the openings in the front of their eyes, like movies. They laugh because they understand that this is my "make sense epistemology." They know that people (including scientists) create answers and theories to explain phenomena, even when they are still unsure; because they have abandoned the excuse, "it must be magic." (Teacher's Reflections during the Third Quarter)

Outcomes and Discussion

SSI instruction is more than an instructional strategy. It can foster the development of content knowledge and a range of skills and dispositions, such as curiosity, problem solving, communication and collaboration skills, decision-making, and self-directed learning. Instead of presenting a prefabricated lesson plan, teachers present science content through the introduction of open-ended and messy problems. Delivering science content is replaced with argumentation and discourse-based instruction, developing collaborative group, communication, and problem-solving skills. Convincing students that investigating and arguing issues related to real-world problems or simulations of real-world problems that have more than one solution are effective methods of learning content knowledge that can best be accomplished by a teacher with confidence in the method, good presentation skills, understanding of performance-based assessment, and the willingness to transform roles from teacher-centered to student-focused.

We have previously reported on research outcomes associated with advances by students in reflective judgment and reasoning (Zeidler et al., 2009), moral sensitivity (Fowler, Zeidler, & Sadler, 2009), NOS (Walker & Zeidler, 2007) and embedded content knowledge (Sadler & Zeidler, 2005). Here, we wish to present other facets of the research project more directly related to the pedagogical practice of SSI. Therefore, the scope of this chapter is intentionally limited to descriptive observations by the classroom teacher, in conjunction with two researchers, as students' core beliefs about issues related to SSI topics were challenged. Students were constantly challenged to align their core beliefs with evidence supporting and/or opposing various perspectives related to socioscientific issues.

The teacher utilized multiple opportunities for noting daily responses and gradual changes in individual and class understandings of anatomy and physiology. Weekly discussions between the teacher and the two researchers served to identify and clarify observed trends in students' behavior. During the course of the academic year, and at the end of the school year, the teacher and researchers collectively identified and synthesized the main outcomes. Next, we offer descriptive indicators of each outcome with respect to the major factors competing with or facilitating students' epistemological understanding of course content and SSI. Contextual pedagogical factors that impacted the quality of the classroom ecology were also identified and described in a similar manner.

Confronting Core Beliefs

Many deeply held beliefs about the world and scientific issues originate from the mistaken concept that we are separate from the source of knowledge and understanding. Historically, science education has introduced scientific concepts and discoveries attached to the names of famous scientists. A long discussion could be inserted that describes the general home life of adolescents and their belief that they do not possess the necessary knowledge and experience to offer a valuable opinion. Parents and teachers convey the message directly or by subtle commentary that the voice of authority is reserved to a select group, without specifically addressing the knowledge and experience needed to enter the elite assembly. When underlying sources of science information originate from hearsay and secular sources, or is a generalized proclamation handed down from the court of public opinion, students generally adopt the information as core belief because they do not have believable, conflicting evidence. Once embedded, even contradictory data rarely dislodge a core belief.

Throughout our project, students were capable of evaluating and synthesizing data. However, when *SSI provided information that conflicted with their core beliefs,* several interesting patterns emerged. These patterns are summarized in Table 16.3.

Table 16.3 Factors identified when students beliefs were challenged

Major factor	Outcomes	Examples
Core belief persistence and discrepant data	Students often dismissed data (e.g., graphs, charts, and statistics) that were in conflict with their core beliefs or failed to meet the criteria of personal experience.	SSI[a]: Fluoridation of public water supplies. The majority of students believed fluoride was harmful, ignoring substantial evidence that demonstrated 350 million people drank fluoride daily, without side effects or illness. An opposing article provided statements that indicated a possible link to cancers and dental disfigurement. The value of "potential" harm or negative consequences, even unsubstantiated, was more important than well-documented benefits.
Lack of critical reasoning	The perceived value and relevance of information was based upon its fit with personal experience(s).	SSI: Stem cell research. Current media assertions by nonscientist "authorities" (government leaders) proclaimed that stem cell research was comparable to abortion. Without personal experience in areas of fallacious reasoning, the students reverted to fundamental, core beliefs and expressed a genuine fear of possible illegality and religious sin. In contrast, evidence of demonstrating the connection between unhealthy diets, smoking, and heart disease seems only remotely relevant.
Normative reasoning	When students were compelled to defend their opinions to their respective group, the class, and to the teacher, they included their core beliefs and personal experiences in their defenses.	SSI: Animal rights and the use of animals for scientific research. When students were forced to defend a position that was not parallel to their personal belief system, it provided an opportunity to challenge the credibility of their opinion, which had been developed entirely around the love of the family pet and nature-related television programs. Students struggled to develop arguments substantiated with evidence, demonstrating that science requires empirical data.
Reasoning with conflicting data	Students were generally surprised that reliable sources of scientific information at times provide conflicting claims and conclusions.	SSI: Legalization of marijuana. In the activity regarding the safety or harmfulness of marijuana, conflicting evidence regarding the potential harm/benefit of marijuana confused students but encouraged them to evaluate various sources of data and information from "authorities."

[a]SSI refers to the issue which served as a context for the example listed

Our observations of students on a day-to-day basis and over the course of an academic year confirm our position that prevailing cultural perceptions, particularly in the realm of SSI, may be understood as core beliefs. These perceptions reveal themselves as the prevalent beliefs that society (the general population) accepts as true, generally without reflection. Such perceptions form the basis of "socialization," which only involves blind acquiescence to a social norm and does not entail any form of internal evaluation (Zeidler & Sadler, 2008). Many of these shared perceptions form the basis of human awareness. We observed students to be easily influenced by generalized information that was presented as authoritative, with little attention paid to the source of that information. (It is noteworthy that even conspiracy theories that have managed to reach print status inform students' reactions to, and reasoning about, many SSI.) We therefore found it to be extremely important to make the effort to teach students to question whether or not their intuitive (initial) responses were actually true and subsequently had them ascertain, question, examine data from varied sources, and, through active discourse, form judgments about the credibility of information relevant to the subject matter at hand. In this manner, the process of norm acquisition and the formation of judgment in finding the fittingness of conduct to context can be allowed to reflectively develop (Green, 1999).

Confronting Contextual Factors

Contextual factors linked to teaching and learning scientific concepts interact not only with students' learning characteristics, but also with understanding of principles as a group. *When SSI were used as context*, then the content became personally relevant and accessible to students. Table 16.4 summarizes the main outcomes observed as they related to contextual factors.

Students' personal belief systems were, quite often, challenged while at the same time compatible science concepts, when contextualized in a manner that made subject matter personal and relevant, allowed students to frame their understanding of the content in more sophisticated ways. One of the most striking achievements across the class was the development of more mature attitudes toward the formation of consensus resolutions to dilemmas even when individual students' personal beliefs conflicted with the decision of their respective groups. We found that the process of challenging deeply held, personal beliefs and, perhaps their subsequent rejection, is extremely difficult. Indeed, a great deal of anxiety can result in a classroom where personal values are questioned. Thus, it was imperative that we established a learning environment conducive to the safe expression and exploration of ideas and thoughts by individuals and groups. We made constant adjustments to the kinds of contextual factors that would ultimately convey a kind learning environment that valued open inquiry about SSI and independent thinking, one that presented a coherent and consistent experience for the learners, and one that sought to be self-improving through processes of reflection, feedback, and critical inquiry.

Table 16.4 Summary of main contextual outcomes for students using SSI

Major factor	Outcomes	Indicators
Evaluation of evidence and claims	Students' ability to evaluate claims provided by media and other sources was improved when scientific concepts were related to relevant SSI.	Using the students own personal observations and experiences regarding the use and abuse of alcohol, difficult concepts, including the movement of the sodium potassium pump was learned because they "made sense" in the perspective of muscle and nerve failure.
Real-world relevance	Students demonstrated improved understanding of scientific concepts when they were able to attach the concept(s) to relevant SSI.	The case of Terri Schiavo (termination of life support for a brain-dead person) provided the SSI background and an instruction opportunity to discuss the anatomical structure of the brain and the related physiology. Further, students were able to construct meaningful discussions on the various cultural "definitions" of life.
Understanding contextual interrelationships	When presented with contemporary SSI, students were able to transfer conceptual understanding from one context and apply to a new and/or different context.	Examination of the stem cell issue, diseases of the nervous and muscular system, the effect of smoking on respiratory tissue, osteoporosis and contagious diseases such as AIDS and influenza allowed students multiple opportunities to investigate cell structure and the driving principles of homeostasis. Students demonstrated a better understanding of complementarity and the relationship between form and function.
Role playing and Role reversal	Students were able to identify and manipulate key variables (component parts) within a specific context to understand the direct and indirect effect on related concepts.	Students participated in role-playing activities during investigations of SSI, such as organ allocation, animal rights, and the matter of marijuana safety. The random selection of roles allowed students to challenge and defend their beliefs, using evidence they considered reliable. The use of various forms of evidence over time improved their skills in evaluating conflicting information.

Pedagogical Issues: Student-Centered Context

Moving SSI from theory to practice is essential in contemporary classrooms. Science education that includes SSI offer unique opportunities to challenge students' moral reasoning, and in the process, present concepts that seem to make sense because of their relevance and inherent interest. Consistently, the main competition to understanding and coherence are core beliefs, pseudoscience, and lack of personal experience in moral decision-making. The challenge to science teachers is to allow students to discredit their own belief system by having opportunities to be able to formulate new perspectives. Our experiences have allowed us to identify several areas that are potentially problematic for students when engaging in SSI. Student impediments to success included:

- Core beliefs
- Scientific misconceptions
- Lack of personal experiences
- Lack of content knowledge
- Underutilized scientific reasoning skills

In presenting this list, we do not mean to dissuade teachers from attempting an SSI approach. In fact, it is our position that insofar as students have such impediments, teachers have a responsibility to provide them with opportunities that challenge their personal belief systems about the social and natural world. Our experiences in the classroom over an academic year (along with other supporting studies previously cited) have revealed that the SSI approach fostered students' conceptual understanding of course content as well as more sophisticated views of NOS, empathy, and reflective judgment. When science is embedded within current SSI, students become motivated to participate in discussion that presents multiple opportunities for engagement in activities that require understanding of scientific concepts and content. Students demonstrate a greater acceptance and understanding of requisite information when it is connected to a contemporary issue that has personal relevance.

While encouraging students to consider evidence-based alternative arguments is of primary importance, it is equally important that teachers who are interested in using debate or discussion-focused activities also consider the match between their own pedagogical expectations and the theory base guiding the research. For example, an effective teacher engaged in SSI would need to rely on research to better direct classroom debates through various lines of questioning (e.g. epistemological probes, issue-specific probes, role reversal probes, and moral reasoning probes). The importance of exposing students' to discursive activities in the science classroom cannot be overstated if our goal is to increase science literacy. Of course this cannot be accomplished without the development of teacher training programs that focus on the pedagogical techniques necessary to create content-specific and NOS-embedded learning activities that emphasize discourse and debate. This requires that teachers become adept at guiding students in the process of applying their understandings of the nature of science as they decide on and evaluate the worthiness of competing scientific claims. Strategies similar to our SSI approach are valuable in that they allows teachers to reveal and become familiar with epistemological factors of students' reasoning including possible scientific misconceptions, moral reasoning, the ability to interpret and evaluate data, and fallacious reasoning.

Similarly, a teacher looking to the web for SSI fodder recognizes that Internet and issues-based learning activities can also be an invaluable resource in terms of exposing students to diverse perspectives on current scientific reports and claims. Again, current research can suggest important ideas to inform practice. With scaffolded learning interfaces (e.g. Walker & Zeidler, 2007), students can spend their time reading and evaluating the multiple perspectives of a given socioscientific issue instead of "surfing" through a plethora of sometimes misleading information. Of course, this requires that teachers invest the time up front to find both reliable as well as potentially unsound sources of scientific data and perspectives so students may be confronted with mixed evidence and offered scaffolding as they learn to assess the validity of varied claims and data.

The Foresight of Hindsight

> They discuss, argue, and question during each teaching and learning session. The rest of the semester will be dedicated to utilizing their new skills in handling various forms of evidence argumentation skills and learning to become better science students because they know that science is relevant to their lives. I wish we could discuss every question they have… (Teacher's Reflections during the Last Quarter)

While school boards, administrators, and teachers are heatedly debating science curriculum and which science lesson plans make the best medicine, the students have been slipping into a classroom coma. Faculty and department meetings discuss methods of inoffensively introducing contentious topics, such as evolution, while failing to create lesson plans of arguable contemporary scientific issues that are personally relevant to high school students, including issues such as alcohol and drug use, smoking, and obesity. The issues are recognizable, but not as contexts for learning science concepts.

A major problem of education has been the inability of students to identify with the topics they are requested to learn; specifically, the science that does not have easily recognizable relevance. Given that students learn to use cell phones, computers, and iPods without instruction manuals because the content knowledge is useful and meaningful to them, it is not unrealistic to believe that students can also learn science concepts when they meet the same criteria. For individuals to comprehend unfamiliar concepts and materials, they need to create links to personal contexts. The SSI curriculum requires students to formulate claims and conclusions about controversial topics based upon an independent acquisition of information regarding an assortment of socioscientific issues.

What a teacher believes is the reality of their instruction. Creating the mantra of providing rigor and personal relevance in science classrooms is insufficient unless teachers possess pedagogical expertise concerning the investigation of socioscientific issues context to discovering underlying scientific concepts. Encouraging students to examine conflicting evidence, negotiate personal perspective, and challenge their core beliefs about contentious scientific topics is not currently considered standardized curriculum format and lesson planning. However, sociomoral discourse, argumentation, and debate have been clearly established as necessary elements in character development and decision-making ability and therefore should be essential components of science education (Fowler et al., 2009; Sadler, 2006; Zeidler & Sadler, 2008; Zeidler et al., 2009). It is also worth noting that recent academic and educational research has demonstrated the importance of connecting the teaching scientific concepts to contemporary relevance (Applebaum, Zeidler, & Chiodo, in press; Fensham, 2009; Ratcliffe & Millar, 2009; Sadler & Zeidler, 2009; Zohar & Nemet, 2002).

It is important to determine the conditions under which students best grasp the essential concepts of science. The requirements for those conditions, it has been argued and demonstrated, entail that the process of acquiring scientific knowledge should include practices of discovery and learning, where students actively explore socioscientific issues. Current conversations covering the range of issues related to student learning are dramatically different from those of a decade ago. There is a growing national consensus that students should be able to think creatively, work through seemingly ambiguous data, search for novel patterns of thought and tap multidisciplinary expertise (The Council on Competitiveness, 2005; Narum, 2008; Zeidler & Sadler 2011.)

For preservice and practicing teachers, the realization that science education for many (most) students has included years of indoctrination, dogmatism or authoritarianism is a sobering epiphany. However, there is no place in science and, therefore, no place in science education for the protection of concepts and theories from criticism. The challenge for science teachers is to allow students to have personal experiences that do not immediately negate their belief systems; rather, the aim is to provide the conditions necessary to enable the development of a personal epistemology through continued exposure to, and interaction with, the nature of science and SSI. The use of argumentation and relevant SSI as a framework for science curricula is essential for enabling scientific concepts to enter students' individual belief systems.

The customary process of acquiring scientific knowledge should include practices of discovery and learning, where students actively explore socioscientific issues. While this pedagogy requires students to become actively engaged in socially shared activities that "unearth" personal connections and relationships to contentious scientific topics, it is equally important that teachers possess the characteristic leadership and teaching skills necessary for guiding students in their exploration and understanding of science. An aim of socioscientific issues curriculum has been to transform both teachers' and students' epistemological beliefs about the process of learning science by engaging students in a social microcosm where ethical negotiations of "real-world" problems and the use of scientific knowledge in their decision-making is a common occurrence.

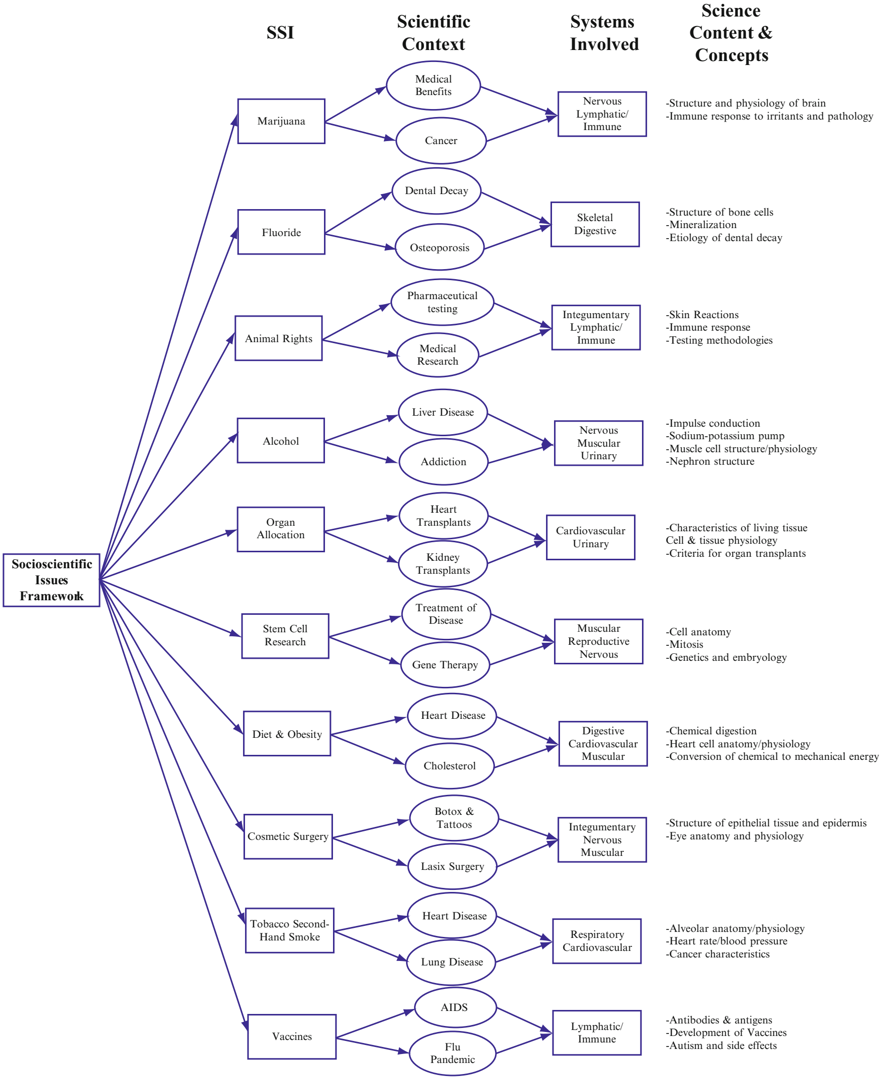
Using personal and social issues as context for learning science and acquiring content knowledge is only a novel experience in school, since this is a common method of constructing science knowledge outside of classrooms. Research has demonstrated that SSI instruction can be successfully instituted in classrooms (Walker & Zeidler, 2007; Zeidler et al., 2009); however, this instruction requires teachers to first transform their pedagogical orientation from being purveyors of scientific knowledge to moderators and mediators of a classroom culture that mirrors society and requires individuals to make informed scientific decisions and exercise moral reasoning. Science has to be learned in school very much the same way that it is practiced out of school.

As an issues-based curriculum, SSI instruction requires teachers to provide activities that demonstrate scientific knowledge is not absolute, but forms as a result of social knowledge construction from argumentation and discourse. Curriculum and pedagogy transformation are evident when daily classroom activities require students to discover the personal relevance of science through problem-solving experiences; in particular, the extraction of content knowledge from contextually embedded investigations. It is noteworthy that the success of using SSI-based curriculum is contingent upon redefining the role of the teacher and the responsibilities of the students. Teachers who include socioscientific issue inquiry in their lesson plans will discover their role is transformed from lecturer to mediator and moderator; their focus will be to assist students develop skills in areas of argumentation and evidence evaluation. As part of the transformation process, teachers will become competent in areas of critical thinking, argument quality assessment, and discussing moral dilemmas.

Innovative pedagogy, such as an SSI curriculum, both challenges and compels science teachers to undergo a transformative process that includes, among other things, discarding antiquated teaching methods. The objective is for teachers to transform their pedagogical focus and scientific epistemology so students can better understand how such knowledge is generated and validated (Abd-El-Khalick, 2006). Within the SSI framework, students are exposed to moral problems that involve a number of discrepant scientific, social or moral viewpoints, many of which may conflict with the student's own closely held beliefs. Teachers need to transform their pedagogical orientation away from introducing science concepts through simple lectures and reconfirming laboratory investigations; instead, teachers can create a classroom environment where students can develop a meaningful understanding of scientific concepts in relationship to real-world circumstances. Deforestation, ecojustice, global warming, viral pathogens, and personal fitness are significant topics; nevertheless, students (particularly middle and high school levels) tend to not regard these subjects as personally relevant because they do not instinctively understand that their lives are directly impacted (Mueller & Zeidler, 2010). A SSI framework allows for these personal connections to unfold by way of providing contexts that are organically connected to the students' worldview. Traditionally, science classroom activities rarely include opportunities to make personal decisions regarding contentious topics. Teachers must guide students through SSI activities so that they recognize the importance of informal reasoning in their daily decision-making.

Teachers who include socioscientific issue inquiry in their lesson plans will discover their role is transformed from a more traditional approach to a more progressive stance; their focus will be to assist students develop skills and habits of mind in areas of argumentation and evidence evaluation. As part of the transformation process, teachers will become competent in areas of critical thinking, argument quality assessment, and discussing moral dilemmas. Teacher transformation is further evident as students are directed to discover the personal relevance of science through problem-solving experiences as in the extraction of content knowledge from an academic investigation of SSI context. Perhaps the truest metric of the success of any classroom-based research project is that it survives after the researchers have left the classroom. SSI continues to be the driving pedagogy for this classroom teacher to date.

Appendix 1. SSI Units, Scientific Contexts, Systems and Concept Relationships



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