[The teacher] if he is indeed wise does not bid you to enter the house of his wisdom but rather leads you to the threshold of your mind.

—Khalil Gibran

I had an amazing teacher. He was inspiring regarding his hands-on-minds-on science approaches. We built a pond, used magnets, set up simple circuits.

—Madelyne, elementary school teacher

I do not recall learning anything about how to teach science...not one thing...I can remember literacy and math and general instructional methods and theory...but in terms of curriculum, nothing on science.

—Gallaway, elementary school teacher

**LEARNING OBJECTIVES**

- Describe what constitutes good or effective teaching.
- Develop a personal philosophy of teaching and learning.
- Explain the domains of teacher knowledge.
- Outline three arguments to explain the purpose of science education.
- Develop a comprehensive understanding of scientific literacy, and discuss how it is enacted in the science curriculum in your province or territory.
- Explore the relationship between science and technology, and describe the role of information and communication technologies in science education.
- Explain how informal environments can be used to teach science.
- Discuss the role of education research in teacher development.
INTRODUCTION

Welcome to the world of teaching and learning! You have chosen to embark on a wonderful profession. No two days are alike, and your journey will be rewarding, exciting, and challenging. You will be teaching and learning in various contexts; working with a range of students; collaborating with other teachers, school staff, and parents; developing curricula; and using an array of materials and resources in creative and interesting ways. Most importantly, you can make a difference in your students’ lives as you help prepare them for the future. Your interactions with students can inspire and motivate them, and instill in them a lifelong love of learning. We are inspired by Lisa Delpit’s (1995) sentiment: As teachers we have the incredible responsibility of caring for children who are not our own.

As a teacher of science you will be able to share your curiosity and sense of wonder in the natural world. The landscape of science education is varied and rich, and includes exploring new ideas, participating in science investigations, learning science content, and critically engaging with issues that cut across science and society. You will no doubt have many questions: Do I know enough science to teach it? What topics do I teach? How will I run investigations smoothly and safely? How can I use technology in my teaching practice? Will I be able to manage 30 students? These concerns are natural, and are part of your professional growth. Although there are no simple answers, this book will provide some guidance, as well as activities that will help you realize your strengths and potential for growth. We’ll also help you build a repertoire of effective strategies, tools, and pedagogical practices.

This book serves as an introduction to becoming a teacher, and in particular to teaching science. Learning to teach is a lifelong process. Throughout this chapter, we invite you to examine your ideas about science education, scientific literacy, and what it means to be a teacher. You will have the opportunity to think critically about teaching and learning and to develop skills of reflective practice. Donald Schon (1983) describes the reflective practitioner as one who is able to reflect upon and analyze his or her own teaching practice. Schon defines reflection in action as what happens during teaching (in other words, thinking on your feet and in the moment), and reflection on action as what happens when you think back on events. The reflective practitioner looks to experience, practice, and theory in building new understandings that inform the skill of teaching. It is our hope that as you begin this journey, you will become thoughtful, judicious educators who care about students and are enthusiastic about teaching science.

Finally, we offer a vision of science education that may challenge some of your assumptions about science and how it should be taught. We hope this book will inspire you to re-imagine a science education that is transformative, relevant, and reflective of a diverse student population.

WHAT MAKES A GOOD TEACHER?

ACTIVITY 1.1

Prior Knowledge and Experience

Think back to when you were an elementary or secondary school student. Recall a “good” teacher you had and explain why he or she was effective. Next, think about a “good” teacher of science you had (either a specialized teacher of science or a classroom teacher whose science lessons you enjoyed) and consider why he or she was effective. Compare your recollections with a peer.

As a class, make two lists: 1) characteristics of good teachers and 2) characteristics of good teachers of science. You might display the similarities and differences in a Venn diagram.
Chapter 1 Teaching Science: Beginning the Journey

The lists you generated in Activity 1.1 probably include the following characteristics of a good teacher:

- is prepared and organized
- plans lessons thoughtfully
- uses different instructional techniques
- is enthusiastic
- has good classroom management skills
- uses students’ ideas
- cares about students
- includes all students
- assesses fairly and in different ways
- sets clear goals

Of course, this is not an exhaustive list, and there are certainly many more traits that constitute effective teaching. You may be beginning to think about which of these traits you possess, which ones you’d like to develop, and some of the challenges you might encounter along the way.

While effective teaching is a critical component of students’ learning experiences, it is not easily defined. Rather, it is informed by a range of assumptions and therefore holds multiple definitions. Kennedy (2008) discusses teacher effectiveness and the importance of recognizing the qualities that support it. She proposes three broad categories of characteristics: 1) personal resources; 2) performance; and 3) effectiveness. A teacher’s personal resources are those qualities that she or he naturally brings to the profession. These include beliefs, attitudes, and values; personality traits; knowledge, skills, and expertise; and credentials. Performance comprises the work done by a teacher on a day-to-day basis, including practices within the classroom (e.g., sharing clear expectations with students), student learning activities (e.g., complex problem-solving tasks), and practices outside the classroom (e.g., interaction with parents and colleagues). Finally, teacher effectiveness typically relates to how well a teacher raises student achievement. Such practices might include fostering student learning, motivating students, and encouraging personal and social responsibility. Good teaching is informed by all of these qualities working together.

DISCUSSION QUESTIONS

1. What do good teachers have in common?
2. What do good teachers of science have in common?
3. What are some of the commonly listed characteristics of effective teaching?
4. How do you view yourself in relation to these characteristics, and how will they inform your teaching practice?

Getting to Know Your Students

Effective teachers are cognizant of the importance of interpersonal relations. Broadly speaking, this means treating all students with integrity. Being positive and setting high expectations is key. Get to know your students; understand their diverse (and sometimes challenging) contexts and try to help them grow. Students will come to class with their own experiences that shape their beliefs about science and about what a teacher of science
should do. Often students view science as a body of facts to memorize and a pursuit that yields definite answers from specific methods. Sometimes students may need to examine biases about science and teaching science before they can be intellectually available for a science education that is empowering and authentic.

Knowing your students is an important part of teaching, and much more will be said about meeting student needs in Chapter 5. For now, we make the point that creating a safe and trusting environment requires, in part, knowing your students, and your students knowing one another. Activity 1.2 is a simple community-building activity that encourages movement, discussion, and sharing of experiences about lives and science. Our version, for you as teacher candidates, appears below and an adaptation you can use with your elementary school students is provided in Appendix 1.A on page 20. Throughout the book, we will provide such paired activities that are ready for use in elementary science teaching.

**ACTIVITY 1.2**

**Find Someone Who...**

Distribute a copy of the table below to each person in the class. For each box, find two people in your class who match the description and record their names. Try to include as many different people as possible. Be prepared to introduce to the class two people from your list.

Find someone who...  

<table>
<thead>
<tr>
<th>Enjoys reading popular science books</th>
<th>Studied science in university</th>
<th>Enjoys the outdoors</th>
<th>Watches nature programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name: Name:</td>
<td>Name: Name:</td>
<td>Name: Name:</td>
<td>Name: Name:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Enjoys bird watching</th>
<th>Has a food garden</th>
<th>Plays an instrument</th>
<th>Speaks three languages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name: Name:</td>
<td>Name: Name:</td>
<td>Name: Name:</td>
<td>Name: Name:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Has a food allergy</th>
<th>Has participated in a local cleanup project</th>
<th>Has a composter</th>
<th>Enjoys cooking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name: Name:</td>
<td>Name: Name:</td>
<td>Name: Name:</td>
<td>Name: Name:</td>
</tr>
</tbody>
</table>

**DISCUSSION QUESTIONS**

1. What descriptions might you change? What descriptions might you add?
2. What are some of the benefits of an activity like this?

**USING THIS ACTIVITY WITH ELEMENTARY SCHOOL STUDENTS**

This activity is best used at the start of the school year. It can help you learn about your students and their experiences in science, and it encourages students get to know each other. Adapt the descriptions as needed to best suit the grade of your students. Be mindful of any students who are new to the school, and support their first few interactions as they make the transition into a new peer group.

1. Have students sit together on the carpet or gathering space in your classroom. Describe the activity and explain that by participating in the activity they will get to know each other and you.
Chapter 1 Teaching Science: Beginning the Journey

DEVELOPING A PHILOSOPHY OF TEACHING AND LEARNING

In this section we explore your ideas about teaching and learning, and help you identify a personal philosophy. It is important to understand, and sometimes to challenge, the values and beliefs that inform teaching practice. It is equally important to articulate a philosophy that underpins our actions. As mentioned, this is only the beginning of your journey. Your teaching philosophy will evolve over time and change with each new experience.

You and your fellow students likely hold a variety of expectations about teaching. Understanding the similarities and differences in these goals is important to your professional growth. In Activity 1.3, you will examine your ideas about teaching and learning through metaphors. Metaphors can provide a powerful way to think about particular concepts, and they convey meaning and advance understanding (Mulholland & Wallace, 2008). They often generate interesting discussion about how we view, for example, teaching, learning, and knowledge. As you work through Activity 1.3, you may find that there is more than one metaphor that illustrates your views. Different metaphors can suit different contexts, and these can, in turn, carry implications for practice.

ACTIVITY 1.3

Conceptions of Teaching and Learning

Part A
Individually, consider the three visual metaphors on the next page. For each, decide who or what represents the learner and the teacher, and what each is doing. Choose one that you feel best captures your views about how teaching and learning in science should occur.

Part B
Form groups of four and compare your individual responses. In your group, rank the metaphors from 1 to 3, with 1 being the metaphor that is best representative of your group’s view of teaching and learning and 3 being the least representative. Be prepared to share your group rankings with the class.

1 Thank you to Elgin Wolfe and Don Galbraith for introducing us to this activity.

continued on next page
In completing Activity 1.3, it becomes clear that there are many metaphors that describe teaching and learning. For example, the teacher can be viewed as a guide, a facilitator, or a sage on the stage. At different times in your career you will take on different roles as appropriate to the context and lesson you have planned. Students also have complex roles, with varying degrees of autonomy and participation. Throughout this book, we encourage developing good judgment as you navigate the principles of effective teaching.
Transmissive, Transactive, and Transformative Approaches to Education

Depending on how you interpreted the metaphors in Activity 1.3, you may have alluded to different educational orientations. Miller (2007) suggests the following three educational orientations: 1) transmission; 2) transaction; and 3) transformation. In the transmission model, the teacher presents knowledge and skills that are absorbed or accepted by the student. This reflects Paulo Freire’s (1970) banking model of education, in which students receive, file, and store knowledge deposits. Knowledge is viewed as a fixed entity, and is broken down into steps to be mastered by students, typically through imitation and repetition. In Activity 1.3, which metaphor(s) reflect a transmission model? The transmissive relationship between the curriculum and the student is shown in Figure 1.1.

The transaction orientation involves more interaction, and emphasizes dialogue, between student and teacher, which includes curricula. Often, students solve a problem or undertake some kind of inquiry-based learning activity. Unlike transmission, where knowledge is seen as fixed, the transaction model views knowledge as dynamic. While dialogue is emphasized, this model focuses on cognitive interactions that highlight analysis rather than on synthesizing or feeling (Miller, 2007). In Activity 1.3, which metaphor(s) reflect a transaction position? Figure 1.2 depicts the relationship between the teacher and the curriculum, and the student.

Finally, the transformation approach views the teacher, curriculum, and student as connected rather than separate entities. This position focuses on the development of the whole person rather than just on a set of learning competencies or skills. Pedagogical strategies include creative problem solving, cooperative learning, and artistic approaches that make learning both personally and socially meaningful for students (Miller, 2007). In Activity 1.3, which metaphor(s) might reflect a transformation position? Figure 1.3 illustrates the relationship between curriculum, teacher, and learner in this approach.

![Figure 1.1 The transmission orientation](source)


![Figure 1.2 The transaction orientation](source)

Domains of Teacher Knowledge

Teaching science is a demanding job with many responsibilities. It is replete with choices (e.g., about content, pedagogy, and representation); teachers are constantly making decisions, building up their repertoire of practices, and developing their craft (Wallace & Louden, 2000; 2002; 2003). Wallace and Louden (2000) remind us that knowledge about teaching develops from a gradual expanding of horizons over time and through experience, rather than through sudden leaps of insight or quick-fix answers. In this section we explore teacher knowledge in an effort to understand practice.

Many theories have been proposed about the art of teaching. One particularly useful theory comes from Lee Shulman. Published in the 1980s, Shulman’s work (1986, 1987) remains relevant to thinking about what it means to be a teacher and, in particular, a teacher of science. His theory of the complex knowledge base required for teaching identifies three domains of teacher knowledge: 1) **content knowledge**, which is knowledge of the concepts and principles of a discipline; 2) **curriculum knowledge**, which includes understanding curriculum documents, school policies, available resources, and educational structures; and 3) **pedagogical content knowledge** (PCK), which is knowledge of how to teach particular content—in other words, it blends content and pedagogy.

Imagine you are teaching the movement of objects in the solar system to a Grade 3 class. The content knowledge includes reviewing objects in the solar system and related vocabulary and concepts. Curriculum knowledge might be achieved by examining Ministry curriculum documents; print, media, and community resources; and other educational materials. Now, how do you teach this topic? What pedagogical tools should you use in order to effectively teach it? One way would be to simply lecture, or, alternatively, you could have students physically act it out using Styrofoam models and other props, or you could make use of computer simulation. Good teachers are able to draw on pedagogical content knowledge to create contextually appropriate learning experiences.

Building on Shulman’s work, Barnett and Hodson (2001) coined the term **pedagogical context knowledge** to refer to knowledge of teaching that is situated in the details of everyday classroom life. The source of this knowledge is both internal and external. It arises from teaching experiences and from interactions with parents, students, other teachers, government regulations, and policies. Barnett and Hodson argue that pedagogical context knowledge can lead to a cultural awareness that involves the following:

- a. understanding the social location of beliefs and practices
- b. acknowledging the context-dependence of what we do
- c. recognizing the existence of distinctive socio-cultural aspects of teaching

Pedagogical context knowledge enables teachers to engage in reflection, look outward for other sources of knowledge, and critique perceptions, while considering the socio-cultural landscapes that influence personal frameworks and understandings.
Chapter 1 Teaching Science: Beginning the Journey

WHAT IS SCIENCE EDUCATION FOR?

This seemingly simple question has long been the subject of debate, often creating tension in the development of curricula and policy. Many have attempted to shed light on the complexities of this central question (see for example, Aikenhead, 2006; Hodson, 1998; Roth & Calabrese Barton, 2004). Part of the complexity stems from the understanding that science education serves many purposes. For example, it aims to teach subject matter, to prepare students to enter science and technology careers, to foster economic growth, and to develop responsible, informed citizens. Sometimes these purposes are at odds with one another; one purpose may be privileged over another, depending on the context, curricula expectations, and goals for a particular lesson. It soon becomes clear, however, that a variety of goals in science education are required, partly to make science interesting and accessible to diverse student populations, and also to facilitate excellence and equity in science education (Pedretti & Little, 2008). As we plan curricula, we need to be aware of the multiple purposes of science education and able to respond to a question that students inevitably ask: Why are we doing this?

Arguments: What Is Science Education for?

Wellington (2001) provides three succinct justifications in response to the question of what science education is for: intrinsic value, citizenship, and utilitarianism.

Intrinsic Value Science is recognized as a major cultural activity, and all young people should be able to understand and celebrate its achievements. This argument seeks to demystify science while making sense of the natural world. It supports the notion of science for the sake of science, and suggests that science education is intrinsically interesting and exciting.

Citizenship Science This justification argues that an understanding of science is necessary for individuals and key decision makers in a democracy in order to participate in debate and make decisions about issues that span the realms of science and society (e.g., waste disposal, climate change, genetically modified foods, and health). Citizenship science includes understanding scientific knowledge, the nature of scientists’ work, scientific evidence, and the scientific enterprise (see Chapter 2).

Utilitarianism The utilitarianism justification for science education suggests that science can be useful. Some parts of this argument relate to individuals, others to the economy. A utilitarian argument includes developing process skills that may be of value to all (e.g., measuring, estimating, evaluating); developing attitudes such as curiosity, skepticism, and a critical disposition; preparing students for careers that include science and technology; and preparing students to become scientists.

Wellington’s justifications are compelling and they can help us understand why particular science topics are in the curriculum. In Activity 1.4, you will examine topics in the science curriculum in the context of Wellington’s justifications.

ACTIVITY 1.4

What Should Be in the Science Curriculum, and Why?

(adapted from Wellington, 2001)

Imagine you are a member of a Ministry of Education committee tasked with the job of determining which topics in a science curriculum should remain and which could be removed.

1. On your own, using the table on the next page, categorize each science topic and provide the reasoning for your selection. (Some topics may have more than one justification.) These topics have been drawn from the Manitoba K-4 science curriculum, but you might alternatively choose topics from your province or territory.

continued on next page
2. Using Wellington’s justifications, determine which of the following categories each topic should be placed in:
   U—utilitarian justification
   C—citizenship science justification
   I—intrinsic value justification
   X—it is not necessary that everyone know this; it need not be included in the science curriculum

3. In groups of four, share your responses, and try to come to consensus for each topic.
   Be prepared to share your results with the class.

### Analyzing Curriculum Topics

<table>
<thead>
<tr>
<th>Science Topic</th>
<th>Your Categorization</th>
<th>Your Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sources of drinking water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Basic parts of a tree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. The effect of forces on structures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Properties of light</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. The importance of senses in various activities, hobbies, and jobs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Uses of inclined planes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Magnets and magnetism</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Fossil formation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Characteristics of soils</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Seasonal changes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### DISCUSSION QUESTIONS

1. How difficult or easy was it to categorize each topic? Explain your answer.
2. Did any topics fall into more than one category? Which ones?
3. How difficult or easy was it to determine whether something should be removed from the curriculum?
4. What role do values play in determining what is “worthwhile” knowledge?
5. Imagine that, in light of teacher complaints about an overcrowded curriculum, two of the science topics had to be removed. Which two would you remove? Why?

### SCIENTIFIC LITERACY

Scientific literacy is often described as a way to conceptualize the purpose of science education. Scientific literacy has become increasingly significant to discussions about the purposes of science education, national and international education policy, and the development of science curricula. It captures the most admirable aspirations for students in the context of science education; in other words, we hope our students become scientifically literate through science education. Although a highly desirable goal, the phrase scientific literacy has become so commonplace that, for some, its meaning has become lost or vague.

In Activity 1.5, we ask you to consider what scientific literacy means to you.

### ACTIVITY 1.5 Exploring Scientific Literacy

Using the mind map on the next page and in groups of three, brainstorm what scientific literacy means to you. Be prepared to share your results with the class in order to generate a comprehensive mind map. You might consider using an online mapping tool (e.g., https://bubbl.us). Analyze
It is likely that the mind maps generated will include understanding scientific principles as one of the main outcomes of scientific literacy. Indeed this is central to any understanding of scientific literacy. For example, many countries have attempted to measure scientific literacy and the quality of their science education programs by measuring students’ understanding of scientific content (e.g., laws, theories, principles) through standardized testing. Such an approach is problematic for a number of reasons. Generalizations about scientific literacy levels based on comparison of test scores do not take into account the broader goals of science education, the highly contextualized nature of teaching and learning, variation in science curricula across jurisdictions, or the myriad social, cultural, political, and economic factors that affect the teaching and learning process (Pedretti & Little, 2008). We would like you to consider a scientific literacy that is more comprehensive and includes understanding key concepts in science, participating in the procedures of science, and preparing for active citizenship. Scientifically literate people are able to navigate the complexities of a world where science is infused in all aspects of life. These ideas are discussed in more detail below.

Toward a Comprehensive Vision of Scientific Literacy

More recent calls for scientific literacy offer frameworks that are comprehensive and inclusive. (See, for example, Fensham, 2002; Hodson, 1998, 2008; Jenkins, 1990; Roth & Désautels, 2002.)

Hodson’s (1998, p. 5) framework for conceptualizing scientific literacy captures three important aspects of science education:

1. Learning science: developing conceptual and theoretical knowledge
2. Doing science: engaging in, performing, and developing expertise in scientific inquiry and problem solving
3. Learning about science: developing an understanding of the nature and methods of science, an appreciation of its history and development, and an awareness of the complex interactions among science, technology, society, and environment

Hodson (2008) embeds these three elements within the notion of critical scientific literacy, which argues for a more politicized curriculum, one that will equip students to engage in responsible decision making, particularly in matters of scientific, environmental, and social consequence. Science education must have a transformative agenda—one that embodies principles of change, empowerment, and action. Furthermore, Hodson argues that educators and researchers must pay attention to obstacles experienced by students, many of them related to socio-economic status, ethnicity, and gender. In response, it is incumbent upon science educators to address inherent biases in science, and to provide authentic and culturally sensitive images of scientific practices. We need to create a learning environment that allows students to feel a sense of belonging; in other words a science for all approach, not science for a privileged few. And so we are challenged with the task of creating a more authentic and inclusive environment that is inviting to all students, while encouraging them to learn, do, and learn about science.

Others (e.g., Aikenhead 2006; Bencze & Carter, 2011; Norris & Phillips, 2002; Roth & Calabrese Barton, 2004) concur with a vision of scientific literacy that is outward and transformative. In Rethinking Scientific Literacy, Roth and Calabrese Barton (2004) argue that school science today fosters social reproduction, remains virtually unchanged, and privileges few. Little has been done to engage diverse and marginalized audiences. Students continue to opt out of science in large numbers; the discipline has become a mechanism to control and sort, rather than to empower and include. Roth and Calabrese Barton argue for what some would call a radical vision of scientific literacy that advocates for expanded agency, social justice, and social reconstruction to improve lives and build positive science identities. In summary, at the heart of our vision is a commitment to scientific literacy—in its broadest sense—as a guiding principle for science education.

Scientific Literacy in Curriculum Documents and Policies

Scientific literacy is part of curriculum documents and policy, and it has helped define science education worldwide for decades. For example, in Science for all Americans (American Association for the Advancement of Science, 1989), a scientifically literate person is described as

one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes. (p. 4)

In Canada, the Council of Ministers of Education (1997) developed what has come to be known as the Pan Canadian Framework. Its purpose was to set out a common vision and foundation statements for scientific literacy in Canada and to clearly articulate that all Canadian students, “regardless of gender or cultural background” (p. 4), have an opportunity to develop scientific literacy. Furthermore, it provided general and specific learning outcomes, along with examples to illustrate these outcomes. The Pan Canadian Framework served as a guide to assist provinces and territories in developing and reforming their science curricula.
The vision for scientific literacy in the Pan Canadian Framework (Council of Ministers of Education, 1997, p. 6) is based on four foundation statements, each delineating an important aspect of students’ scientific literacy. These statements, although presented separately, are overlapping and mutually supportive, and reflect the interconnectedness of learning.

**Foundation 1: Science, technology, society, and the environment (STSE)**
Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.

**Foundation 2: Skills**
Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

**Foundation 3: Knowledge**
Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

**Foundation 4: Attitudes**
Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.


Although the document is from 1997, it is considered critical to science education and to science education reform in Canada. Milford, Jagger, Yore, and Anderson (2010) examined the influence of the framework on the development of provincial science curricula. In general, provincial science curriculum documents followed the framework through either specific reference or by using similar design principles; namely, outlining the four foundations of STSE, skills, knowledge, and attitudes.

Provinces and territories have taken up the call for scientific literacy in varied ways. What differs is the relative emphasis that each curriculum places on these foundation statements. In Activity 1.6, you will have an opportunity to explore how scientific literacy is conceptualized in your province or territory.

**ACTIVITY 1.6**

**Working with Curriculum Documents**

**Part A: Analyzing the Front Matter or Introduction to Curriculum Documents**

Read the front matter (the introductory materials that precede actual curriculum units and outcomes or expectations) of a science curriculum document in your jurisdiction. Describe the vision of science education and scientific literacy in the document.

**DISCUSSION QUESTIONS**

1. How does the curriculum document describe scientific literacy?
2. What theoretical assumptions do you think underpin the view of science education and scientific literacy in your document?
3. Is there evidence of a commitment to critical scientific literacy as a goal? Explain, providing examples if possible.

continued on next page
Part 1 A Vision for Science Education

LITERACY AND NUMERACY

Science education inherently includes literacy and numeracy (Lemke, 1990; Yore et al., 2004). Students, for example, need to solve problems; describe their findings from science investigations in prose, numerically, or graphically; explain phenomena orally or in writing; and produce and interpret graphs. Indeed, science is a wonderful way to address literacy and numeracy skills that are promoted in policy documents.

Fundamental to scientific literacy is literacy itself. Norris and Phillips (2002) identify two distinct yet related understandings of literacy: a fundamental sense of literacy refers to reading and writing, and a derived sense of literacy refers to being knowledgeable and educated in a discipline such as science. Typically, when we speak of scientific literacy, we refer to this derived sense. However, as argued by Norris and Phillips, a derived sense of scientific literacy is dependent on possession of fundamental literacy—in this case, being able to read and write science. Noted by Yore, Bisanz, and Hand (2003), language is a critical component of science and scientific literacy, for it is

a means to doing science and to constructing science understandings [and] also an end in that it is used to communicate about inquiries, procedures, and science understandings to other people so that they can make informed decisions and take informed action.

(p. 691)

As a teacher, particularly of elementary school students, recognizing and supporting the development of both fundamental and derived senses of literacy is key. Curriculum and instruction that support reading and writing permeate all subject areas.

The importance of language in science is also evident in mathematics. Numeracy is critical in informed citizenry and is similarly important in science education. Many mathematical skills, such as basic computations, measurement, spatial sense, patterning, graphing, and data management, are foundational to science topics (see Bowen & Roth, 2005; Frykolm & Glasson, 2005; Roth & Bowen, 2001a). For example, it is difficult to be successful in many topics of physical science without the ability to perform basic number operations, measure mass, and calculate area and volume. Specific math skills may need to be explicitly taught or reviewed in the context of your science program.

Throughout this book, we recognize the importance of literacy and numeracy across the elementary curriculum and specifically highlight activities that support them. We suggest activities that cross disciplinary boundaries and provide opportunities to meaningfully bring other components of education into your science teaching. We revisit literacy and numeracy in more detail in Chapter 5, with a focus on the language and mathematics of science and the challenges they can present to learners. Take time to investigate children’s literature online and in your local library or school board.

Part B: Analyzing a topic or unit in the curriculum document

Choose a topic or unit from a science curriculum document in your jurisdiction. Read what you are expected to teach. Analyze how the terms of the foundational statements (STSE, skills, knowledge, attitudes) are represented. For example, in Ontario, skills are referred to under the heading “Developing Skills of Investigation and Communication”; in Alberta, STSE is combined with knowledge outcomes; and in some provinces the statements remain unchanged.

DISCUSSION QUESTIONS

1. How do your documents describe the foundation statements?
2. Are some foundations emphasized more than others? Speculate as to why this might be the case.
Chapter 1 Teaching Science: Beginning the Journey

THE ROLE OF TECHNOLOGY IN TEACHING SCIENCE

In the following section we consider the relationship between science and technology and the role of information and communication technologies (ICT) in the teaching and learning of science. (These topics are revisited and analyzed throughout the text.) The relationship between science and technology is complex and fluid, and the boundaries between the two have become increasingly blurred.

Exploring the Relationship Between Science and Technology

Conventionally, science is thought to be about the pursuit of knowledge that is often abstract and decontextualized, while technology is viewed as the application of knowledge in more contextualized ways. We are reminded of Ursula Franklin’s (1999, p. viii) whimsical definition of technology as “practice—as the way things are done around here.”

Many view science as the attempt to understand natural phenomena and to organize these understandings into ordered systems; technology involves applying ideas to design tools that affect quality of life. Bencze (2001) describes their respective goals. The scientific intent, he states, has traditionally been to document, explain, and predict natural phenomena (e.g., species growth and propagation), while the technological intent is to change objects and events in ways considered desirable (e.g., “stopping” invasive species). The argument that there are differences between science and technology with respect to contextualization is also helpful. At one extreme, some science can be conducted in an idealized context (e.g., studying the Higgs Boson or God particle), while technology is often more contextualized and takes into account a number of variables (e.g., designing hybrid cars). Innovation and design are hallmarks of technological pursuits; in elementary science, this is often referred to as design and technology (further explored in Chapter 8).

While science and technology can be viewed as separate enterprises, they are often practised together and are deeply interconnected. Each discipline informs the other, propelling it forward. As Bencze (2001) explains, both are theory-driven (that is, both make use of conceptual structures and knowledge); both make use of similar processes; both rely on some form of rigorous debate; and both inform one another. Indeed, science and technology have become so intertwined that numerous hybrid fields have emerged, such as biotechnology, genetic engineering, and robotics. Science and technology impact human relationships, work, community, citizenship, and the notion of collective social responsibility (Franklin, 1999). As future teachers of science, we encourage you to adopt a critical stance about the purposes of science and technology.

ACTIVITY 1.7

Teaching Science, Literacy, and Numeracy Through Children’s Literature

Imagine you are teaching a Grade 1 or 2 class. Locate Graeme Base’s book The Waterhole, a wonderful story that weaves together reading and counting with ecology. With a partner, read the book and brainstorm how you might use it in a cross-curricular lesson that launches a unit on ecology. Include in your lesson both a literacy component and a numeracy component. Consider the different types of literacy you could include as well as a range of numeracy applications. In a chart, table, or other graphic format, outline what your goals are for the activity, what your students would be doing, and how literacy and numeracy are integrated into the lesson. Locate other examples of children’s literature to support your theme. Share your ideas on your class wiki or another online learning environment.
Information and Communication Technologies (ICT) and Teaching Science

Information and communications technology (ICT) provides a range of tools that can enrich teachers’ instructional strategies and support students’ learning in science (Shanahan, 2011). Hewitt (2005) describes three compelling reasons for using ICT: a) concretizing abstract concepts; b) providing students with tools for conducting and analyzing scientific processes; and c) supporting connections between people as they learn. To this list we add using technology to enhance lesson delivery and assessment practices and to provide tools that can support student needs.

The use of ICT to concretize abstract concepts is particularly important to help science students visualize abstract ideas. Imagine you are teaching about forces in natural hazards, the properties of air, or tidal patterns. These concepts can be difficult to visualize or even observe firsthand. Tools to assist student learning might include simulations (e.g., Starry Night to investigate astronomical principles), virtual manipulatives (e.g., Géomètrie), application software, CD-ROMS, and DVDs. Other technologies play a more significant role in conducting inquiry and research. For example, probes and sensors are helpful for data collection, storage, and analyses. Through online and CD-ROM technology, students can access primary sources held in libraries and other public institutions for research purposes.

ICT can be used in creative ways to connect students and provide access to the global community—for example, through virtual learning environments such as Moodle and Blackboard, and through social media technologies like wikis, Facebook, and Twitter. There is also a range of web-based collaborative tools that allow students to participate in online discussion forums, peer reviews, and debates. In this way, students can learn from one another and engage in scientific inquiry (Shanahan, 2010; Slotta & Linn, 2009). While powerful, virtual learning environments and social media technologies provide a level of anonymity that can be problematic. We urge you to adopt a critical stance with regard to their appropriateness and to consider carefully how to prepare students for their use in order to avoid exclusion, alienation, or bullying.

Teaching and learning can be further supported by presentation software (e.g., PowerPoint, Keynote) and technologies such as interactive whiteboards (e.g., SMART Boards), which operate on the principle of touch detection and allow for dynamic, collaborative lessons. Many schools are equipped with interactive whiteboards. Another interactive technology is the clicker, a personal response device that resembles a remote control and can be registered to a specific student in order that he or she can participate in class discussions. In response to questions set by the teacher, each student registers her or his opinion or answer anonymously. Class responses are tabulated immediately and can be seen by the whole class via a projector or monitor. This technology can provide formative and summative assessment and provide direction for further discussion.

Technology is ubiquitous in our homes, places of work, and schools. Advocates of technology-rich classrooms argue that ICT has the potential to transform teaching and learning. We agree that technology can be a powerful learning tool; however, as Hewitt suggests, we need to move beyond broad generalizations and “move towards developing a deeper sense of the kinds of situations in which technology is best used” (2005, p. 161). In other words, the teacher needs to consider if, how, when, and why technology is appropriate for the particular goals he or she has set. Context is important, as is the premise that ICT is best used alongside classroom practices that effectively support learning.

Science, Technology, and the Curriculum

How then, do science and technology play out in curricula? Most provinces and territories have dedicated science courses and dedicated technology courses at the secondary level. In British Columbia, students can study industrial design and electronics, for example, in
addition to the usual selection of science courses. Similarly, Quebec offers science education in the traditional domains as well as in manual and technical courses. However, provincial elementary curricula tell a different story. Ontario explicitly combines science and technology at the K–3 and 4–6 levels in the Grades 1-8 Science and Technology Curriculum (Ministry of Education, 2007). Elementary science is similarly combined with technology in Quebec. Unlike in Ontario and Quebec, though, the British Columbia elementary curriculum focuses on science alone; it is not explicitly combined with technology. This is also the case in other western provinces and in Atlantic Canada. That said, all curricula make use of ICT.

The boundaries between science and technology are not distinct; rather, they are interconnected and impact one other. It is important to understand how science and technologies are addressed in your province or territory. We invite you to consider the relationship of technology, in all its manifestations, to teaching and learning science today, and how you can help prepare students to understand and critique the role of technology in the new millennium.

ACTIVITY 1.8

Using Technology to Support Learning

As a class, create a virtual learning environment to post responses to discussion questions and to share resources throughout the year. For example, you might collaborate on a class wiki or blog.

SCIENCE BEYOND THE CLASSROOM

Whether through school trips to science centres and museums, media, or engagement in recreational activities (e.g., hiking and camping), we are always learning. It is widely recognized that science learning occurs in both school and non-school settings and throughout our lives.

The learning that occurs beyond schools is often referred to as informal learning, and can occur in museums, science centres, aquaria, botanical gardens, and zoos (Davidson, Passmore, & Anderson, 2009; Falk & Dierking, 2001; Jagger, Dubek, & Pedretti, 2012; Pedretti, 2012; Stocklmayer, Rennie, & Gilbert, 2010). These are typical destinations for school field trips, which are organized on the premise that they complement the curriculum and support learning in meaningful ways. Furthermore, such sites can create a holistic, inclusive approach to curricula and provide experiences that students may otherwise never have. Millions of other visitors also flock to these places, for both entertainment and education purposes. As you consider informal learning venues, be sensitive to the beliefs, values, and emotions of your students and their families. Some venues may be viewed as controversial and can be potentially upsetting (e.g., zoos, issues-based exhibitions). Be sure to maintain open conversation with parents and guardians when considering these types of learning experiences.

Media provide another source of science learning beyond the classroom (e.g., television, popular science books, and magazines). Television programs increasingly portray a variety of scientists and forensic specialists at work. Virtual worlds are increasingly available and accessible through information and communication technologies (Braund & Reiss, 2006). Community organizations, after-school programs, and local areas such as parks and ravines can provide yet another place to explore science beyond the classroom.

Research suggests that informal learning can enhance attitudes toward science and foster interest and enthusiasm (Falk & Dierking, 2001; Hodson, 1998). Learning opportunities outside the classroom can be a powerful experience for students, teachers, and the community. For example, Mayer-Smith, Bartosh, and Peterat’s (2007) Intergenerational Landed Learning Project brought together students, elders, and teachers on an urban farm to explore how farming practices can be integrated with curricula to promote environmental

Watch
Physics at an Amusement Park
knowing, and an ethic of care and responsibility. Calabrese Barton (2003) describes the positive effects of after-school programs for marginalized youth. There are many other examples. We urge you to consider the role of informal learning as you plan your curriculum, and to make use of the rich resources available beyond the walls of the classroom.

SCIENCE EDUCATION RESEARCH

A vast research literature base exists to provide science educators with empirical and theoretical perspectives to inform practice. We encourage you to delve into the science education research literature. Well known academic journals include Science Education; Journal of Research in Science Teaching; Canadian Journal of Science, Mathematics, and Technology Education; School Science Review; Science and Education; International Journal of Science Education; Cultural Studies in Science Education; and School Science and Mathematics. Activity 1.9 asks you to read some peer-reviewed articles. Another resource is professional organizations, which produce journals such as Science and Children, Science Scope, the Science Teacher, the American Biology Teacher, and Interactions. One of our goals throughout the book is to engage you in the research literature in an effort to connect practice and theory. Reading journals and publications will become an important part of your professional learning journey.

ACTIVITY 1.9

Read and Reflect: Learning About Science Education Research

Choose one of the three articles listed below from your university library or Google Scholar. Read the article, and answer the questions that follow. Be prepared to share your responses in small groups of your peers who have read the same article.

1. Does this article help you become a better teacher? If so, how?
2. What are the implications for students? For the classroom?
3. What ideas in the paper challenged you? Surprised you?


CONTEMPORARY ISSUES IN SCIENCE EDUCATION

Periodically throughout the book we will raise issues pertaining to science education, such as constructivism as a theory of learning, the use of computer simulations in place of hands-on work, and the role of informal learning in science curricula. There is no end to the issues faced by contemporary science educators. In this chapter, we present a few concerns related to science literacy and to conflicting views of the aims of science education. In the spirit of critical thinking, get together with your classmates and discuss the following issues.

Standardized Testing

In groups of four, research the structure and use of standardized tests such as the Trends in Mathematics and Science Studies (TIMSS) and the Programme for International Student...
Assessment (PISA). Find the most recent published reports for either TIMSS or PISA. How does Canada perform in relation to other countries?

1. What is your position on standardized testing (consider cost, purpose, etc.)?
2. What are the implications of standardized testing for teaching at the elementary level?
3. What are the implications of standardized testing with respect to scientific literacy?
4. What are the implications of standardized testing for students?

Conflicting Visions of Science Education

In groups of four, share your vision of an ideal science program. Now imagine you are part of a staff that has a different vision for the science program.

1. How do you work with others who have different views?
2. Is there a view of science education that is better for students? Explain.

Science Specialists in Elementary Schools

Many elementary schools have music and language specialists. Should elementary schools also have science specialists? In groups of four, discuss the pros and cons of having science specialists in elementary schools.

1. What are the benefits of having specialist teachers of science in elementary schools?
2. What are the drawbacks?
3. What are the implications of science specialists at the elementary level for teacher education programs?

CONCLUDING THOUGHTS

Teaching is a complex enterprise. No two students are alike; no two teachers or communities are alike. While teaching occurs within a rich myriad of variables that challenge us and require constant sensitivities, it is also the diverse nature of students and communities from which we draw strength and inspiration. What follows is a summary of the key ideas related to the learning objectives provided at the beginning of the chapter.

Good or effective teaching

Although no two teaching situations are alike, there is consistency in what constitutes good or effective teaching. A good teacher is someone who is prepared, plans lessons thoughtfully, uses different instructional techniques, is enthusiastic, has good classroom management skills, uses students’ ideas, cares about students, assesses students regularly and in different ways, knows his or her science, and sets clear goals. The reflective practitioner looks to experience, theory, and practice in an attempt to build new understandings of teaching and to inform and improve their pedagogy.

Philosophy of teaching and learning

It is important to develop a philosophy of teaching and learning that can be articulated and can guide practice.

Particular views—for example, about the roles of teacher and student—carry implications for curriculum planning, implementation, and assessment.

Domains of teacher knowledge

Shulman’s (1986, 1987) theory of the complex knowledge base that is required for teaching identified domains of teacher knowledge as content knowledge, pedagogical content knowledge (PCK), and curriculum knowledge. Barnett and Hodson (2001) introduced the idea of pedagogical context knowledge.

Arguments to explain the purpose of science education

The question, “What is science education for?” has been the subject of debate for decades. Wellington (2001) provides three justifications in response to this question: He describes science education as having intrinsic value, promoting citizenship science, and having utilitarian functions.

Scientific literacy

Scientific literacy has become increasingly significant to discussions about the purposes of school science education, guiding national and international education policy.
Part 1 A Vision for Science Education

We advocate a framework for scientific literacy that is comprehensive and inclusive, and includes learning science and doing science (Hodson, 1998). Central to this formulation are the guiding principles of transformation and social justice.

Science and technology, and the role of information and communication technologies in science education

Science is thought to be about the pursuit of knowledge that is often abstract and decontextualized, while technology is viewed as the application of knowledge in more contextualized ways. However, they are often practised together and are deeply interconnected. Information and communications technology (ICT) provides tools that can enrich teachers’ instructional strategies and support students’ learning through concretizing abstract concepts, providing students with tools for conducting and analyzing scientific processes, and supporting connections among people as they learn. It is important to adopt a critical stance with regard to appropriateness of ICT.

The role of informal environments to teach science

Science learning occurs in both school and non-school settings and throughout our lives. The learning that occurs beyond schools is often referred to as informal learning, and can take place in museums, science centres, aquaria, botanical gardens, and zoos. Other informal learning environments include media, the internet, community organizations, after-school programs, and local parks. Research suggests that informal learning can enhance attitudes toward science and foster enthusiasm.

Education research

The field of education has a large research literature that can provide educators with empirical and theoretical perspectives to inform practice. It is important to be familiar with the academic and professional journals in the field.

BRINGING IT ALL TOGETHER: FINAL QUESTIONS

1. Describe your personal philosophy of teaching and learning.
2. What makes a teacher different from a caring and knowledgeable adult?

APPENDIX 1.A
Find a Classmate Who...

<table>
<thead>
<tr>
<th>Likes to read books about science</th>
<th>Has a pet</th>
<th>Likes to explore the outdoors</th>
<th>Likes to watch programs about science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name: Name:</td>
<td>Name: Name:</td>
<td>Name: Name:</td>
<td>Name: Name:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Likes bird watching</th>
<th>Likes cooking</th>
<th>Can play a musical instrument</th>
<th>Can speak more than two languages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name: Name:</td>
<td>Name: Name:</td>
<td>Name: Name:</td>
<td>Name: Name:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Has an allergy</th>
<th>Recycles at home and in the community</th>
<th>Has a brother or sister</th>
<th>Has been to a museum or science centre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name: Name:</td>
<td>Name: Name:</td>
<td>Name: Name:</td>
<td>Name: Name:</td>
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