Concern for people and their fate must always be the chief interest of all technical [and scientific] endeavours in order that the creations of our mind shall be a blessing, not a curse, to humanity. Never forget this amid your diagrams and equations.

—Albert Einstein (www.engr.psu.edu/sts/about)

STSE? What do those letters stand for anyway?

—middle school teacher
INTRODUCTION

We live in a time of rapid scientific and technological change. Issues and controversies abound within the scientific community and the public at large. For example, how do we understand and make decisions about genetically modified foods or bottled water? Should pipelines to transport crude oil (for example, from Alberta, Canada, to U.S. destinations) be built? What do we do about forest depletion or climate change? How do teachers and students understand such complex issues—many of which have moral and ethical implications? How are informed, responsible decisions made? What is the relationship between science and social responsibility? Science, technology, society, and environment (STSE) education provides an avenue to explore some of these questions within the science curriculum.

Science, technology, society, and environment education is multi-disciplinary and includes moral and ethical perspectives as well as political, philosophical, historical, and economic considerations. Such perspectives attempt to acknowledge, explore, and critique the connections among science, technology, society, and the environment. Simply put, STSE positions science in larger social, cultural, and political contexts, equipping students to understand socio-scientific subject matter, make informed and responsible decisions, and take action. In our view, STSE education offers hope—a way of re-imagining our world and our relationship with nature, and solutions to problems. The goals of this chapter are to introduce you to STSE education and to explore some of the theoretical and practical issues arising from an STSE orientation.

STSE: A BRIEF HISTORY

There are many reasons for the evolution and growth of STSE education. Some of the influences include increased attention to science and social responsibility, the prevalence of issues that cut across science and society, a desire to humanize science, a decreased enrollment in physical sciences, and a renewed concern for the environment. One of the earliest mentions of STSE appeared in a 1971 Science Education article by Jim Gallagher, where he wrote, “For future citizens in a democratic society, understanding the interrelationships of science, technology, and society may be as important as understanding the concepts and processes of science” (1971, p. 337). This marked the beginning of a new way of conceptualizing science education.

A range of significant texts published during the 1970s, '80s, and '90s pointed to an ongoing commitment to STSE education and a collective desire for fundamental change in school science. (See, for example, Hurd, 1986; Pedretti, 1996; Solomon, 1993; Solomon & Aikenhead, 1994; Yager, 1996; Ziman, 1980.) In 1994, prominent researchers and educators Joan Solomon and Glen Aikenhead edited a landmark book entitled STS Education: International Perspectives on Reform. This publication did much to bring STSE to the fore. In this book, Aikenhead (1994) describes STS[E] education as:

…relevant, challenging, realistic, and rigorous. STS[E] science teaching aims to prepare future scientists, engineers, and citizens alike to participate in a society increasingly shaped by research and development involving science and technology. (p. 59)

These and other publications began to challenge the status quo of science education. They called for a science education that was accessible and relevant to everyone—a science for all philosophy. Recall (from Chapter 1) that science for all recognizes everyone’s (not just the scientists’) need for some science education that promotes critical thinking, informed decision making, and action on science and technology issues that affect the quality of one’s life and community, and beyond. In other words, it was the beginning of citizenship science. STSE policy and curriculum themes began to be developed in many

1For the purposes of this text, we will use STSE, understanding that its roots are in STS education.
countries around the world. For example, governments in Canada, the United States, the United Kingdom, Australia, and Israel developed documents that consistently called for science education to be more than the acquisition of scientific concepts. In Chapter 3 we outlined how Calabrese Barton and Upadhyay (2010) consider this a social justice and civic rights issue.

In 1984, the Science Council of Canada published Science Education in Canadian Schools, Volume 1 (Orpwood & Souque, 1984), which described a science curriculum that included a science and society emphasis. Later, the Council of Ministers of Education, Canada (1997) published the Common Framework of Science Learning Outcomes: Pan-Canadian Protocol for Collaboration on School Curriculum, which provided a vision for scientific literacy that emphasized and prioritized STSE education. It boldly recommended that scientific literacy would be best achieved through STSE education:

The vision of scientific literacy included in this document sets out the need for students to acquire science-related skills, knowledge, and attitudes, and emphasized that this is best done through the study and analyses of the interrelationships among science, technology, society and the environment (STSE). (CMEC, 1997, p. ii)

ACTIVITY 10.1

Prior Knowledge and Experience: Connecting Science to Society

Recall your experience as a student (both in middle and secondary school and at university). Identify an example of a time your science instructor raised issues of science and technology and their effects on society. It might have been a controversial issue, a current event, or an historical example of science and society. Describe the issue or event: what methods did the teacher use (e.g., lecture, discussion, readings, or a video)? What did the students do?

DISCUSSION QUESTIONS

1. What was your response to the teacher’s approach?
2. Did you see it as relevant? Inspiring? Uncomfortable? Explain.
3. Make a list of all the reasons that you, as a teacher, might include issues related to how science and technology are affected by society, and vice versa.

Benefits of STSE Education

Much has been written about why educators and policy makers should include and prioritize STSE education. (See for example, Hodson, 2011; Pedretti & Little, 2008; Pedretti & Nazir, 2011; Solomon & Aikenhead, 1994.) Recall from Chapter 1 that the call for science education includes goals of scientific literacy, citizenship education, public understanding of science, and science and social responsibility. STSE advocates and programs worldwide articulate these goals. The list you generated in Activity 10.1 probably contains similar responses to the question why “STSE” education? In summary, STSE education:

- fosters student engagement and raises student interest in science
- empowers learners
- requires collaboration and discussion among students and teachers
- raises awareness of current issues
- includes global as well as local perspectives
Part 4 Science, Technology, Society, and the Environment (STSE)

- promotes active global citizenship (decision making and action) for social good
- enhances student learning
- nurtures intellectual independence
- develops critical-thinking skills
- advocates for social justice
- contextualizes science
- provides a more balanced view of science and scientists
- reflects a more humanistic approach
- encompasses a broader vision of scientific literacy
- includes an interdisciplinary approach
- seeks to prepare young people to meet the challenges of the future

One of the criticisms levelled against STSE education is that content is watered down, or not attended to at all. This is not the case; content is taught, but in context. In other words, the teaching of scientific concepts and processes occurs within a rich “science and society” context. For example, imagine students learning about energy sources—solar, wind, coal, thermal, hydroelectric, agricultural biomass, and tidal, to name a few. Each of these could be taught in a conventional way—each source identified and examined with little consideration for the complex context in which they operate. Alternatively, a teacher may decide to teach about these sources of energy through an STSE approach, using for example, case studies which touch on the political, social, and economic messiness that each energy source brings to the table. In both approaches, students are “learning” about various energy sources, but in very different ways.

Bennett, Lubben, and Hogarth (2007) spoke to the content-context issue with their comprehensive review of the international research evidence on the effects of STSE approaches to teaching school science. They concluded that STSE education results in improved attitudes toward science while maintaining understanding of scientific ideas. Similarly, Aikenhead’s (2006) analyses of an accumulated body of research demonstrates that, compared to students in a traditional setting, students in non-traditional science classes that favour a humanistic and STSE approach can significantly improve their understanding of social issues and the nature of science as well as improve their attitudes toward science, science classes, and learning; make modest but significant gains in thinking skills and application of established science content to everyday events; and improve critical and creative thinking and decision-making skills. Knowing becomes an essential component of scientific and technological literacy. As Aikenhead (1994, p. 58) rightly suggests, “In STS[E] science teaching, traditional science content is certainly taught, but students learn this content by constantly linking it with their everyday world.” In other words, content becomes appropriately embedded in context.

Historically, proponents of STSE education have argued for a vision of science education that is inclusive, relevant, and reflective of the interconnectedness of science and society. Today, this desire for change in school science continues. In many jurisdictions across Canada, STSE education has become an important part of school science curriculum and the student experience. However, the recommendation to emphasize STSE is taken up differently by each province and territory. In Ontario, for example, recent science curriculum revisions have given STSE education a central position, while in the Curriculum Consortium of Canada’s four Atlantic Provinces STSE is viewed as a means of achieving balance and integration in the science curriculum (and is part of the nature of science). In Alberta, STSE and knowledge outcomes are combined and listed first, followed by skills and then attitude outcomes. The extent to which STSE is given priority carries important implications for policy and practice across the country. In Activity 10.2, you will have an opportunity to examine STSE policy and curriculum in your jurisdiction.
Chapter 10 Science, Technology, Society, and Environment (STSE) Education

CHARACTERISTICS OF STSE EDUCATION

STSE education is multi-disciplinary, drawing from, for example, history, economics, environmental studies, politics, sociology, and ethics. It would be a mistake to assume that STSE education is a single, well-articulated coherent approach to science education. There is no single, widely accepted view of STSE education; rather, it is a movement with a number of different strands, each with a distinct history, and some tensions as well. By its very nature, it defies definition; this is its strength and its weakness. As Ziman (1994, p. 21) writes:

The movement for STS[E] 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. That is not necessarily a defect. The same would apply to other great movements of our times, such as those for peace and for the environment. Such movements are kept alive by countless personal and collective commitments that cannot be captured in a few thousand words of didactic prose.

Solomon (1993), for example, suggests that the general characteristics of STSE education include understanding local and global environmental pressures, being aware of economic and industrial dimensions of technology, recognizing that science as a process is fallible, exploring personal values, and engaging in democratic action.

Building on the work of others, we provide a set of characteristics for STSE education in Table 10.1. The list is the result of an analysis of STSE research, curriculum, and national and international policy documents. The following characteristics of STSE education consistently emerged: stewardship, decision making, values, action, and nature of science.

It is important to note that these characteristics often overlap and work in synergy. They are not mutually exclusive, no single one is better than another, many work in tandem, and different characteristics are used at different points in the curriculum for different purposes. For example, exploring the Atlantic fisheries or the northern Ontario Temagami forest or the Alberta tar sands might include aspects of stewardship, decision making, and values, while learning about plants and nutrition might include an action component of reclaiming abandoned school gardens to grow vegetables. Not all of the characteristics can be included in each lesson or unit, nor should they. As always, it is up to you as the teacher to be judicious about your STSE planning.

ACTIVITY 10.2

Working with Resources: STSE Curriculum and Policy

Choose a Grade 9 or 10 science curriculum document from your jurisdiction. Briefly summarize what the front matter says about STSE education. Then, choose a topic or unit and read the STSE outcomes or expectations. Analyze these in terms of the language used, suggested activities, and accompanying strategies. Use specific examples to support your analyses.

DISCUSSION QUESTIONS

1. In general, how would you characterize the relative emphasis of STSE in each science curricula?
2. What are students expected to know, do, and value with respect to STSE outcomes or expectations?
3. Imagine how you might create a unit using the STSE curriculum outcomes or expectations as a frame or anchor for the unit.

CHARACTERISTICS OF STSE EDUCATION

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Table 10.1  Characteristics of STSE Education

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stewardship</td>
<td>Caring for the environment, studying resource use, and consideration of long-term human needs in an effort to maintain a life-sustaining environment.</td>
</tr>
<tr>
<td>Decision Making</td>
<td>Understanding how decisions are made at the local, provincial, and national government levels as well as within the private and industrial sectors; helping people make informed, responsible decisions.</td>
</tr>
<tr>
<td>Values</td>
<td>Coupling of science and values education, a departure from the presentation of science as value free, objective, and linear.</td>
</tr>
<tr>
<td>Action</td>
<td>Empowering citizens to become responsible agents of change at a personal and social level; promoting responsible participation in society; developing both the potential to act and the disposition to do so. Exercising intellectual and ethical skills in determining the benefits and costs of any scientific or technological development, recognizing that underlying political and social forces drive the development and distribution of scientific and technological knowledge and artefacts, and honouring principles of social justice.</td>
</tr>
<tr>
<td>Nature of Science (NOS)</td>
<td>Recognizing that scientific knowledge is tentative (subject to change); empirical (based on and/or derived from observations of the natural world); subjective (theory laden); the product of human inference, imagination, and creativity; and socially and culturally embedded.</td>
</tr>
</tbody>
</table>


ACTIVITY 10.3

Read and Reflect: A Case Study of STSE in Practice

For this activity, read the following article:


In this article, the authors provide an account of an STSE investigation that allowed students to gain an in-depth understanding of the interactions between organisms and their environment, and to experience connecting science to society and their lives. Briefly describe what this project was about and answer the questions below. Be prepared to share your answers with the class.

**DISCUSSION QUESTIONS**

1. What motivated the class to embark on this project?
2. What characteristics of STSE education are reflected in it? Explain each one, with examples from the project.
3. What is the relationship between content (understanding relevant science concepts) and STSE education?
4. Assessment can be a challenge in a project such as this. Discuss what assessment strategies were used and for what purpose, (e.g., a test for content or a rubric for collaboration).
5. What is your response to a project of this magnitude?
6. What concerns might you have with respect to implementing similar kinds of projects?

**ANALYZING CHARACTERISTICS OF STSE EDUCATION**

In the following sections we discuss in more detail the features of STSE education outlined in Table 10.1 above. Activities or series of questions are included as entry points for personal reflection and dialogue with your peers as you begin to think about developing and implementing curriculum with an STSE orientation.
Chapter 10 Science, Technology, Society, and Environment (STSE) Education

Stewardship

Many have argued that the environment is in crisis: climate change, ozone depletion, loss of biodiversity, deforestation, and pollution are but a few examples. Our connection to the land and to the environment is precarious and requires our immediate attention. Many issues arise when we consider, for example, what we preserve, how we preserve it, over what timeline, and who should make the decisions. Some argue that the standard of living we currently enjoy in North America is predicated upon bountiful supplies of inexpensive fuel and other commodities, often at the expense of underdeveloped countries and people living in poverty.

Over the years, there has been a resurgence of interest in environmental education locally, nationally, and internationally. For example, the years 2005–2014 have been declared the United Nations Decade of Education for Sustainable Development (DESD). A review of the literature (see, for example, Bateson, 2000; Hart & Nolan, 1999; Palmer, 1998; Suzuki & Hanington, 2012) suggests that education for stewardship is about:

- heightening appreciation for all forms of life and for the earth as the only life-sustaining environment we know
- enabling people to understand the interdependence of all life on earth
- making explicit the natural structures and processes that sustain life
- critiquing the way humans alter the integrity of ecosystems
- engaging students in a process through which they come to recognize personal and societal practices, attitudes, and forces (e.g., economic, political, social, cultural, technological, ideological) that foster or impede sustainability
- challenging the imagination to envision alternative practices and life-enhancing roles for humans in the web of ecosphere relationships
- providing students with the skills, knowledge, and values they need to live responsibly as global citizens

It has been argued that stewardship and sustainability can (and should) be promoted across the curriculum. However, STSE education (with an emphasis on the E) provides a natural starting point from which to teach and learn about stewardship in the context of science education. (Chapter 12 specifically addresses environmental education in science.) Stewardship includes caring, protecting, and preserving natural resources so that subsequent generations can continue to use and enjoy them. It entails conserving existing ecosystems and restoring damaged and endangered ones. It is necessary for governments, organizations, and communities to work together to accomplish these goals. As you continue reading, think about how you might weave stewardship into your science teaching. What role do science and technology play in stewardship? How might different value perspectives affect stewardship? For example, Aboriginal people in Canada hold a worldview that deeply connects the land to its people: “Embedded within the Aboriginal worldview is the concept of collective responsibility for tending the land and using only that which is needed for sustenance. Important, as well, is the interconnectedness and interdependence of all life forms—humankind, flora, and fauna, and all that exists of the Earth” (Manitoba Education and Training, 2000, p. 49). More is said about different worldviews in Chapters 3 and 12.

Decision Making

Science and technology today play a vital role in the lives of individuals and societies. At the individual level, we often make decisions based on scientific evidence; for example, we choose to consume certain foods and reject others or choose to use particular
household cleaners over others. At the social level, we decide whether it is an acceptable risk to live next to a nuclear power plant and which public health campaigns to support. Almost all of these decisions are guided by scientific authorities in whom the public places implicit trust. However, “science and technology are essential social enterprises, but alone they can only indicate what can happen, not what should happen. [What should happen] involves human decisions about the use of knowledge” (National Research Council, 1996. p. 199).

STSE education is rooted in understanding and participating in the decision-making process. Students are encouraged to gain a clear understanding of how decisions are made at the local, provincial, and national government levels, and also within the private and industrial sectors. As Aikenhead (1994, p. 18) writes:

STS[SE] science is also expected to fill a critical void in the traditional curriculum—the social responsibility in collective decision making on issues related to science and technology. Such a commitment requires that political influences, economics, ethics, motivation and the evolving politics of science, and their relationship to the decision-making process are explicitly communicated and explored with students.

Decision making is an inherently complex process involving multiple possibilities, values, and agendas. Decision makers rely on criteria to manage the complexity of the issues and distinguish among the possible solutions. This includes understanding the underlying value positions of various stakeholders as well as the values underlying the criteria, and conducting cost-benefit analyses for the alternatives. Experts might support a number of different decisions and perspectives on a single issue, making it complicated for students. However, this should not preclude science educators from attempting to teach decision making. Rather, it points to the need to provide students with critical-thinking skills that assist them in evaluating the alternatives and their consequences, and in reaching informed decisions while participating as citizens in a democratic society. Providing your students with a framework for decision making is helpful. Many curriculum documents do just that.

ACTIVITY 10.4

Studying the Locavore Movement

Locavores are people interested in eating foods that are locally produced—that is, produced within 100 miles of point of purchase or consumption—rather than foods shipped very long distances to their destination. In groups of four, research the locavore movement and answer the following:

• Explain what motivated the locavore movement.
• Describe three benefits of eating locally produced foods.
• What are some of the criticisms levelled against locavores?
• Do you already choose to eat locally grown food? If not, would you consider changing your own diet to consume more locally grown food? Why or why not? If so, what changes would you need to make to your diet?
• Imagine it is autumn in the northern hemisphere and you are planning a dinner party. Plan a three-course meal according to locavore practices (be sure to describe the specific foods used).

DISCUSSION QUESTIONS

1. Would you use an activity like this with your students? Why or why not?
2. What science content do your students need to know or understand in order to complete this activity?
3. Imagine secondary students doing this assignment. Construct an assessment tool to grade the locavore menu.
4. What might be some of the challenges for a teacher and for students in using this activity?
For example, Newfoundland and Labrador (Government of Newfoundland and Labrador, 2002, p. 8) offer this decision-making framework:

- Gather information from a variety of sources.
- Evaluate the validity of the information source.
- Evaluate which information is relevant.
- Identify the different perspectives that influence a decision.
- Present information in a balanced manner.
- Use information to support a given perspective.
- Recommend a decision and provide supporting evidence.
- Communicate a decision and provide a “best” solution.


In the Saskatchewan Science 9 curriculum, (Ministry of Education, 2009, p. 20), a framework for engaging students in STSE and decision-making skills is provided and includes the following:

- Clarifying an issue.
- Evaluating available research and different viewpoints on the issue.
- Generating possible courses of action or solutions.
- Evaluating the pros and cons for each action or solution.
- Identifying a fundamental value associated with each action or solution.
- Making a thoughtful decision.
- Examining the impact of the decision.
- Reflecting back on the process of decision making.

Source: Adapted from Saskatchewan Ministry of Education, (2009). Saskatchewan Science 9 Curriculum. Adapted and used with the permission of Saskatchewan Ministry of Education.

As you continue reading, think about the following. What should inform our decision making? What is the role of science and technology in contemporary collective decision making? How might we encourage informed decision making with our students?

**Do We Need Plastic Shopping Bags?**


When we are finished using a plastic bag, we are faced with its disposal. Recycling is one option, but this uses energy and resources—possibly more than it took to make the plastic bag in the first place. Plastic bags and other polyethylene products often end up in landfill or as litter and may not break down for decades.

To consider the question, “Do we need plastic shopping bags?” form groups of four and work through the following:

- Identify and research two advantages and two disadvantages of using plastic bags.
- Identify two alternatives to using plastic bags along with the positive and negative consequences of those alternatives.
- Decide your position on the above question and defend your stance.
- Create a way to communicate your findings to a larger audience (such as via a blog or podcast).

**continued on next page**
DISCUSSION QUESTIONS
1. Would you use an activity like this with students? Why or why not?
2. What science content do your students need to know or understand in order to complete this activity?
3. Imagine your own intermediate or secondary students doing this assignment. What criteria will you use to judge their decision-making process? Use your criteria to create a checklist or rubric for assessment.
4. What are some of the challenges or barriers that you foresee, as a teacher, in implementing decision-making activities?

Science and Values

STSE education seeks to re-couple science and values education, departing from a more traditional misrepresentation of science as value free and objective. The underlying assumption here is that science cannot be separated from its moral and ethical responsibilities to society, nor can society abdicate responsibility to science (Venville & Dawson, 2012). However, embedded in these issues and reciprocal responsibilities are questions of whose values will be privileged. Aspin’s (2002, p. 15) use of the term values refers to those “ideas, conventions, principles, rules, objects, products, activities, practices, procedures or judgments that people accept, agree to, treasure, cherish, prefer, incline toward, see as important and indeed act upon.” Combining science and values can be challenging for science educators as they strive to take into account alternative cultural mores, customs, and beliefs.

STSE education seeks to be sensitive to the range of values and ideologies, particularly in a multi-ethnic society such as Canada. Conceptual ideologies about progress, sustainability, democracy, and educational purposes differ. When dealing with controversial subject matter, educators face the challenge of recognizing pluralism, biases, and indoctrination, while taking account of alternative values. For example, students might study different cultural beliefs about reproductive technologies or the different value positions regarding a new quarry. As you continue reading, think about the following. How should teachers accommodate diverse cultural contexts and ways of thinking about the world and our relationship to it? Whose values are advocated? What topics could you use with your students that show how values are implicated in scientific research?

Action

If education is to enable young citizens to look critically at society, to analyze the values underpinning that society, and to ask what can be done to create a more socially just society, then science education must share the same goals (Bencze & Carter, 2012; Hodson, 2011; Pedretti, 2003; Roth & Désautels 2002). An STSE orientation is one way for science curricula to explore goals of social reconstruction and social justice. For example, how can we ensure that people have access to safe drinking water or that local green spaces are protected? It is not enough to simply develop awareness or make decisions about what might be done; science educators must also provide, when appropriate, opportunities for students to take action. For example, students might participate in cleaning up a local ravine or write letters to the editor concerning a local environmental issue. Understanding that science and technology exist within a broader socio-cultural context, and critiquing or solving social and ecological problems through human agency or action, are the key points here.

Hodson (2003) describes four levels of preparation for student action. The first level helps students to explore and appreciate that science and technology impact society. Level two considers how the power, wealth, and special interests affect decisions about science and technology. In level three, teachers help students develop personal positions and value perspectives of their own, and level four encourages students to take action. Educators often attend to levels one, two, and three, and for many it comes easily and intuitively. However,
Chapter 10 Science, Technology, Society, and Environment (STSE) Education

**ACTIVITY 10.6**

**Animal Experimentation**


Individually, complete the table below, “Where Do I Stand?” In groups of four, explain and discuss your decisions and the thinking behind them. Try to achieve consensus around each statement.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Agree</th>
<th>Undecided or don’t know</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animals, like humans, feel pain and distress.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preventing human suffering justifies using animals in scientific experiments to test new drugs.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I would buy a “cruelty-free” shampoo rather than one tested on animals, even if it were double the cost.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Testing substances on animals is unreliable because they often respond differently than human beings.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Animal experimentation to ensure the safety of products that make us look, smell, or feel nicer is unjustified.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With diseases such as cancer, AIDS, and multiple sclerosis to conquer, animals will have an important part to play in medical research for the foreseeable future.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The major killers in wealthy societies (heart disease, cancer, and road accidents) are better prevented by changes in lifestyle, not through animal testing.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>There are good alternatives (e.g., computer simulations, tissue culture, and testing outside the body) that, with the right financial investment, could replace all animal tests.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Animal experiments have played an essential part in medical progress.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The use of animals for dissection in science classrooms is acceptable.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DISCUSSION QUESTIONS**

1. How do your views about animal experimentation compare with those of your colleagues?
2. Was it difficult to come to consensus within your group? Explain, using an example.
3. As a teacher, would you share your personal views? Explain.
4. Describe three challenges or barriers that you foresee when including values in your science class.

Level four is the real challenge. The final level—action—can take many forms: for example, lobbying local governments, conducting surveys, promoting environmental awareness through a blog or newsletter, caring for environmentally sensitive areas, establishing nature trails, or helping the school establish more environmentally friendly energy use practices. The key to translating knowledge into action is ownership and empowerment. Students need to have a personal understanding of the issue, a feeling of investment in addressing and solving the problem, and the opportunity to take action.

community-based science projects to transform their spaces, essentially empowering them to build a socially just world. She argues that science, schooling, and society must intersect to help build a more socially just, critically informed, and sustainable society. Bencze (see, for example, Bencze & Sperling, 2012; Bencze & Carter, 2011) has developed STEPWISE (Science and Technology Education Promoting Well-being for Individuals, Society and Environment), a framework assisting teachers and students in taking informed and responsible actions to eliminate or reduce problems such as chemicals in toys, cigarettes, and plastic bottles. These approaches align well with the community-informed pedagogy discussed earlier in the book.

In summary, to achieve the action level, there must be a shift from an education with a transmission orientation (i.e., the passive transmission of knowledge, concepts, theories) to one with a transformation orientation (i.e., an emphasis on personal growth and social change in the lives of students, the community, and society at large). A transformative lens supports an action-oriented and politically informed pedagogy that promotes critical thinking, problem solving, analysis, synthesis, and evaluation. This shift inevitably raises questions about the purpose of schooling, the form we wish society to take, and what constitutes science curriculum and science education (Barrett & Pedretti, 2006). As you continue reading, think about the following questions. Should science classes advocate social reconstruction? Why or why not? Is it appropriate for teachers to politicize the science curriculum? What kinds of action, if any, should teachers encourage students to take? What role does or could science and technology play in social reconstruction?

**ACTIVITY 10.7**

**Lobbying the Community**

This activity focuses on level four of the Hodson levels discussed earlier.

Imagine that you and your students live in a community about to build a shopping centre on prized parkland. Many families use the park, and there is an abundance of flora and fauna native to the region. After extensive research and engaging in a cost-benefit analysis (see Appendix A), the class decides to oppose the mall construction (Hodson’s level three). Students have brainstormed the following ideas to get their message across to the public:

- a. Design a pamphlet for distribution to community members and local politicians.
- b. Create a two-minute commercial for television, radio, or a social media platform.
- c. Write a short article (250 words) for a community newsletter or blog.

As their teacher, design an appropriate assessment tool for one of a, b, or c. Compare the assessment tools with your peers.

**DISCUSSION QUESTIONS**

1. What were some of the challenges of designing an assessment tool for an action-oriented assignment? Could there be a common assessment tool?
2. Do you think that action should be a part of the mandate of science education? Why or why not?
3. What kinds of action, if any, should teachers encourage students to take?
4. Describe three challenges or barriers that you foresee in promoting action in your science classroom.
Nature of Science (NOS) Revisited

A message often communicated to students is that science is objective—only concerned with facts, and that the scientific method and peer review process prevent science from being affected by human values. Others argue (Harding, 1991; Hubbard, 2001) that throughout the history of western science there are examples of how emotions, biases, racism, sexism, classism, and religious doctrine have influenced developments in science and technology. Nature of science is an important part of science, technology, society, and environment education because it helps students understand how scientific knowledge is constructed, how claims are made and used to support arguments, and how science is practised. Typically, little attention is paid in schools to how scientific knowledge is generated (epistemology), how scientists decide what they believe to be true, or how science is practised. As a result, science is misrepresented as an orderly, objective, and abstract pursuit using a reliable method to find factual knowledge about the universe. However, nature of science is a field of research that provides a more realistic image of science and scientific practice. (See Chapter 2 for a more thorough overview of NOS.) As you continue reading, think about the following questions. How do scientists create knowledge? Is it important to teach students about how science works? Why or why not?

ACTIVITY 10.8

Media Literacy and NOS

Almost every day, articles having connections to science, technology, society, and/or environment are written. For example these might be articles in a local or national paper on the value of eating organic food or of flu vaccinations. Locate a newspaper or magazine article (either in print or online) with a science and society focus. Briefly describe the article and answer the following questions.

DISCUSSION QUESTIONS
1. What techniques are used to persuade the reader to take a particular position, if any?
2. What claim(s) is the author making?
3. What evidence is used to support the claims? Is this a valid use of data?
4. Is the argument compelling? Trustworthy? Why or why not?
5. What are the challenges of using media resources?

In the following activity, you will have the opportunity to engage, in a summative way, with characteristics of STSE education (stewardship, decision making, values, action, and nature of science perspectives) described in Table 10.1.

ACTIVITY 10.9

Connecting Theory and Practice: STSE Characteristics

In this activity, you will explore two science topics from an STSE perspective: space travel and agricultural chemical use. In small groups, brainstorm how the different characteristics of STSE can be included in teaching each topic and complete the table. Locate two online resources as well as textbooks to help you. Be prepared to share your results with the class. The first topic, renewable and non-renewable resources for generating electrical energy, is completed for you.

*continued on next page*
DISCUSSION QUESTIONS

1. Compare how easy or difficult it was to do this for each of the earth and space science and chemistry topics.

2. Which of the characteristics of STSE education resonated with you and why?

3. Which ones, if any, are problematic for you, and why?

4. What aspects of STSE education seem to be favored in science? What is absent? Speculate as to why this might be the case.

5. Discuss the strengths and limitations of the two websites you used.

STSE CHALLENGES AND TENSIONS

An emphasis on STSE education presents both practical challenges (e.g., lack of time, resources, and professional development opportunities) and ideological challenges (e.g., the role of action) for educators. The ideological positions and assumptions that underpin different views of science education in general and STSE education in particular are important to unpack. Working through some of the activities in this chapter, you no doubt came to a similar conclusion. In spite of the challenges, support for STSE education continues to grow. STSE education engages students; increases interest in science; makes science more accessible, meaningful, and relevant to students’ lives; connects science to social, cultural, and political contexts; and conveys a more humanistic view of the institution and practice of science. In this section, we explore challenges and tensions for teachers and students as they engage in STSE education.
There are a number of challenges that relate to STSE pedagogy and teaching. For example, because of its trans-disciplinary nature, some teachers may feel that they lack content expertise required to engage in STSE in rich and complex ways. A teacher may wonder, for example, how to integrate politics, economics, and history into a science lesson. The challenge of translating outcomes and expectations into teaching practices (i.e., pedagogical content knowledge, or PCK) that support STSE characteristics can be another tension. Finally, assessment presents a particular challenge; the pedagogy of STSE often includes teaching strategies that are inherently difficult to assess (e.g., debates, town hall meetings). Chapter 11 explores planning and pedagogy in the context of STSE education.

**Values and Student Identity**

How do teachers reconcile the coupling of science and values in their practice? How do they address personal values in the classroom while accommodating diverse cultural contexts and ways of thinking about the world? How do teachers create an environment where students feel safe to share their ideas, ask questions, and discuss issues? Students may feel vulnerable and be reluctant to participate for many reasons, including the following:

- feeling uninformed
- being shy
- being an English language learner
- feeling marginalized or excluded by louder, more self-confident students
- holding a non-dominant worldview or being a member of a non-dominant culture

There may be a social hierarchy in your classroom that your students are keenly aware of and you are not. Ideas should be judged based on their merit rather than on who voiced them. A safe and trusting environment where no one is silenced and the diversity of voices is respected is key. The following are some suggestions regarding how to accomplish this:

- Begin building relationships among students early in the year.
- Create opportunities for small-group discussion and ensure that students work with different people within the class.
- Discuss ground rules for discussion at the outset, repeating when necessary.
- Ensure that all students have a chance to speak during class discussions.
- Honour difference with respect to race, ethnicity, gender, and socio-economic class.
- Form small groups for discussion to allow more opportunities for individuals to contribute.
- Within small groups, use techniques that give each student equal time (e.g., give each student three playing cards, returning a card each time he or she speaks).
- Intervene when intolerant views toward groups or individuals are expressed.

Discussion of values and science can easily deteriorate into a “values clarification” discussion, where students believe that anything goes if you can justify it to yourself. The other extreme is indoctrination, where students are told what to believe, support, or choose (usually by the teacher). There is a delicate balance between relativism and indoctrination, which teachers must negotiate carefully.

**Teacher Positioning**

When considering the place of STSE education in science classes, the role of the teacher must be examined—in particular, how the teacher positions himself or herself with respect to controversial issues raised. Our experience as intermediate and secondary teachers is that students, consistently, want to know where the teacher stands on specific issues, and why.
Unfortunately, there is no definitive rule on the role a teacher should assume in these cases. There are differing views among educators and researchers (not surprisingly). Regardless of the choice you make, remember that, as a teacher, you have influence not only on what views are expressed (or not expressed) in class, but what views students adopt. A teacher might assume a position of neutrality, of commitment, or of balance (van Rooy, 2012). Each position is discussed below.

**Neutrality** The neutral teacher either supports all viewpoints or does not support any viewpoint. If you decide to remain neutral, it is helpful to explain to your students why you have decided to keep your opinion to yourself (to avoid influencing the discussion and allow students to explore possibilities). In reality, remaining neutral is difficult, as facial expressions and body language can convey bias. Also, students are often interested in knowing what your view is. It can also be argued that neutrality might stifle discussion and communication.

**Commitment** In this case, the teacher discloses her or his personal position at an appropriate time in the unit. A teacher’s endorsement of a particular position could imply to students that it is the best position and the one to adopt. Thus, teachers must be careful when disclosing their position. If you choose to share your opinion it is crucial that you have established an atmosphere in your classroom where students understand that you do not expect them to share your view.

**Balance** For a balanced position, the teacher ensures that all viewpoints are represented equally. This can be done either through student statements or published sources. The teacher facilitates and organizes student contributions in a systematic way, and refrains from stating personal positions. This may allow for freer discussion and critique among students and avoids the issue of indoctrination. At times, the teacher might deliberately adopt a provocative and oppositional stance, irrespective of personal viewpoint. However, teachers need to de-brief this technique and disclose to the class their purpose in playing “devil’s advocate.”

**ACTIVITY 10.10**

**Exploring Teacher Roles**

Discuss the pros and cons of each of the three positions a teacher might take. Provide concrete examples to explain your reasoning. Describe an example in which you would adopt a neutral position, a committed position, or a balanced position.

**The Politicization of the Curriculum**

Sometimes the action we take may be political in nature—for example, writing a letter to a local MP about an environmental concern relating to development in the community or becoming involved in a project to provide clean drinking water to a community overseas. Action and the politicization of science present another set of tensions. A socio-political science curriculum that promotes social justice and transformation provides a very different vision of science teaching and science education, and for some, this can be disconcerting. There are a number of considerations:

- What actions, if any, are appropriate to promote with students (e.g., letter writing, cleaning up a local ravine, picketing)?
- How might you involve parents?
- What is the school ethos? What are the school norms?
- To what extent is action supported in your curriculum, policy, and school board?
- How comfortable do you feel in promoting action with your students?
Some would argue that it is not a teacher’s job to promote action or to be political in the classroom. Others feel that students should be taught that there are different perspectives to issues, and that we should not remain impartial. Still others argue that choosing not to politicize is a political decision in itself. We argue that students need opportunities to develop skills for asserting their political positions and for taking action. However, teachers need to consider, in light of the particular school context, the needs of students and the curriculum.

A Research Perspective

Many have written about the challenges of adopting an STSE approach. In a study conducted with preservice secondary science students, Pedretti, Bencze, Hewitt, Romkey, and Jivraj (2008) were interested in determining teacher candidates’ inclinations toward teaching with an STSE orientation, and how their science teacher identity intersected with adopting STSE education. These preservice teachers watched a video case study of a Grade 10 teacher and her students working through a climate change unit. Central to the unit was a town hall debate on the Kyoto Protocol. In general, the researchers found that these preservice teachers supported STSE education (they expressed confidence and motivation) but were unlikely to engage in STSE education in their early years of teaching, as expressed in their comments below:

- My first consideration when implementing STSE would be about my expertise. I have to take an inventory of my own expertise, identify my limitations and my strengths. (p. 952)

- There's so much to cover in the curriculum, STSE would take a lot of time away from that. (p. 952)

- Other teachers are probably using a standard teaching approach and a teacher using STSE would be concerned about whether the students are going to retain the same amount of information. (p. 952)

- I was impressed with the project overall…spending all that time looking at the politics of Kyoto and she mentioned having her students read The Globe and Mail, the Post, and the Star… but should a science class spend that much time on politics? (p. 953).

In further exploring this paradox, the authors found that five problems of practice, or tensions, consistently emerged. These included issues related to control and autonomy, support and belonging, expertise and negotiating the curriculum, politicization and action, and ideological bents. Activity 10.11, below, explores the research from this article in more detail.

**ACTIVITY 10.11**

**Read and Reflect: Identity and Ideology**

Read the following article:


Answer the following questions and be prepared to share your responses.

**DISCUSSION QUESTIONS**

1. Explain the concept of “science teacher identity” and its relationship to STSE education.
2. Describe each tension and your response to it.
3. Which of these tensions (if any) are you most worried about and why?
4. What can you do to alleviate these possible problems of practice?
CONCLUDING THOUGHTS

To close this chapter, consider one of the questions raised in Chapter 1—that is, what is science education for? If we believe that science education should be about transformation and agency as well as about understanding the discipline we call science, then STSE will hold a prominent place in the science curriculum. This view represents a major shift in the way that science education, and therefore science teaching, are conceptualized. Below, key ideas related to the learning objectives provided at the beginning of the chapter are summarized.

STSE education
Science, technology, society, and environment education positions science in larger social, cultural, and political contexts. It is about equipping students to understand socio-scientific subject matter, make informed and responsible decisions, and take action. There is no single, widely accepted approach to STSE education. Rather, it is a movement with a number of different strands that began well over forty years ago.

The benefits of STSE education in science education
Studies and practice have shown that students engaged in STSE education are motivated to learn, and are empowered by and interested in what they are learning. Secondly, STSE nurtures intellectual independence, develops critical thinking skills, promotes collaboration, and prepares students to meet the challenges of the future. Thirdly, STSE education raises awareness of current issues, promotes citizenship for social good, advocates for social justice, contextualizes science, and links science to other subject areas.

Characteristics of STSE education
The characteristics of STSE education that consistently emerge are stewardship, decision making, values, action, and nature of science. These characteristics are not mutually exclusive and often work in tandem, supporting one another and the goals of the curriculum.

STSE challenges and tensions
An emphasis on STSE education presents challenges for educators that are both practical and ideological in nature. Ideological challenges include the coupling of science and values, teacher positioning, and the place of action; while practical challenges related to teaching and pedagogy include lack of time and resources, teacher confidence, and assessment concerns.

Education research related to STSE education
There is no shortage of research in the area of STSE education. We have drawn upon a few researchers in the field including Glen Aikenhead, Larry Bencze, Derek Hodson, Wolff Michael Roth, and Erminia Pedretti. We encourage you to read the work of these researchers as well as the many others who have contributed to this field over the last few decades.

BRINGING IT ALL TOGETHER: FINAL QUESTIONS

1. What is the relationship between learning and understanding science content and STSE education?
2. How does STSE education contribute to scientific literacy?

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