Christine D. Tippett · Todd M. Milford
Editors

Science Education in Canada

Consistencies, Commonalities, and Distinctions

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ISBN 978-3-030-06190-6 ISBN 978-3-030-06191-3 (eBook)
https://doi.org/10.1007/978-3-030-06191-3

This Springer imprint is published by the registered company Springer Nature Switzerland AG.
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Acknowledgements

This publication would not have been possible without the contributions of a large number of people.

More than 30 science educators from across Canada agreed to write to our specifications and patiently responded to our numerous requests for revisions. An equal number of reviewers provided valuable feedback that was used to craft high-quality and informative chapters.

Joël Rivard (GIS and Geography Librarian, University of Ottawa) and Catherine Millar (Data Analysis Coordinator, Parent Resource Centre) created the large maps for us. The small maps were made at https://www.gasfoodnolodging.com/visited-states/us-canada/.

Hélène Roulston provided French translation services, and Gavin Nesbitt from Pirurvik Centre (ᐱᕈᕐᕕᒃ) in Iqaluit, Nunavut, provided Inuktitut translations.

Bernadette Ohmer and Claudia Acuna at Springer were unfaltering in their support, from discussion of our initial idea through to publication.

The University of Ottawa partially funded copyediting and translating.

Shari Yore provided stellar copyediting; without her efforts, this book would not be as coherent, clear, or concise as it is. Her skillset is unparalleled and she was always only an email away.

Larry Yore supported us through all phases of the project and was always willing to talk with us via email, phone, or Skype. His mentorship was instrumental in our endeavours, and this book would not have been completed without him.

Chris and Todd

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Chapter 1
Introduction: Setting the Scene for a Meso-level Analysis of Canadian Science Education

Todd M. Milford and Christine D. Tippett

Abstract Canada is a country with an international reputation for strong science achievement; as such, it can offer insight into effective policies, structures, and pedagogies. However, there is scant literature on science education in Canada in general; and the specific aspects of science curriculum and science teacher education—both preservice and inservice—are even more limited. Some publications have addressed science teacher education in Canada, but much of this literature has been on a macro level, where a Canadian example is situated within an international context offering a systems perspective in comparison with other systems (Dopfer, Foster, & Potts 2004). There is a small though growing body of *micro*-level science education literature that consists of highly contextualized cases, where individual studies describe specific components of the system. This book provides a *meso*-level description and analysis of demographics, science education, and science teacher education across all 13 jurisdictions within Canada. The author teams provide informed insights that serve as a basis for examining the provincial and territorial systems so as to explore the diverse Canadian system as a whole. In this chapter, we include a geographical, historical, and cultural background; the general structure of education and science education across the country; an overview of teacher education and science teacher education programs; and professional development as advance organizers for making sense of the next 13 chapters.

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C. D. Tippett, T. M. Milford (eds.), *Science Education in Canada*,
https://doi.org/10.1007/978-3-030-06191-3_1

1.1 Introduction

Canada is a country with an international reputation for strong science achievement; as such, it can offer insight into effective policies, structures, and pedagogies. However, there is scant literature on science education in Canada in general; and the specific aspects of science curriculum and science teacher education—both preservice and inservice—are even more limited. Some publications have addressed science teacher education in Canada, but much of this literature has been on a macro level, where a Canadian example is situated within an international context offering a systems perspective in comparison with other systems (Dopfer, Foster, & Potts, 2004). There is a small though growing body of *micro*-level science education literature that consists of highly contextualized cases, where individual studies describe specific components of the system. This book provides a *meso*-level description and analysis of demographics, science education, and science teacher education across all 13 jurisdictions within Canada. The author teams provide informed insights that serve as a basis for examining the provincial and territorial systems so as to explore the diverse Canadian system as a whole. In this chapter, we include a geographical, historical, and cultural background; the general structure of education and science education across the country; an overview of teacher education and science teacher education programs; and professional development as advance organizers for making sense of the next 13 chapters.

1.2 Why This Book?

Across the six rounds of the Programme for International Student Assessment (PISA), Canadian students have consistently scored well in science, ranking 10th or higher out of 41–75 participating nations (the number of participants has grown steadily since the first iteration in 2000), with the exception of a rank of 11th in 2003. Most high-performing nations, such as Singapore, Finland, and Japan, are relatively small in geographic area with high population densities, comparatively homogenous populations, and centralized education systems. In contrast, Canada is one of the few high-performing nations that has a low population density (due to its expansive geographic area) and a heterogeneous population (due to its high immigration rate). Additionally, Canada is the only top-performing nation that does not have a national department or ministry of education (Tippett & Milford, 2017). So what is it about Canada's science education system that leads to such strong performance in international assessments?

If we consider science education in Canada to be a complex system with multiple interacting components, we can apply a micro-meso-macro analytical framework (Dopfer et al., 2004; Li, 2012) to the available literature in an effort to identify factors that might contribute to strong science performance. Unfortunately, there is a limited body of literature on science education in Canada, and most of this literature is at a micro level of analysis. Examples of micro-level research include highly contextualized studies like an examination of one Grade 11 physics teacher's use of problem-based learning (Watson, 2016) or a 10-month exploration of the professional learning of two Grade 4 science teachers in Newfoundland and Labrador (Goodnough & Murphy, 2017).

There is some literature at a macro level of analysis that offers a systems perspective in comparison with other systems (Dopfer et al., 2004). For example, science teacher education in Canada has been discussed in comparison with the United States (Olson, Tippett, Milford, Ohana, & Clough, 2015) and across a range of other countries (Milford & Tippett, 2016; Tippett & Milford, 2017). International large-scale standardized assessments such as PISA can also be considered macro-level analyses (Organisation for Economic Co-operation and Development [OECD], 2016).

Meso-level analyses (Dopfer et al., 2004), which view the system—in this case, Canadian science education—as a whole, are limited. This level of analysis is needed to provide a reference point for macro-level analyses and to enable the synthesis of micro-level analyses. Examples of meso-level analyses include historical overviews of Canadian science education policies, practices, and achievements (Connelly, Crocker, & Kass, 1985, 1989), an argument for the articulation of uniquely Canadian science education (Murray, 2015), and publications from the Council of Ministers of Education, Canada (CMEC) reporting jurisdictional results of national (e.g., O'Grady & Houme, 2014) and international assessments (e.g., O'Grady, Deussing, Scerbina, Fung, & Muhe, 2016). The applicability of the results of macro- and micro-level studies is hampered by the lack of current meso-level information on Canadian science education: theoretical, descriptive, or empirical. A meso-level perspective would contextualize macro and micro perspectives, provide a foundation for future research, and expand the body of literature, thereby allowing connections to be made within Canada (metasyntheses) and between Canada and other nations.

The need for meso-level information, for both Canadian and international readers, was the impetus for this book, which provides an in-depth analysis of science education in each of Canada's 13 provinces or territories. This book develops an insider perspective, with chapters written by science education professionals working in each jurisdiction. We asked authors to focus on geographical and cultural background, structure of science education curriculum, science teacher education and certification, professional development opportunities for teachers of science, and issues specific to their jurisdiction. The remainder of this chapter provides a brief context for these areas.

1.2.1 Canada's Geographical, Historical, and Cultural Contexts

Canada is a vast nation (Fig. 1.1), second only to Russia in terms of area, spanning from the Pacific Ocean in the west to the Atlantic Ocean in the east and from the Arctic Ocean in the north to its border with the United States in the south. Its

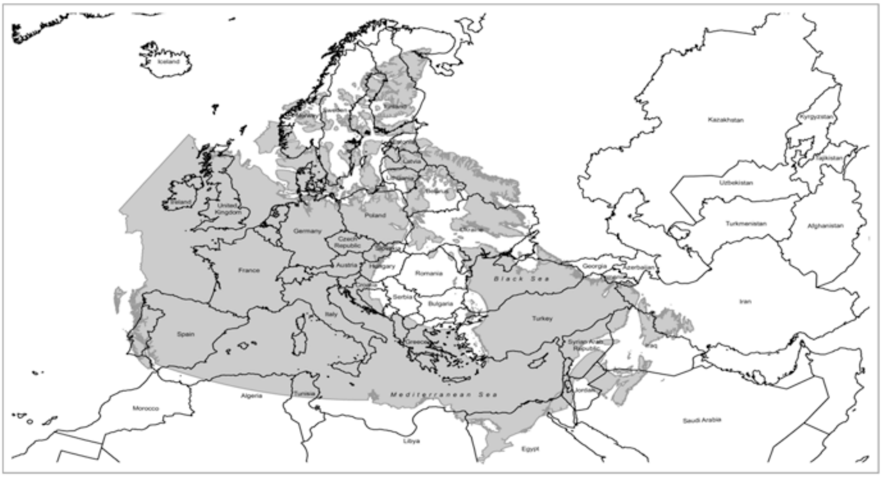

Fig. 1.1 Canada compared to Europe—to scale

10 provinces (west to east: British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador) and three territories (west to east: Yukon, Northwest Territories, and Nunavut) comprise approximately 10 million square kilometres. However, the country is sparsely populated (international rank of 37th) with just under 37 million people and a population density of 3.9 people/km^2 in 2017 (Statistics Canada, 2017d). Canada's reported population growth rate of 1.0%—mostly due to immigration—is the highest of all G7 countries; outside of the G7, Australia, Mexico, India, Indonesia, Saudi Arabia, South Africa, and Turkey had rates higher than Canada (Statistics Canada, 2017d).

Canada is a relatively young nation; in 2017, it recognized the 150th anniversary of its confederation. The French established the first settler colony of New France in the early 1600s, although Indigenous peoples had already inhabited North America for centuries. The British took control of New France in 1763, renaming it the Province of Québec. In 1791, Québec was divided into Upper Canada (the precursor to modern-day Ontario) and Lower Canada (the precursor to modern-day Québec) that in 1840 were reunited to form the Province of Canada. In 1867, the Dominion of Canada was formed through the confederation of two British colonies, New Brunswick and Nova Scotia, with the Province of Canada. At the same time, the Province of Canada was divided into the two provinces of Québec and Ontario to maintain linguistic cohesiveness, with French and English gaining official recognition. The Dominion of Canada continued to expand until 1949 when the province of Newfoundland and Labrador entered Confederation; in 1999, the Northwest Territories became the two separate territories of Nunavut and the Northwest Territories.

1.2.2 Ethnic Diversity in Canada

Canada is a diverse nation, with a large Indigenous population and one of the highest per-capita immigration rates in the world. Almost 2.1 million people indicated an Indigenous ancestry in response to the 2016 Census (Statistics Canada, 2017b). Over 20% of the population was born outside of the country (Statistics Canada, 2017c), which was the highest proportion of all G7 countries (OECD, 2017). More than 60% of recent immigrants reside in one of Canada's three largest population centres of Toronto, Montréal, and Vancouver (Statistics Canada, 2013). Over 200 ethnic origins and 200 languages were reported in the 2016 census (Statistics Canada, 2017e). At least 1 million people reported the following ethnic origins: English, Scottish, French, Irish, German, Indigenous, Chinese, Italian, East Indian, Ukrainian, Dutch, and Polish (Statistics Canada, 2017b). Additionally, in excess of 7 million people spoke a language other than French or English at home (Statistics Canada, 2017a). Some urban school districts have reported more than 75 different languages or dialects spoken by students at home (Labrecque, Chuy, Brochu, & Houme, 2012).

1.2.3 Indigenous Peoples of Canada

The history of relations between Indigenous and settler peoples in Canada has been and continues to be complicated. Central issues include treaties and land claims, self-governance, linguistic Indigenous language revitalization, and education. Treaties are negotiated relationships between Indigenous peoples and Canada's federal government; there are 70 treaties with 364 out of 617 First Nations, representing over 600,000 people (Indigenous and Northern Affairs Canada [INAC], 2013). Land claims arise from the "unfinished business of treaty-making" (INAC, 2015a, para. 1), and there are two types of land claims: one associated with treaties (specific) and the other associated with land not covered by treaties (comprehensive). Self-government agreements that are based on specific historical, cultural, and political contexts contain provisions for Indigenous communities to "govern their internal affairs and assume greater responsibility and control over the decision making" (INAC, 2014b, para. 1). There are currently 22 self-government agreements across Canada involving 36 Indigenous communities and more than 400,000 people (INAC, 2014a, 2015b). Language is inextricably linked to culture and is the embodiment of a people's identity (First Peoples Cultural Council, 2014); several studies suggest that Indigenous languages in Canada are endangered (Cardwell, 2010).

In the 19th and 20th centuries, many Indigenous children were removed from their families, placed in residential schools, and no longer allowed to communicate in their own language. While purported to be centres of education, residential schools were, in many cases, centres of religious and cultural indoctrination. Efforts to address these years of injustice include *Honouring the Truth*, *Reconciling for the*

Future, the final report of the Truth and Reconciliation Commission of Canada (2015), and the *Accord on Indigenous Education* (Association of Canadian Deans of Education, 2010). Both documents position education as an avenue for change.

1.3 Canada's Education System

Governmental responsibilities within Canada are typically separated into federal and provincial portfolios. At the federal level, portfolios include areas such as fisheries, Indigenous affairs, and national defence; at the provincial level, portfolios include areas such as property, health, and, most relevant for this book, education (Beaudoin & Panneton, 2006/2015). Originally, territorial portfolios were under the oversight of the federal government. Since the 1970s, however, territories have been moving toward independence and autonomy, with each territory currently having varying levels of authority within different portfolios, including education. Education at the elementary, secondary, and postsecondary levels is overseen by provincial or territorial ministries or departments, resulting in 13 distinct although similar systems influenced by local geographical and cultural contexts. However, the Council of Ministers of Education, Canada (n.d.) serves as a national forum in which policies related to early childhood through postsecondary education can be discussed.

Each province or territory is generally subdivided into school districts that encompass one or more schools serving K–12 students (ages 5 to 17 years). The actual grade configurations for schools vary across and within districts and provincial/territorial jurisdictions; common configurations include elementary schools (K–5, K–6, K–7, or K–8), middle schools (Grades 6–8, 7–8, or 6–9), and secondary or high schools (Grades 7–12, 8–12, 9–12, or 10–12). The school year is typically between 180 and 200 days long and runs from September through June. Secondary schools might follow a semester system of two or three semesters during the school year. In order to graduate, students must complete a certain number of required and elective courses as determined by each province or territory.

Historically, formal education in Canada was provided by missionaries, beginning with the Jesuits in the 1600s. The continuing influence of religion is apparent in the existence of separate denominational schools and in some cases separate districts; in some provinces, denominational schools are publically funded. Across the country, education is available in French or English; it is mandated from Grades 1–10 (ages 6 to 15 years) but is usually offered from K–12 (ages 5 to 17 years) and approximately 93% of students attend publically funded schools (CMEC, 2012). Canada's upper secondary school graduation rate was 86% in 2014 (Statistics Canada, 2016).

1.3.1 Science Education in Canada

In every jurisdiction, science is a required subject beginning in Kindergarten or Grade 1 and continuing to Grade 10, with curriculum outlined in mandated documents. While these documents vary across jurisdictions, there are some similarities. For example, most students in Canada study *rocks and minerals* in Grade 4 and *chemical reactions* in Grade 10. These similarities are due to the influence of the *Common Framework for Science Outcomes K to 12* (CMEC, 1997), commonly referred to as the *Pan-Canadian Framework*. This document is the result of a collaborative CMEC initiative in the late 1990s that involved government officials, science consultants, and teachers; it described foundations for scientific literacy and listed suggested learning outcomes that were developed after examination of learning outcomes from every jurisdiction except the Yukon. The *Common Framework* influenced the subsequent development of curriculum documents across the country; however, there are points of divergence as jurisdictions interpreted the outcomes in their own manner and subsequent curriculum revisions further added to the variety.

1.3.2 Teacher Education, Certification, and Professional Development in Canada

Across the country, teachers are generally required to hold a bachelor's degree in education (BEd) and a teaching certificate. However, the lack of a national regulatory body impacts how teacher education and teacher certification are structured. Each province has the authority to develop and maintain postsecondary programs; as a consequence, at the 66 provincial institutions currently offering teacher education programs (Fig. 1.2), there are at least 450 different programs (Olson et al., 2015).

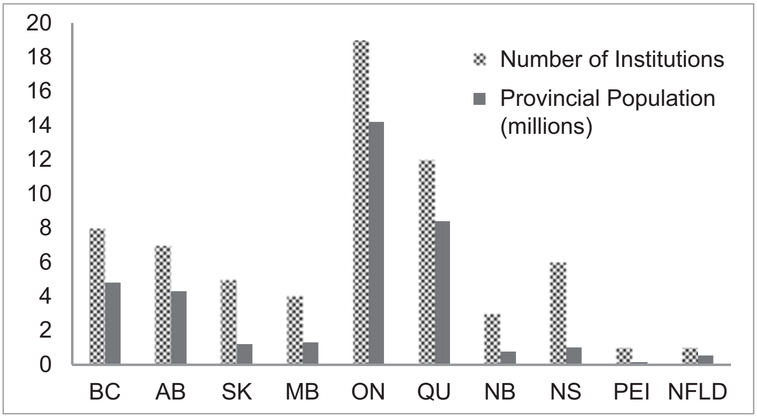

Fig. 1.2 Numbers of institutions offering teacher education programs in each province. As can be seen, these numbers reflect the populations of each jurisdiction

Each territory has a single postsecondary institution that offers teacher education courses and is affiliated with a particular provincial institution for the completion of a BEd. There are three main pathways to obtaining a BEd:

- *Direct*, a 4- or 5-year program undertaken after high school
- *Consecutive* (sometimes referred to as *post-degree*), an 8–20 month program undertaken after completion of a university degree
- *Concurrent*, a 5-year program undertaken after high school that leads to a combined degree such as a BEd/Bachelor of Science (Olson et al., 2015)

The direct pathway is the least common, the consecutive pathway is the most common, and the concurrent pathway is typical in Québec but less usual in other parts of the country (Crocker & Dibbon, 2008). Universities typically have three semesters: September–December, January–April, and various configurations throughout May–August.

In most cases, elementary teachers are generalists, teaching all subject areas, and complete only one science methods course during their teacher education program. Secondary teachers are specialists and are usually required to declare academic teaching areas that are most commonly known as *teachables*. Most secondary science teachers complete at least two science methods courses during their teacher education program. Teachers are certified to teach K–12 in eight jurisdictions, K–6 or 7–12 in two jurisdictions, K–6 or 7–11 in one jurisdiction, preK–12 in one jurisdiction, and K–6, 4–10, or 7–12 in one jurisdiction.

Although participation in professional development (Pro-D) is typically a requirement for teachers across the country, the format, content, and expectations are not usually prescribed. Pro-D opportunities, which may involve ongoing professional learning communities, range from one day workshops to extended collaborations between schools and universities. Some provinces have well-established science teacher associations that host annual conferences or, in some cases, publish journals. In most provinces, teachers can take advantage of informal opportunities such as those offered by science museums and other outreach programs.

1.3.3 Jurisdictional Issues

Each province and territory has its own particular issues that impact science education. In subsequent chapters, the jurisdictional issues explored by authors include language, science teacher preparation, geographical isolation of communities and schools, a low priority of science in comparison with mathematics and language arts, Indigenous perspectives, and STEM—an acronym that in Canada indicates the collaborative and purposeful integration of science, technology, engineering, and mathematics, typically independent of governmental and economic strategies (DeCoito, Steele, & Goodnough, 2016; Shanahan, Burke, & Francis, 2016). However, these issues play out according to local context. For example, language issues are highly regionalized and range from English Language Learners, French Language Learners, Francophone communities, and Indigenous languages.

1.3.4 Terminology

In accordance with the recommendations of leading scholars (N. Claxton, personal communication, September 5, 2017; D. Wiseman, personal communication, May 30, 2017), we use *Indigenous* as a collective noun to include Aboriginal, First Nations, Métis, Inuit, and Indian peoples, although the term *Indian* is now rarely used in Canada. Chapter authors were asked to use Indigenous unless a program or course specifically used another term (e.g., Saskatchewan has a range of programs including the First Nations University of Canada and the Indian Teacher Education Program). We use *settler* to include Western, white, and Euro-Canadian peoples; chapter authors also use this term unless citing sources incorporating other terminology.

1.4 What to Expect from This Book

This introductory chapter is intended as an advance organizer for readers, providing an entry point to subsequent chapters on science education and emergent issues at the provincial or territorial level. The next 13 chapters—organized by province and then territory, from west to east as they appear on a map—provide a rich description of science education in each jurisdiction. The final chapter reports on the current status of science education in Canada from a national perspective. It serves as a synthesis of the 13 jurisdictional chapters, highlighting elements of regional contexts, curricula, and teacher education systems and identifies trends in the most pressing, topical issues described by authors from across the country. To present a comprehensive view of science education in Canada, we superimposed the 13 jurisdictional chapters to examine issues and trends, revealing 3 categories that capture the essence of science education in Canada:

- Aspects that are consistent across the country (e.g., curriculum topics)
- Aspects that are common but with jurisdictional variations (e.g., language issues)
- Aspects that are unique to particular jurisdictions (e.g., pedagogical approaches)

Consideration of these aspects may provide insights into Canada's sustained record of strong science performance on international assessments, facilitating more structured opportunities for macro-level comparisons across systems (Cresswell, Schwantner, & Waters, 2015). The meso-level perspective on science education presented in this book offers information regarding policies, organizational structures, and pedagogies implemented across the country. This book provides a snapshot of the current state of science education in Canada, setting the scene to reimagine science education while establishing a baseline for future research and policy decisions within and across jurisdictions, and facilitating nation-to-nation comparisons.

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Chapter 2
Science Education in British Columbia: A New Curriculum for the 21st Century

David Blades

Abstract British Columbia (BC) is the third largest province in Canada and has the third largest number of students attending schools. Separated geographically from Canada by the Rocky Mountains, BC embraces a kind of regionalism in its social fabric, which in turn has affected the development and evolution of science education in the province. Since 1960, BC has engaged in a series of science education curriculum renewal projects. In the 1970s, curriculum changes reflected American post-Sputnik curriculum reforms in science education; but since the mid-1980s, BC has increasingly developed a science education curriculum that displays the creative energy and particular interests of this province. In 2016, the BC Ministry of Education introduced a new science curriculum that encourages "21st century thinking." This chapter documents the evolution of the BC school science curriculum, especially the shift from an integrated, resource-based approach toward a new digital literacy that has fewer, but higher-level, outcomes. The purpose of this shift is to provide more flexibility to explore students' interests and passions in science education with the intention of fostering dynamic thinking skills and job-applicable skills. This new curriculum faces many hurdles, however, which may include the volatile nature of BC politics. The changes implemented in the province are a significant departure from previous approaches to science education in BC and in Canada; the success of these bold initiatives in the years ahead may depend on the support offered to BC teachers by the Ministry of Education.

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C. D. Tippett, T. M. Milford (eds.), *Science Education in Canada*,
https://doi.org/10.1007/978-3-030-06191-3_2

2.1 Introduction

British Columbia (BC) is the westernmost province in Canada, geographically separated from the rest of the country by the Rocky Mountains (Fig. 2.1). This physical barrier seems to permeate the very social fabric of the province—contributing to what Resnick (2000) called in his review of BC politics "BC regionalism" (p. x) where its residents take pride in their difference from the rest of Canada. This sense of difference likely originated in the political history of the province. Several factors contributed to BC moving from being a British colony to a province in the Dominion of Canada. Citizens of the area were concerned about losing the British sense of the region due to a large influx of Americans encouraged by the gold rush in northern BC and Alaska. At the same time, the very real possibility existed of assimilation with the United States (US) as part of an American desire to form a west coast corridor from its western territories north to Alaska. For these reasons, the citizens in BC were persuaded to join Canada with the promise of infrastructure support and a transcontinental railway connection to the east coast. Without consultation with any of the many Indigenous peoples, BC entered confederation with Canada in 1871 as Canada's sixth province (Tattrie, 2014/2015). This action resonates through the

Fig. 2.1 Map of British Columbia

recent history of the province in the form of recurring issues that permeate the education system and in particular science education: the role of Indigenous views of nature and science, the relationship of the province's educational reforms to federal government educational initiatives, and a growing regionalist sense of independence from influences south and east of provincial borders.

Today BC is a vibrant province rich in natural and social resources where one can expect to live a long life. As of July 1, 2016, the average age of the population was 42.3 years with 18% over 65 (Statistics Canada, 2017). A 23% increase in population over 65 from the 2011 census reflects the province's changing demographics. In fact, BC residents have the longest life expectancy in Canada—82.2 years—and rank third in the world, behind Japan and Switzerland (Conference Board of Canada, 2015). The population of BC in 2016 was 4.65 million, up almost 6% from 2011 (Statistics Canada, 2017). The majority of BC's inhabitants live in urban centres; the seven major centres and their populations are Greater Vancouver (2.5 million), Greater Victoria (368,000), Kelowna (195,000), Abbotsford (181,000), Nanaimo (92,000), Kamloops (90,000), and Prince George (66,000) (Statistics Canada, 2017).

Despite a net provincial population growth, the number of children attending BC schools has not risen proportionally. During the 2016–2017 school year, approximately 640,000 students attended BC schools, an increase of 0.4% from 2012–2013 (British Columbia Ministry of Education [BCME], 2018). This difference might not seem substantial but taken together with the overall population increase such demographics suggest an aging population, which has implications for school closures and financing. One would expect, for example, that a larger increase in the taxpayer base combined with a smaller increase in student population would translate to more financial support for education. In fact, this expectation appears to be realized; total funding for the K–12 school system was maintained in 2013–2014, meaning that the average per pupil funding in BC increased "to $8,603 in 2013–14, the highest ever" (Government of British Columbia, 2013, para. 2). In 2018, per pupil funding in public schools was increased slightly to $8657. However, according to the Fraser Institute (MacLeod & Emes, 2017), even with this increase, BC still ranks second to last among the 10 provinces of Canada in education funding. As discussed later in this chapter, in 2016 BCME introduced a new science curriculum that reflects the creative energy of BC regionalism. Increased funding may be critical to a successful implementation of this new approach to science education in the province.

BC has considerable variation in geography that includes a rugged coastline of 27,700 km containing extensive fjords, three major rivers, and 20,000 farms on rich farmland in the valley of the Fraser River and interior of the province, with 64% of the province covered in forest (149 million acres). BC is also rich in minerals and fishing resources. This abundance implies that wealth in BC comes from the development and exploitation of natural resources, which has certainly been the case in the past. Yet over the past two decades, there has been a shift in BC's economy from resource extraction to the growth areas of "construction, high tech, finance and real estate, retail trade, and professional, scientific and technical services" (Conversations for Responsible Economic Development [CRED], 2013, para. 8). Over 76% of BC's gross domestic product comes from the service sector, almost all from small businesses, and more than any other province (CRED, 2013). This shift in economic direction away from natural resources toward what are sometimes called 21st century technologies is reflected in recent revisions to the BC science education curriculum. The perception of economic opportunity and the high quality of life in retirement are likely causes of migration from other provinces to BC.

2.2 Science Education in BC

Public education in BC is free to students who meet age and resident requirements. Education is a legal requirement in BC, and children typically begin school in Kindergarten (K) at the age of 5 and progress annually through Grades 1–12. These grades are normally grouped by clusters or grade configurations (Table 2.1) although regional variations exist.

BC has only one public school system but partially funds under the supervision of this system a series of "independent" (private) schools. This education system is organized into 60 districts, each supervised by a Ministry-appointed Superintendent and publically elected school board. According to the BC Ministry of Education (2017b), during 2016–2017 there were 641,127 students enrolled in BC public schools: 371,763 in elementary schools and 265,135 in secondary schools (the remainder graduated during 2016–2017). There are 1,566 public schools in the province with "85% fewer classes with more than 30 students in 2016/17 than in 2005/06" (p. 3). Children in the province can also elect to attend independent schools. According to the Federation of Independent Schools Association in BC website (2016), there are 26 member schools with a total student population of approximately 12,000 students. The independent schools that offer the full BC curriculum and whose students meet provincial standards receive 50% of the per pupil funding support offered to public schools by the BCME (80% of independent schools receive this funding); the other half of their funding is achieved through school tuition fees and private donations. Twenty percent of independent schools in BC use blended curriculum approaches (i.e., mixing provincial curriculum with different curriculum topics and approaches), and these schools receive 35% funding; approximately 360 students in 2016–2017 attended a school with no provincial funding support.

While general enrolment has declined over the past decade, the number of students "enrolled in language programs have significantly increased" (BCTF, 2017, p. 2) with programs offered in French Immersion increasing 83% since 2001. As well, the number of students who are non-residents of BC (mostly international students) having part or all of their education in BC schools has dramatically

Table 2.1 Common grade configurations in BC schools

Student ages	Grades
5–10 years	Elementary (K–Grade 5)
11–13 years	Middle school (Grades 6–8)
14–17 years	Secondary/high school (Grades 9–12)

increased from 2,954 in 2000–2001 to 14,330 in 2015–2016—an increase of nearly 400%. These students are included in Ministry statistics about school enrolment.

In the public schools under the supervision of school principals, elementary school teachers have professional autonomy in determining how many hours are spent on school subjects, including science. In classroom practice, science in K–5 may exist as a single subject, be blended with another subject, or be part of a thematic approach. For example, an elementary school teacher might integrate science with social studies or other school subjects; this autonomy makes it difficult to determine the number of hours spent teaching particular science-related concepts. By Grades 6–10, however, science is likely to be taught as a separate course with a set number of hours and often by separate teachers. By Grade 11, science tends to be organized into specialized courses that reflect the particular disciplines of biology, chemistry, physics, or earth science; for example, Physics 11 is a first course in physics available for students enrolled in secondary schools.

Historically, BC school-based or home-school-based science education (hereafter called science education) was influenced, as it was in all of Canada, by the massive reforms of science education in the US following the launch in 1957 of the satellite Sputnik by the former Union of Soviet Socialist Republics (see Blades, 1997). The resultant public outcry led the US to link military defense to education, which subsequently provided millions of dollars for the development of school science education programs. These programs (e.g., Biological Sciences Curriculum Study, CHEM study, and Physical Sciences Curriculum Study) were imported into Canada in their entirety in the late 1960s, including the schools of BC. (A personal observation: I was in secondary school when they arrived in BC, and I remember the introduction of these science programs. They were so new that initially teachers had only one copy of the textbook, so we students had to make do with mimeographed copies of the textbook pages.)

Despite using primarily American examples (e.g., ecosystems in New Mexico for high school biology), the new programs initially did attract many students to consider science-related careers; and achievement and enrolment initially increased in secondary school science courses (Kyle, Shymansky, & Alport, 1982). However, by the early 1980s, there was a drift from science (Stenhouse, 1985) as young people sought careers in almost every area but science—a worldwide phenomenon. There were many reasons for this shift, including social factors such as a growing public distrust of scientists due to a worsening environmental crisis and the role of scientists in the development and production of napalm and other weapons used during the Vietnam War (Blades, 1997). During this time, the US published its highly influential *A Nation at Risk* (US Department of Education, 1983), which depicted the lack of success in American education, and particularly science education, as a threat to a perceived superiority of Americans in business and innovation. One recommendation arising from this document was: "Standardized tests of achievement (not to be confused with aptitude tests) should be administered at major transition points from one level of schooling to another and particularly from high school to college or work." (US Department of Education, 1983, Recommendation B3). The intent of this examination-based system of surveillance was to raise the standards of science education through rigorous examinations.

That same year, BCME announced that all Grade 12 science students would be required to complete government-created final examinations worth 40% of their final grade, a requirement that continued until 2011 (Heese, 2015). Students used to complete province-wide examinations in Science 10, which is the last science course taken by all students, but those examinations were eliminated in 2016; Grades 11 and 12 science courses are electives and currently do not have government-administered final exams.

The elimination of final exams for senior secondary school science courses is fairly recent for BC. The influence of American thinking on educational developments in BC, including within science education, is revealed in the way that BC previously incorporated high-stakes examinations precisely as recommended in the US in 1983. American influence on the BC science curriculum, however, has been waning since the 1980–1984 Science Council of Canada (SCC) study of science education in Canada whose aims were:

- To establish a documented basis for describing the present purposes and general characteristics of science education in Canadian schools
- To conduct a historical analysis of science education in Canada
- To stimulate active deliberation concerning future options for science education in Canada (SCC, 1984, p. 2)

This study led BCME to shift science education curriculum content and assessment away from explicitly American influences and examples toward more provincially-relevant examples, such as studies of boreal forest ecologies, mining, and other topics related to the natural resources and studies of technologies being developed in BC.

Historically, science education nationwide was redirected by the results of the SCC study. Describing Canadian science education as in a crisis, the authors delineated recommendations that became the template for science education renewal across the country. Blades (1997) noted that the SCC report contained many concerns about science education in Canada, including “a lack of Canadian content in science education, missed opportunities for all students to study science, the entrenchment of science programs that present an inaccurate view of the activity of science and the failure of science courses to relate science to technological or societal issues” (p. 22). The results of this study and others, such as the US 1985–1986 National Survey of Science and Mathematics Education (Weiss, 1987), the Centre for the Assessment of Educational Progress study of science and mathematics worldwide, *A World of Differences: An International Assessment of Mathematics and Science* (Lapointe, Mead, & Phillips, 1989), and the American Association for the Advancement of Science (1989) publication *Science for All Americans*, pointed toward the need to develop science programs that encouraged the involvement of all students, in contrast to the post-Sputnik programs that were designed to entice only those students interested in science-related careers. The *science for all students* concept became an international movement by the end of the 1980s.

The SCC study also called for science education that reflected the interactions of science, technology, and society—the so-called STS approach. Gaskell (1980) noted that BC was particularly influenced by the STS movement. Evidence of this influence was BCME's creation in 1994 of two new courses in technology studies: Science and Technology 11 and 12. These courses included some integration of environmental education, although not to the extent recommended in 1987 by Paul Hart, an environmental educator at the University of Regina advocating that STS education include "E" for environment: STSE science education (Hart, 1987). The move to add E to STS was slowly embraced by the entire country over the next decade and became worldwide (for a useful overview of the STSE movement, see Pedretti & Nazir, 2011). As a result of this influence, BC's other science courses began to be adapted toward an STSE focus. Collectively, the science for all, STS, and STSE approaches can be seen as an approach to science education primarily focused on science literacy for citizenship education and development.

2.3 Science Curriculum in British Columbia

The 1990s saw curriculum reform encouraging growth of students' science literacy. In her review of BC science curriculum development, Monkman (2001) noted that new conceptions of science literacy meant that new science programs would:

- Address attitudes, skills, and knowledge
- Develop inquiry, problem solving, and decision-making abilities
- Encourage creative, critical minds and strive for original thought
- Enable students to sift through a wealth of information and ignore that which is unsound
- Build on previous knowledge (constructivist approach)
- Encourage a critical sense of wonder and curiosity to be lifelong learners
- Explore, analyze, evaluate, synthesize, and appreciate
- Emphasize relationships of science, technology, society, and environment
- Make real-world connections that focus on personal lives, community, careers, and the future to encourage responsible action (p. 4)

These curriculum directions were also strongly encouraged in the recommendations of the federally-sponsored *Common Framework of Science Learning Outcomes: K–12* (Council of Ministers of Education, Canada [CMEC], 1997). BC continued to embrace the STSE approach to science education emphasized in the *Common Framework* and developed extensive curriculum guides for teachers.

2.3.1 1995–2015: Integrated Resource Packages

Between 1995 and 2015, the mandated curriculum was distributed in teacher guides that were not intended to be prescriptive but instead were intended to serve as resources for teachers to support lesson planning and assessment. Thus, rather than call them curriculum guides, BCME labeled these new curriculum documents

Integrated Resource Packages (IRPs). There was an IRP for Science K–7 as well as individual IRPs for Science in Grades 8, 9, and 10, while the IRPs for Grades 11 and 12 were discipline-specific. Science for K–10 was a general course of study organized into strands that reflected three major conceptual fields of science: life science, physical science, and earth and space science. In this organization, each grade level of the science curriculum featured a particular topic in each strand (Table 2.2).

The K–10 science IRPs used what might be called a mild-spiral approach to topic arrangement, where topics introduced in the lower grades reappeared in more depth in later grades. For example, in Grade 1, children studied the concept of forces

Table 2.2 BC science curriculum by grade, strand, and topic

<table>
<tr><th>Grade</th><th>Processes and skills of science</th><th>Life science</th><th>Physical science</th><th>Earth and space science</th></tr>
<tr><td>K</td><td>Observing
Communicating (sharing)</td><td>Characteristics of living things</td><td>Properties of objects and materials</td><td>Surroundings</td></tr>
<tr><td>1</td><td>Communicating (recording)
Classifying</td><td>Needs of living things</td><td>Force and motion</td><td>Daily and seasonal changes</td></tr>
<tr><td>2</td><td>Interpreting observations
Making inferences</td><td>Animal growth and changes</td><td>Properties of matter</td><td>Air, water, and soil</td></tr>
<tr><td>3</td><td>Questioning
Measuring and reporting</td><td>Plant growth and changes</td><td>Materials and structures</td><td>Stars and planets</td></tr>
<tr><td>4</td><td>Interpreting data
Predicting</td><td>Habitats and communities</td><td>Light and sound</td><td>Weather</td></tr>
<tr><td>5</td><td>Designing experiments
Fair testing</td><td>Human body</td><td>Forces and simple machines</td><td>Renewable and nonrenewable resources</td></tr>
<tr><td>6</td><td>Controlling variables
Scientific problem solving</td><td>Diversity of life</td><td>Electricity</td><td>Exploration of extreme environments</td></tr>
<tr><td>7</td><td>Hypothesizing
Developing models</td><td>Ecosystems</td><td>Chemistry</td><td>Earth's crust</td></tr>
<tr><td>8</td><td rowspan="3">Safety
Scientific method
Representing and interpreting scientific information
Scientific literacy
Ethical behaviour and cooperative skills
Application of scientific principles
Science-related technology</td><td>Cells</td><td>Optics
Fluids and dynamics</td><td>Water systems</td></tr>
<tr><td>9</td><td>Reproduction</td><td>Atoms, elements, and compounds
Characteristics of electricity</td><td>Solar system and the universe</td></tr>
<tr><td>10</td><td>Sustainability of ecosystems</td><td>Chemical reactions and radioactivity
Motion</td><td>Energy transfer
Natural systems</td></tr>
</table>

Note. From BCME (2006, p. 16)

through experiential aspects in the topic Force and Motion, again in more depth and application with a study of Forces and Simple Machines in Grade 5, and finally through an introduction to Newtonian Mechanics in Grade 10 (BCME, 2008a).

Science subjects in Grades 11 and 12, however, were organized as entire courses of study in the particular field of science. These courses contained topics that were similar across Canada. For example, the cell biology topics of DNA transcription and translation are typically found in high school biology; detailed studies of Newtonian mechanics are usually part of physics in Grade 11; and oxidation/reduction reactions, including calculations of their potential energies, are found in high school chemistry. All of these secondary school science courses were considered essential preparation for continued studies in science at the postsecondary level; and every course reflected, in its content, the science courses originally developed as part of the post-Sputnik US curriculum reforms.

Two notable exceptions were Science and Technology 11 and Sustainable Resources 11 and 12, which were more directly related to topics and issues relevant to BC. Science and Technology 11 was based on a choice of study modules; some modules examined the "major natural resources found in British Columbia" (BCME, 2008c, p. 28) or the BC Building Code (home and technology module). Sustainable Resources 11 included an examination of the "importance of agricultural resources in the development of Canada with emphasis on British Columbia" (BCME, 2008b, p. 25) and similar provincially-relevant topics in mining, forestry, and fisheries. The Science and Technology 11 and Sustainable Resources 11 and 12 courses generally were not accepted as sufficient background for further postsecondary studies in science but were acceptable as a secondary school science requirement to other non-science postsecondary programs.

2.3.2 Prescribed Learning Outcomes

In the IRPs, the content standards were called Prescribed Learning Outcomes (PLOs); and teachers were legally required to ensure that PLOs were addressed. Table 2.3 provides an example of the PLOs that were in place for Grade 5 until 2016.

2.3.2.1 Strengths of the 1995–2015 Science Curriculum

IRPs varied by subject but in science all documents were comprehensive—the IRP for Science K–7, for example, was 500 pages long—and typically included considerations for program delivery such as safety, addressing local contexts, involving parents and guardians, and working with Aboriginal communities. Each IRP provided additional, topic-specific information that teachers would find useful such as how to deal with creationism in secondary school biology. While the IRPs reflected the *Common Framework's* (CMEC, 1997) goals for science education, they also

Table 2.3 Grade 5 science: Strands, topics, and Prescribed Learning Outcomes, 1995–2015

Strand	Topic	Prescribed Learning Outcomes
Life sciences	Human body	*Students should be able to:* Describe the basic structure and functions of the human respiratory, digestive, circulatory, skeletal, muscular, and nervous systems Explain how the different body systems are interconnected
Physical sciences	Forces and simple machines	*Students should be able to:* Demonstrate how various forces can affect the movement of objects Demonstrate mechanical advantage of simple machines, including lever, wedge, pulley, ramp, screw, and wheel Design a compound machine Describe applications of simple and compound machines used in daily life in BC communities
Earth and space science	Renewable and nonrenewable resources	*Students should be able to:* Analyze how BC's living and nonliving resources are used Identify methods of extracting or harvesting and processing BC's resources Analyze how the Aboriginal concept of interconnectedness of the environment is reflected in responsibility for and caretaking of resources Describe potential environmental impacts of using BC's living and nonliving resources

Note. Adapted from BCME (2005)

introduced new directions to science curriculum, including teacher authorship and autonomy; integration of Indigenous perspectives; environmental responsibility; assessment *for*, *of*, and *as* learning; and a range of approved resources.

Teacher Authorship and Autonomy Even though the IRPs were officially mandated by BCME, their authors were almost exclusively teachers, not Ministry officials. This change represented a divestment of authority for guiding instruction toward a more teacher-based focus. In addition, the IRPs listed target content along with the processes of science to be encouraged and suggested achievement indicators to assist teachers in gauging an age- and grade-appropriate level of instruction. For example, a Grade 3 PLO of "compare familiar plants according to similarities and differences in appearance and life cycles" was accompanied with an achievement indicator suggesting that students should learn to "accurately illustrate the life cycle of a flowering plant" (BCME, 2005, p. 77). One consequence of listing achievement indicators was that some teachers may have missed the word *suggested*. This omission could restrict creative planning as a teacher adhered to the achievement indicators. Despite this potential confusion, the IRPs were innovative in how they provided concrete examples of ways to assess student understanding of content and demonstration of science processes, while allowing teachers considerable professional autonomy in how they approached science instruction.

Indigenous Perspectives The science IRPs included new PLOs that incorporated Indigenous perspectives in science education. The BCME's position was that:

> Incorporating of Aboriginal science with western science can provide a meaningful context for Aboriginal students and enhance the learning experience for all students. The inclusion of Aboriginal examples of science and technologies can make the subject more authentic, exciting, relevant and interesting for *all* students. (BCME, 2005, p. 12)

It was noted, in what amounts to an understatement, that for most teachers "numerous difficulties arise when trying incorporate indigenous [sic] knowledge and world views into the western science classroom" (p. 12). This purposeful integration of Indigenous perspectives can be seen from many angles. In discussions with Ministry officials during this time, the author was told that some of the reasons for including Indigenous views were helping Indigenous students find culturally-affirming examples in their science education (presumably to also assist achievement) as well as challenging a positivist scientism. The IRPs could also be seen as an attempt to begin the process of including long-excluded voices—an act of social justice that responded to the fact that the formation of BC as a province completely neglected the involvement of the Indigenous peoples.

Environmental Responsibility The science IRPs provided teachers with additional topics related particularly to the resources of BC, which were most frequently presented in the light of environmental responsibility. This change was clearly reflected in, for example, the Grade 5 science curriculum, where students studied how BC's living and nonliving resources were used, environmental impacts of using resources, and methods of extraction, harvesting, and processing. Also included were the Indigenous concepts of interconnectedness and caretaking of resources. The emphasis on environmental responsibility was notably missing, however, in the Grades 11 and 12 curricula for biology, chemistry, and physics.

Assessment for, of, *and* as *Learning* The IRPs encouraged a broad view of student assessment, incorporating examples of assessment for learning, of learning, and as learning. Assessment *for* learning involves both teacher and student in a process of reflection and review of progress. A key component of assessment *for* learning was the expectation that "teachers adjust their plans and engage in corrective teaching in response to formative assessment" (BCME, 2005, p. 44). Assessment *of* learning involved summative portrayals by teachers of students' learning; those results would be used to make criterion- or norm-referenced judgments. Assessment *as* learning required students to "use assessment information to make adaptations to their learning process and to develop new understandings" (BCME, 2005, p. 44). For example, students would review what they understood about a science concept and "determine what they have not yet learned" (BCME, 2005, p. 43); this determination can be difficult in science, where what is yet to be learned may be unknown to a student.

A Range of Approved Resources The IRPs supported a move away from teaching primarily with textbooks—and a reliance on textbook-related worksheets—toward incorporating a range of approved resources, many of which were published in the province. Approved resources were identified through a process of teacher recommendation and review by BCME staff and were listed in the IRP, making the gathering of resources easier for teachers. In this way, IRP authors envisioned teachers supporting instruction with locally-produced resources, thus the idea of an *Integrated Resource Package*. For example, videos on plant growth produced by a Vancouver company were listed as an approved resource for the Grade 3 topic of Growth and Changes in Plants. All resources approved for inclusion were recommended for use province-wide although the availability of resources varied considerably.

2.3.2.2 Problems with the 1995–2015 Science Curriculum

From the author's personal perspective, teachers and preservice teachers appeared to appreciate the science IRPs for their comprehensive, sound advice on what and how to teach. However, the sheer size of the documents caused some teachers to ignore the preliminary pages and move directly to the list of PLOs for a particular grade or subject. As a result, teachers could essentially miss important aspects such as the emphasis on process skills. This omission was particularly evident in combination with government examinations, which invariably focused on science content knowledge. Moreover, in addition to some confusion about the role of the suggested achievement indicators, many teachers continued to rely on paper and pencil assessment methods to measure student achievement in science.

2.4 The 21st Century and the New BC Science Curriculum: 2016 and Beyond

Recognizing that 21st century education was evolving rapidly, BCME began a substantial revision of the K–12 curriculum including science; in 2016, a radically different approach to science education was implemented. A new curriculum for K–9, available only online due to its nonlinear structure, was implemented in the fall of 2016, Science 10 was implemented in the fall of 2018, and the Grades 11 and 12 subjects are expected to be implemented in the fall of 2019.

In 2011, the BC Minister of Education introduced the *BC Education Plan*, a document summarizing months of community consultation and extensive discussions with teachers, parents, and university teacher educators. The key point of this document was that education based on 19th and 20th century models of learning and teaching was no longer valid in the 21st century, particularly due to the rapid development of digital applications. What was needed, the plan argued, was a new approach to curriculum, one in which it would be easier for teachers to use their professional knowledge to guide students in developing the skills and understanding that would help them become successful citizens. The BCME, reflecting perhaps a sense of regionalism, decided that BC should be the province to lead the way in Canada with new approaches to learning that addressed current realities and potential technological developments. The ease of obtaining information by simply asking Internet search engines a question potentially displaces teachers as the primary source of science information and presents the opportunity for students to pursue particular interests. Recognizing this shift in the role of teachers, BCME initially intended the new curriculum to have fewer, but higher, level outcomes in order to give teachers and students more flexibility to explore students' interests and passions (BCME, 2011). In science education, this argument translated into the development of a new approach to the curriculum that initially had less emphasis on understanding content and more emphasis on developing science processes skills. The substance of the PLOs remains, but in a new form called Learning Standards that "include curricular competencies and concepts and content for each area of learning" (BCME, 2015, p. 1). What is significant for science education in BC is that the competencies now include, as part of what students should learn, the processes of science organized around key big ideas (Table 2.4).

The development of a sweeping new approach to the school curriculum is somewhat familiar territory for the BCME. A Royal Commission on Education, the so-called Sullivan Report, advocated massive and extensive changes to the BC system

Table 2.4 Big ideas for the new BC K–9 science curriculum

Grade	Big ideas			
K	Plants and animals have observable features	Humans interact with matter every day through familiar materials	The motion of objects depends on their properties	Daily and seasonal changes affect all living things
1	Living things have features and behaviours that help them survive in their environment	Matter is useful because of its properties	Light and sound can be produced, and their properties can be changed	Observable patterns and cycles occur in the local sky and landscape
2	Living things have life cycles adapted to their environment	Materials can be changed through physical and chemical processes	Forces influence the motion of an object	Water is essential to all living things, and it cycles through the environment
3	Living things are diverse, can be grouped, and interact in their ecosystems	All matter is made of particles	Thermal energy can be produced and transferred	Wind, water, and ice change the shape of the land
4	All living things sense and respond to their environment	Matter has mass, takes up space, and can change phase	Energy can be transformed	The motions of Earth and the moon cause observable patterns that affect living and nonliving systems
5	Multicellular organisms have organ systems that enable them to survive and interact within their environment	Solutions are homogeneous	Machines are devices that transfer force and energy	Earth materials change as they move through the rock cycle and can be used as natural resources

(continued)

Table 2.4 (continued)

Grade	Big ideas			
6	Multicellular organisms rely on internal systems to survive, reproduce, and interact with their environment	Everyday materials are often mixtures	Newton's three laws of motion describe the relationship between force and motion	The solar system is part of the Milky Way, which is one of billions of galaxies
7	Evolution by natural selection provides an explanation for the diversity and survival of living things	Elements consist of one type of atom, and compounds consist of atoms of different elements chemically combined	Electromagnetic force produces both electricity and magnetism	Earth and its climate have changed over geological time
8	Life processes are performed at the cellular level	The behaviour of matter can be explained by the kinetic molecular theory and atomic theory	Energy can be transferred as both a particle and a wave	The theory of plate tectonics is the unifying theory that explains Earth's geological processes
9	Cells are derived from cells	The electron arrangement of atoms impacts their chemical nature	Electric current is the flow of electric charge	The biosphere, geosphere, hydrosphere, and atmosphere are interconnected, as matter cycles and energy flows through them

Note. Adapted from BCME (2017a)

of public education (Sullivan, 1988). The Report noted that public school education in BC should emphasize creative and critical thinking since the world of work "rewards those who can think flexibly and solve problems in creative ways" (Sullivan, 1988, p. 22). Remarkably, in directions and recommendations, the Report uses almost the same arguments employed by the present BCME to justify recent changes to the BC curriculum (Hansman, 2016). BCME used the Sullivan Report to launch a new approach to schooling and curriculum in BC, which was promoted by the Ministry as a "Year 2000" curriculum—preparing for the year 2000 and beyond. This initiative (see Kuehn, 1993), which among many ideas included multi-age grouping and the elimination of letter grades on report cards, was met with considerable resistance by some parents and some members of the postsecondary education community although the initiative was generally supported by teachers. Acknowledging the concerns of some members of the public, BCME abandoned the curriculum changes in 1993 after a provincial election that saw the incoming NDP government commit to higher standards that included letter grades and standardized exams (Kilian, 2011). Clearly, curriculum renewal in BC can be directly affected by changes in government; and it is too early to gauge how the 2017 provincial election will affect the full implementation of the new science curriculum.

BCME does not provide a graphic that illustrates the relationships in its new approach to K–9 science, but it could be conceptualized as a set of gears (Fig. 2.2). The largest gear, Core Competencies, includes communication, thinking, and personal and social competency. Core Competencies vary by grade; thus, a Grade 4 student would be expected to “represent and communicate ideas and findings in a variety of ways” (BCME, 2017a), while a Grade 5 student would be expected to “communicate ideas, explanations, and processes in a variety of ways” (BCME, 2017a). The second gear, Big Ideas of Science, facilitates the achievement of Core Competencies. The content as listed is grouped by the Big Ideas for each grade level, so these Big Ideas naturally suggest units of instruction. The third gear, Learning Standards, enables students to learn the Big Ideas; it has two components intended to form a dynamic space for student learning. The first component, Curriculum Competencies, is similar to the processes of science in the old IRPs. However, in the new curriculum, the processes are given more emphasis and are elaborated as expectations. The list of Curriculum Competencies for each grade is extensive, with the intention that every competency listed will be developed as part of students’ science education. The second component, Content, provides context for competency development and is formatted as expectations. The intent is that students will develop Curriculum Competencies using the Content. For example, under Content in Grade 5, students are expected to know solutions and solubility; one way to teach the skill of questioning and predicting might be for students to conduct an experiment based on their predictions about the solubility of some common household products.

The individual components of the three gears in Fig. 2.2 can be accessed through the multiple layers of the online curriculum document. Table 2.5 provides a snapshot of the first and second layers of information that BCME provides for Grade 5 science.

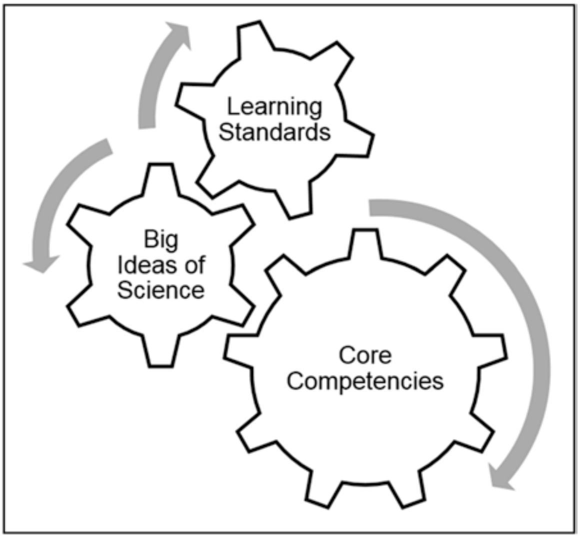

Fig. 2.2 Conceptual organization of the new BC K–9 science curriculum

Table 2.5 Grade 5 Science: core competencies, big ideas, and learning standards

Core competencies[a]		
Communication	Thinking	Personal and social

Big ideas[b]			
Multicellular organisms have organ systems that enable them to survive and interact within their environment	Solutions are homogeneous	Machines are devices that transfer force and energy	Earth materials change as they move through the rock cycle and can be used as natural resources

Learning standards[c]	
Curricular competencies	***Content***
Questioning and predicting Demonstrate a sustained curiosity about a scientific topic or problem of personal interest Make observations in familiar or unfamiliar contexts Identify questions to answer or problems to solve through scientific inquiry Make predictions about the findings of their inquiry	Basic structures and functions of body systems: • Digestive ➔ *mouth, stomach, intestines, etc.* • Musculo-skeletal ➔ *muscles and skeletons* • Respiratory ➔ *trachea, lungs, and diaphragm* • Circulatory ➔ *heart, blood, blood vessels*
Planning and conducting With support, plan appropriate investigations to answer their questions or solve problems they have identified Decide which variable should be changed and measured for a fair test Choose appropriate data to collect to answer their questions Observe, measure, and record data, using appropriate tools, including digital technologies	Solutions and solubility ➔ *Solutions (e.g., apple juice, coffee) that can be separated through distillation, evaporation, and crystallization* ➔ *Solubility of solids, liquids, and gases (e.g., salt [solid], honey [liquid], carbon dioxide [gas in water makes pop])* ➔ *Properties of solutions: concentration, pH, etc.* ➔ *Dissolving: process of forming a solution*
Processing and analyzing data and information Experience and interpret the local environment Identify First Peoples perspectives and knowledge as sources of information Construct and use a variety of methods, including tables, graphs, and digital technologies, as appropriate, to represent patterns or relationships in data Identify patterns and connections in data Compare data with predictions and develop explanations for results Demonstrate an openness to new ideas and consideration of alternatives	Properties of simple machines and their force effects ➔ *Levers, wedge, inclined plane, wheel and axle, pulley, and screw* ➔ *Force effects include changing direction and multiplying force*
	Machines • Constructed ➔ *combinations of simple machines form complex machines* • Found in nature ➔ *the lever is the basis of nearly every aspect of the musculo-skeletal system*
	Power – the rate at which energy is transferred ➔ *Examples include students racing up a hill, machine power ratings, motors*

(continued)

Table 2.5 (continued)

Evaluating Evaluate whether their investigations were fair tests Identify possible sources of error Suggest improvements to their investigation methods Identify some of the assumptions in secondary sources Demonstrate an understanding and appreciation of evidence Identify some of the social, ethical, and environmental implications of the findings from their own and others' investigations	The rock cycle Local types of earth materials ➔ *Include mineral, rock, clay, boulder, gravel, sand, soil* First Peoples concepts of interconnectedness in the environment ➔ *Everything in the environment is one/connected (e.g., sun, sky, plants, and animals) and we have a responsibility to care for them* The nature of sustainable practices around BC's resources
Analyzing and innovating Contribute to care for self, others, and community through personal or collaborative approaches Co-operatively design projects Transfer and apply learning to new situations Generate and introduce new or refined ideas when problem solving *Communicating* Communicate ideas, explanations, and processes in a variety of ways Express and reflect on personal, shared, or others' experiences of place	First Peoples knowledge of sustainable practices

Note. Adapted from BCME (2015)

[a]Clicking on each of the Core Competencies takes the user to a hyperlinked page providing more information

[b]Hovering over the Big Ideas brings up sample questions to support student inquiry

[c]Hovering over the Learning Standards brings up additional information (shown in the table proceeded by ➔)

BCME was committed to a full, public discussion of the new science curriculum for Grades 10–12, so that the courses would evolve with the consultation of multiple stakeholders, including universities who use secondary science courses to determine student suitability for admission to specific programs. Processes of science continue to be emphasized in the form of Curricular Competencies, and each course has prescribed content that students must learn. What is notable is that the content to be covered has, in some cases, increased. For example, Science 10 includes some of the content listed in the previous IRP for Science 10 as well as the topics of formation of the universe, structure of DNA, and First Peoples perspectives on energy (BCME, 2016). The curricula for Biology 11, Chemistry 11 and 12, and Physics 11 and 12 also include content similar to what was previously included in these subjects. Biology 12 has been reconceptualized as Anatomy and Physiology 12, placing a greater emphasis on the anatomy and physiology of organisms, with a particular focus on humans. Earth Sciences 11 and Geology 12 contain aspects of the previous courses Earth Science & Geology 11 and 12. Science for Citizens 11 replaces Science and Technology 11 and has a broader scope of potential topics, including a unit on careers in science-related fields, and leaves much to local teacher development. BCME has also introduced entirely two new courses, Environmental Science 11 and 12, which focus on evidence-based decision making and the role of science in promoting sustainability of ecosystems. Social and environmental responsibility is especially featured in Environmental Science 12.

2.5 Science Teacher Education and Certification

Teacher certification is entirely the responsibility of the provincial government, which oversees certification through an agency within BCME—its Teacher Regulation Branch (TRB). The TRB identifies the minimum requirements to obtain a certificate of qualification needed to teach in public schools. This certificate also enables educators to work in independent and First Nations schools. In almost every case, teachers in private schools are certified or eligible for certification although no such requirement exists for private schools. As of 2016, there were nine postsecondary institutions where one could complete the required coursework and school experience to become certified to teach in BC as identified by the TRB's requirements.

One might expect that with nine institutions providing teacher education, there would be considerable variation between the programs; in fact, almost every institution offers a similar combination of courses. Programs typically include field experiences (practicum placements) along with courses on human development, learning theory, educational foundations (history and philosophy of education), curriculum and instruction in content areas, diagnosis of educational needs, and assessment. The content and structure of teacher education programs must be approved by TRB, in essence meaning that TRB sets the outline of these programs. TRB bylaws require any applicant for certification to successfully complete a teacher education program that is approved or acceptable to TRB. This program must include "48 credit/semester hours or equivalent of professional education course work including any credit granted for practice teaching" (BC TRB, 2016, p. 13); these credit hours are specified in broad terms that include the areas listed above. Thus, in effect and intention, TRB standardizes teacher education in the province by outlining the minimum requirements.

However, teacher education programs do find opportunity to vary practicum length and admission requirements. For example, TRB (2016) requires all applicants to an approved elementary education program to have completed a minimum of 3 credit hours, which is equivalent to 36 contact hours, of science in a faculty outside Education. Prospective secondary teacher applicants need a degree in the subject(s) they intend to teach, or a minimum of 24 credit hours of coursework, which translates into eight courses of 36 contact hours each, outside the Faculty of Education in their teachable area.

As a result of these admission requirements, every elementary teacher in BC has successfully completed at least one full semester course in postsecondary science. Most secondary science teachers have completed at least eight science courses, and many have a science degree. However, these are TRB's minimum requirements; and institutions offering teacher education programs can and sometimes do require more. For example, at the University of Victoria, applicants to the elementary teacher education program currently need two full semester science courses—one of which must be laboratory-based—and applicants to the secondary teacher education program require a course in the history or philosophy of science in addition to TRB requirements.

Teacher education programs vary in the required coursework for science education teaching methodology. Table 2.6 lists the nine postsecondary institutions currently offering teacher education programs leading to certification along with the credit hours of science methods coursework required in elementary and secondary programs.

Courses on how to teach children science are part of every elementary school teacher education program; however, Table 2.6 reveals that elementary school teachers receive at most one course on teaching science. Most institutions, with the notable exception of the University of Victoria, require only one postsecondary science course for admission to their program; therefore, teachers typically complete a maximum of 6 credit hours of science—3 focused on science content and 3 focused on learning how to teach science. The emphasis in elementary programs seems to be

Table 2.6 Teacher education program—required science methods credit hours[a] by program

Institution (Location)	Elementary	Secondary science specialist
Simon Fraser University (Vancouver)	3	3
Thompson Rivers University (Kamloops)	3	Not offered
Trinity Western University (Vancouver)	1	2
University of British Columbia (Vancouver)	3	6 (3 Lecture, 3 laboratory)
University of British Columbia-Okanagan (Kelowna)	2	3 (Combined with mathematics; program under review as of 2016)
University of Fraser Valley (Abbotsford)	2	3
University of Northern British Columbia (Prince George)	2	0 (Will allow coursework in sciences for a major in secondary science)
University of Victoria (Victoria)	3	3
Vancouver Island University (Nanaimo)	3	Program subject to enrolment

[a]Three credit hours is equivalent to 36 to 39 contact hours

on learning how to teach mathematics and literacy skills. For example, teacher education programs include between 1 and 3 credit hours of science methods, while most programs require 3 credit hours of mathematics and 4 of language and literacy. The situation in BC suggests that elementary teachers may be unprepared to teach science. Since science has a history of being poorly taught or not being taught at all in Canadian elementary schools (SCC, 1984), a complete, province-wide review of the science education requirements for preparing future elementary school teachers should take place.

Secondary science teachers fare better, but in most cases receive only one course on how to teach science. Secondary science methods courses are remarkably consistent throughout education programs. Common topics that might be featured in these courses include how to write lessons plans, familiarity with provincial curriculum requirements for science education, assessment strategies in science education, how to plan and conduct laboratory and field experiences, strategies to develop positive science attitudes in students, and ways to teach science safely. Institutions depend on practicum placements to fill in the gaps of understanding that cannot be developed during classroom instruction due to lack of time.

Depending on field experiences to supplement science teacher education deserves closer examination, especially in light of the new educational reforms in BC. First, this dependency assumes that classroom teachers are actually incorporating best practices in science teaching, utilizing effective assessment strategies, and including Indigenous perspectives. Second, for teacher candidates to adopt 21st century approaches to the new BC science curriculum, they should not be placed in classrooms where approaches to science education reflect the content-driven, science-career orientation of the post-Sputnik reforms. The changes in science education envisioned in BC might be better enhanced with a minimum requirement of 72 contact hours in science teaching methods courses, in partnership with field experiences where teacher candidates can be mentored by practicing teachers who have fully adopted the approaches of the new curriculum.

2.6 Problems and Possibilities in BC Science Education

The BC curriculum has moved away from the US influences of the 1960s and 1970s to reflect a more Canadian context, largely encouraged by the *Common Framework* (CMEC, 1997). Since the late 1980s, BCME has developed new ways to guide and articulate science education in the province, first through the curriculum reform arising from the 1988 Royal Commission on Education in BC (Sullivan, 1988) and then the development of extensive IRPs, shifting authorship to practicing teachers. Provincial examinations for Grades 11 and 12 science courses have been eliminated; more recently, changes to the science curriculum have been part of the provincial move to an education system that reflects 21st century approaches. This latest shift places curriculum more firmly in teachers' control, with increased emphases on science processes and on creating dynamic learning environments where students can access multiple sources of information to construct understanding of the big ideas of science.

BC's new science curriculum presents some challenges in structure and presentation. The K–9 science curriculum does not provide the depth of description or support for assessment that was found in previous IRPs. For example, the curriculum for most grades is described in approximately two pages, whereas the previous IRP contained 30 pages. However, BCME intends to provide hyperlinks from the Big Ideas and Learning Standards with information on assessment likely to follow. It may be tempting, however, for teachers to continue to use the outmoded IRPs because of their comprehensive nature, which could hinder adoption of the new curriculum.

The draft secondary curriculum also presents some challenges. The Content included in the Learning Standards reflects a move from an STSE approach to a science, technology, engineering, and mathematics (STEM) approach. Some critics note that a major rationale for STEM is economic competitiveness, infused with a neo-liberal agenda (for a further and extensive critique of STEM, see Weinstein, Blades, & Gleason, [2016] and Zeidler [2014]). If the BC curriculum features topics increasingly aligned with STEM, this would represent a turn back to a more US-based influence. However, a close reading of the new curriculum reveals that while STSE topics are not part of the Content, STSE perspectives are encouraged as part of the Curricular Competencies. For example, in Science 10, the Curriculum Competency of evaluating requires that students "consider social, ethical, and environmental implications of the findings from their own and others' investigations" (BCME, 2016, p. 2). The new curriculum thus seems to encourage STSE development as part of the Curricular Competencies.

Another issue with the new secondary science curriculum is that the Learning Standards require the teaching of more content than the PLOs of the previous IRPs. As well, much of the content appears remarkably similar to the content in the previous IRPs; some teachers may choose to ignore the perspectives and approaches advocated by the new curriculum, such as helping students see connections between the big ideas in a science or developing understanding through a Curricular Competency-Content dynamic. Teachers may consider this increase in content as a list of topics they should be teaching and thus miss the process-related Curricular Competencies that are supposed to be the reason for the content. In this way, the success of the previous IRPs as a resource for supporting secondary and elementary school science education may prove a hindrance to curriculum innovation.

To ensure fidelity of implementation of the new curriculum, BCME may consider bringing back some form of province-wide summative assessment for secondary science. In fact, a return of such summative assessment is now being considered for numeracy and literacy upon secondary graduation; it is likely that science literacy would be included. The history of government-administered examinations in secondary school science suggests that reintroducing some form of these examinations could actually entrench a focus on content at this level, which would be even more counterproductive to the implementation of curriculum change in secondary school science. However, the goal of the evaluations under consideration would be to evaluate both the Curricular Competencies and Content as reflected in the new curriculum.

The new BC science curriculum requires teachers to have an understanding of the processes of science, yet research suggests that science educators, especially those teaching in elementary schools, generally have very poor understandings of the nature of science (Abel & Smith, 2007). If BCME intends for science processes to be a focus in the new science curriculum, teachers and teacher candidates will need stronger backgrounds in science and science pedagogy. For example, TRB could require two, instead of one, university-level science courses for admission to teacher education programs and a minimum of 36 contact hours in science education methods for all elementary teachers.

The new BC science curriculum continues to infuse Indigenous perspectives, with at least one content suggestion per grade level (Table 2.5). However, there is a real possibility that teachers may struggle to figure out exactly how to infuse Indigenous perspectives in their science classes since the new curriculum, unlike the previous IRPs and as yet, offers no advice on this infusion.

Finally, to enable teachers to understand the new directions proposed by BCME, teachers may need professional development in the form of inservice workshops and extensive coaching. Given that BC is one of the wealthiest provinces in Canada but spends the least in per pupil funding (BCTF, 2017) the opportunity certainly exists for increasing such support. The extent to which BCME helps teachers understand the new science curriculum will be a clear indication of the depth of its commitment to ensuring the envisioned curriculum reform. We shall see.

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Chapter 3
Science Education in Alberta: A Complex History of Shifting Educational Influences

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Abstract This chapter discusses the history and current state of science education in Alberta. Science education in Alberta has been influenced by a complex past, including an agricultural- and resource-based economy, shifts between progressive and populist governments, and relationships with First Nations, Métis, and Francophone peoples and communities. Historically, the provincial science curriculum has been characterized by swings between progressive educational philosophies (e.g., enterprise approach) and content-focused curricula. The current science curriculum is organized around emphasis areas (e.g., nature of science, science and technology) and incorporates Indigenous perspectives at most grade levels. Science teacher education programs in Alberta are diverse and quite variable across the province in regard to science content and science education pedagogy requirements. As Alberta is currently engaged in a major curriculum revision process across all subject areas, it is not yet known how the influences of the past and the pressures of the present will shape the future of science education in the province.

3.1 Introduction

Originally part of the Northwest Territories, Alberta was established as a province in 1905. Since the province's founding, its geography, economy, politics, and history have influenced the development of science curriculum and teacher education.

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C. D. Tippett, T. M. Milford (eds.), *Science Education in Canada*,
https://doi.org/10.1007/978-3-030-06191-3_3

Science education in Alberta has been characterized by pushes and pulls among different groups and conceptions of what education should be, including radical educational experiments (Taylor, 2001). In the contemporary context, Alberta is well known internationally as an educational leader, given the consistently high-ranking performance of its students on international assessments (e.g., O'Grady, Deussing, Scerbina, Fung, & Muhe, 2016), particularly in science. The demand for Alberta curriculum and expertise internationally is high, and Alberta Education (2017a) has accredited 12 schools outside of Canada to use the provincial curriculum.

The fourth largest province (and 6th largest jurisdiction) in Canada in terms of land area, at 661,848 km^2, Alberta has a diverse landscape with boreal forest and peatlands in the north, the Rocky Mountains and foothills in the west, grasslands in the south, and aspen parkland in the east and central areas (Government of Alberta, 2016a). The economy is based on a range of industries including agriculture, natural resources, construction, manufacturing, and service-related employment. The oil sands in the northern part of the province contain the third largest oil reserves in the world and are a significant driver of Alberta's economy (Alberta Energy, 2017). Alberta's population is just over 4 million people with 76% concentrated in the Calgary–Edmonton corridor (Fig. 3.1), which covers only 6% of the province's geographical area (Statistics Canada, 2017b).

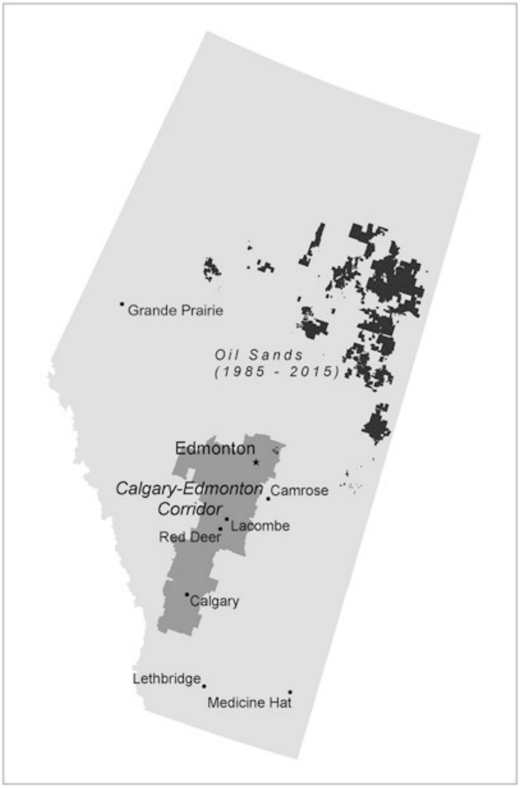

Fig. 3.1 Map of Alberta

Table 3.1 Alberta school authority types, schools, and enrolment data

Type	Authorities	Schools	Students[a]
Public	42	1,537	464,519
Separate (mostly Catholic)	17	409	162,654
Francophone	4	41	8,066
Charter	13	22	9,277
ECS private operator	95	129	5,689
Private	148	182	28,763
Provincial	19	54	1,565
Federal—First Nations	35	64	10,253
Federal—Corrections Canada	1	7	862
Total	**374**	**2,445**	**691,648**

Note. ECS = early childhood services

[a]Registered in 2015–2016

Alberta has several types of school authorities (Table 3.1). The majority of students attend public schools, which are primarily secular. Separate schools are primarily Roman Catholic schools that are publicly funded and managed by their own school boards. Francophone schools are also publicly funded and provide instruction in French as a first language. Charter schools are non-profit public schools that provide education in a way that differs from what is available locally (e.g., Calgary Arts Academy). Early childhood services (ECS) private operator schools offer early childhood programs. Private schools are not part of the public or separate school boards; however, they can receive some public funding. Provincial schools include institutions such as colleges that offer high school courses. Federally-funded schools in Alberta include First Nations schools and schools run by Corrections Canada. In 2015–2016, there were approximately 691,000 students registered in 2,262 schools and educational programs from early childhood through Grade 12 (Alberta Education, 2017f). The majority of these students attend schools in the large population centres of Calgary, Edmonton, Lethbridge, and Medicine Hat.

The majority of Alberta's population consists of settler people who are not indigenous to the Americas but call the province home. The 2011 census reported that 86.7% of Albertans identified English as their primary language, followed by Chinese (2.1%), Tagalog (1.4%), German (1.0%), and French (0.7%) (Statistics Canada, 2017a).

Indigenous people—First Nations (status and non-status), Métis, and Inuit (FNMI)—account for just over 5% of the population. There are 45 First Nations in three treaty areas that were established in the late 1800s; Treaties 6, 7, and 8 cover most of contemporary Alberta as well as parts of British Columbia, Saskatchewan, and the Northwest Territories. There are eight Métis settlements in northern Alberta. Approximately half of the Indigenous people live in urban areas (Statistics Canada, 2015) with Edmonton home to the second largest urban Indigenous population in Canada (Indigenous and Northern Affairs Canada, 2016). Urban populations include groups such as the Papaschase Cree, who do not fall within existing treaties

(Government of Alberta, 2013). The Indigenous population is very young, with 49% under the age of 25 (Statistics Canada, 2016); education is thus a significant concern for Indigenous communities (Wiseman, 2016). Indigenous students may attend either community-based on-reserve schools run and administered by local education authorities or provincial schools run and administered by school boards. The *Memorandum of Understanding for First Nations Education in Alberta* is a tripartite agreement signed by the Chiefs of Treaties 6, 7, and 8, the Government of Alberta, and the Government of Canada, whereby there is a shared vision for on- and off-reserve education "where First Nations students are achieving or exceeding the full educational outcomes, levels and successes of all other students in Alberta" (Confederacy of Treaty 6 First Nations, Treaty 7 Management Corporation, Treaty 8 First Nations of Alberta, Government of Alberta, & Government of Canada, 2010, p. 3).

3.2 History of Science Education in Alberta

The forces that have influenced education in English-speaking Canada have many common threads, such as the ubiquity of colonial and religious influences in its early educational history (Gustafson & Shanahan, 2010; Tomkins, 1986). There are, however, a few distinguishing features within the Alberta context. Most notably, its rural agricultural beginnings, shifts in political governance, and accompanying tensions between populist and progressive movements have influenced Alberta's educational history and contemporary practice (Taylor, 2001).

Political governance in the province has shifted among five long-serving political parties since its formation in 1905—each with its own philosophy and vision for education. From 1905 to 1921, Alberta was governed by the Liberal Party whose centrist platform was guided by the central statement "that the intelligent opinion of the people is the true and just source of all political powers" (Thomas, 1947, p. 412). As such, it sought to create an efficient and centralized system of common schools, emphasizing access to primary education for all children. This included nature study—seen as a means for shaping an "intelligent attitude towards the things of the external world" (Alberta Department of Education [ABDE], 1914, p. 51). The next half-century saw major political change with two successive populist governments in the United Farmers of Alberta (UFA) Party (1921–1935) and the Social Credit Party (1935–1971). Both sought large-scale social and political reform, including an emphasis on progressive ideals and practical subjects such as agriculture and hygiene for social improvement in primary schools. The women's branch of the UFA, in particular, fought for the inclusion of sex education in the curriculum (Finkel, 1992). In 1971, the Progressive Conservatives took power and, during their three decades of governance, oversaw several waves of curricular reform—many of which addressed narratives of increased educational accountability through highly specified outcomes-driven curricula and increased system-wide standardized testing (Wallner, 2008). The New Democratic Party was elected in 2015 on a platform of increased funding for education and accessibility for rural Albertans. A major curricular reform and redevelopment project is currently underway. Since the province's founding, this political landscape of large ideological shifts between long-serving governments has had a strong influence on the structure and goals of science education.

At the beginning of the 20th century, science education in Alberta was aimed primarily at elementary students whose courses included nature study, physiology, and hygiene (Kohlstedt, 2010). There has been a commitment and a consistent emphasis on the value of early science with nature study and later elementary science as hallmarks of the elementary school program (ABDE, 1914, 1930). High school education, however, was accessible to and designed for only those bound for careers in religious orders, teaching, law, and medicine (Chalmers, 1967). There was no required science content in secondary schools before 1890 except for a single course in physiology for those who wished to gain certification for teaching in elementary schools after high school. That year, a new provisional program added chemistry, hygiene, botany, and agriculture to an expansive program that ranged from the classical (e.g., Latin, French, geometry) to the practical (e.g., bookkeeping and spelling) (Chalmers, 1967). Curriculum for this program was set through the selection of approved textbooks rather than provincially-created curriculum guidelines. New secondary school program requirements were launched in 1906 and included courses in botany and physics in the equivalent of Grade 10, animal life and chemistry in Grade 11, and conceptual physics in Grade 12 (Chalmers, 1967). This program continued to rely heavily on approved textbooks as curriculum documents. As outlined in the 1930 *Handbook for Secondary Schools* (ABDE, 1930), normal school entrance requirements continued to be a strong influence on the creation and delivery of high school science courses. Many early 20th century Albertans attended high school for the purpose of gaining entry to normal school (Chalmers, 1967).

As the 1930s progressed, however, Alberta led the country in progressive educational reforms (Lemisko & Clausen, 2006). Influenced by the desire of the UFA's interwar government to leverage education as a means of creating a more democratic, cooperative, and transformative society, the 1936 elementary curriculum was the first in Canada to fully advocate integrated project-based teaching organized around multidisciplinary *enterprises* (ABDE, 1936; Gustafson & Shanahan, 2010; Lemisko & Clausen, 2006). The first iteration required integration only for geography, history, and civics—an integration that persists to this day; but by the revision in 1940, the Integrated Programme included science, health, and physical education (ABDE, 1940; Lemisko & Clausen, 2006). The program stated explicitly that different subjects were only to be introduced as they arose naturally during the progress of an enterprise: "No attempt is made to differentiate between the various subjects throughout the program. They appear as they contribute to a better understanding of the particular concept of study involved" (ABDE, 1940, p. 47). Elementary year programs were laid out in a series of themes (i.e., "How environment effects man's food," p. 44) upon which teachers were to develop locally-meaningful and subject-integrated guiding problems and activities for students. The program of studies provided an example enterprise on the topic of "The story of wheat" with problems such as “Types of climate and soil required for successful wheat growing [that students would address through activities such as conducting germination tests in different soils, starting a local seed club and doing] arithmetic problems dealing with the yields of wheat on Alberta farms” (p. 39). The imperative for strong rural education was a key influence in this curriculum reform because an integrated program oriented around students’ interests was considered to be well suited to one-room schools, which dominated the province’s educational system (Lemisko & Clausen, 2006).

However, concerns over the availability of appropriate resources, teacher expertise, the form and legitimacy of teacher-created assessments, and the necessity of subject area knowledge were ongoing struggles for reformers (Lemisko & Clausen, 2006). The discovery of oil at Leduc in 1947, followed by the economic boom of the 1950s, set Alberta to focus on how students could be better prepared to take advantage of its opportunities (Taylor, 2001). In the shift away from the enterprise curriculum, elementary science and health were the first subjects to be removed from the integrated program, becoming stand-alone subjects again in 1953 (Lemisko & Clausen, 2006). The new science program included lists of required concepts and scientific skills. Similarly, secondary science courses again became required elements; they had been optional under enterprise-era reforms.

From that time through the 1970s, science education aimed to provide students with a solid foundation of scientific content knowledge, presented often in the context of scientific problem solving (Roberts, 1995). Other emphases (e.g., the nature and structure of science, and relationships between science and technology) were largely absent or were presented in a way that separated and decontextualized them from the core scientific concepts (Roberts, 1995). In contrast, later reforms sought to explicitly guide teachers in approaching scientific concepts through a lens of the nature of science, science and technology, or social and environmental concerns. In addition to these curricular changes, a concurrent back-to-basics movement—pushed forward with rhetoric around parent and employer satisfaction (Panwar & Hoddinott, 1995)—arose throughout the 1970s and culminated partly in the 1980s with the reintroduction of widespread standardized testing in elementary and secondary grades (including science) and diploma examinations at the end of secondary school (Matsumoto, 2002).

3.2.1 Indigenous Education

As in other parts of Canada, the education of Indigenous young people in Alberta is caught up in the historical tensions of relationships between settler and Indigenous peoples as well as the imposition of schooling and school structures on FNMI communities. While the nature of these relationships and structures have been subject to ongoing change since the province’s founding, they are still very much at play today. Alberta’s education history thus includes residential schools and other settler government policies intent on the assimilation and cultural genocide of Indigenous peoples (Truth and Reconciliation Commission of Canada, 2015; Wiseman, 2016).

From 1905 to 1975, Alberta housed 25 federally-funded residential schools, the most of any Canadian jurisdiction (Truth and Reconciliation Commission of Canada, n.d.). These schools slowly closed as federal policy with regard to the education of Indigenous children moved to their integration and assimilation within public schools. In 1971, First Nations in northeastern Alberta staged a school strike to protest conditions in on-reserve schools (Kirkness & Bowman, 1992), which helped precipitate formation of the National Indian Brotherhood's resistance through the influential position paper, *Indian Control of Indian Education* (ICOIE; National Indian Brotherhood [NIB], 1972). In the years following ICOIE, more than 50 band-operated schools have been established in Alberta (Indian and Northern Affairs Canada, 2009).

The calls in ICOIE (NIB, 1972), combined with growing populations of urban Indigenous students, led Alberta to reconsider Indigenous education within provincial schools in the 1980s (Abele, Dittburner, & Graham, 2000; Kirkness & Bowman, 1992). In 1987, the government introduced the Policy Statement on Native Education (Alberta Learning, 2002; Betkowski, 1987) that focused on better attending to the 23,000 FNMI students in provincially-run schools. Of particular note, the policy stated that the educational projects and resources developed from funding targeted at policy implementation might benefit non-Indigenous students as well (Alberta Learning, 2002). However, the idea that the learning of all students might be enhanced by deeper understanding of the histories, contributions, and practices of Indigenous peoples was not broadly taken up by Alberta school boards, schools, or teachers until two decades later (Wiseman, 2016).

In 2002, Alberta adopted the *First Nations, Métis and Inuit Education Policy Framework* (Alberta Learning, 2002). Like the Policy Statement on Native Education, the framework focused on improving educational outcomes of Indigenous students. It supported "education programs and services which provide enhanced opportunities for *all* [emphasis added] Alberta students to develop an understanding and appreciation of Native histories, cultures and lifestyles" (p. 2), a goal that includes increasing "awareness, knowledge and understanding of First Nations, Métis and Inuit history, lands, rights, languages, cultures, and contemporary perspectives on governance, education, *science*, [emphasis added] wellness and other issues" (p. 17). Read as a whole, the framework mandates the integration of FNMI perspectives across K–12 curricula in all subject areas, including science.

3.3 Alberta Science Curriculum

In Alberta, government-defined and government-developed science curricula are referred to as programs of study. Current programs of study in the sciences are direct descendants of a major curriculum change initiated in the mid-1980s. At that time, conversations across Canada about the purposes and structures of science education (Orpwood & Souque, 1984) occurred concurrently with an Alberta Government White Paper, *Proposals for an Industrial and Science Strategy for*

Albertans – 1985 to 1990 (Government of Alberta, 1984). Both processes argued for curricula with greater attention to the nature of science and technology and their relationship to society, along with science education for citizenship, and better preparation of students for future careers and challenges (Roberts, 1995).

The attention to nature of science, technology, and society is apparent in the rationale, philosophy, and structure of the current science programs of study. The science programs at all levels are structured according to knowledge, skills, attitudes, and aspects of science, technology, society, and environment (STSE) consistent with the *Common Framework of Science Learning Outcomes, K to 12* (Council of Ministers of Education, Canada [CMEC], 1997). The programs of study follow a curriculum development framework (Roberts, 1982, 1995) in which individual units and/or outcomes are identified as having specific emphasis areas (e.g., scientific inquiry, nature of science) that must be integrated with science concepts to be meaningful. A complete listing of science curriculum topics and areas of emphasis by grade level is provided in Table 3.2.

Science courses for Grades 1–10 include a combination of topics from life science, physical science, earth science, and chemistry. The Science 1–6 program of study contains five topics at each grade level (four scientific inquiry and one technological problem solving) that can be addressed as independent units or integrated with other topics and subject areas (Alberta Education, 1996). Alberta Education (2016) recommends that science should comprise 10% of instructional time for students in Grades 1–2 and 15% for Grades 3–6.

Each course in the junior high (Grades 7–9) and high school (Grades 10–12) science programs of study, which was last updated in 2014, contains four or five science topics—each focused on one or more emphasis areas (e.g., nature of science, STSE). Most students in Grade 10 take Science 10 although students with a course grade below 50% in Science 9 are typically enrolled in Science 14. Students are required to take at least one science course in addition to Science 10 or Science 14 to obtain a high school diploma; the second course is usually a 20-level course (e.g., Biology 20, Physics 20, Chemistry 20, Science 20, or Science 24). In addition to the courses listed in Table 3.2, some schools offer locally-developed science courses (e.g., Marine Biology or Forensic Science). Alberta also has a Knowledge and Employability science curriculum (Alberta Education, 2017d) for students in Grades 8–12; these courses are designed for students who demonstrate "reading, writing, mathematical and/or other levels of achievement two to three grade levels below their age-appropriate grade" (para. 3) and "learn best through experiences that integrate essential and employability skills in occupational contexts" (para. 1).

3.3.1 Indigenous Perspectives in the Science Curriculum

Since the introduction of the *First Nations, Métis and Inuit Education Policy Framework* (Alberta Learning, 2002), changes to science curricula in Alberta have addressed the mandate for engagement with Indigenous perspectives. The first

Table 3.2 Science curriculum topics and emphasis areas

Grade/course	Topics (emphases)
1	Creating colour (SI); Seasonal changes (SI); building things (PST); senses (SI); needs of animals and plants (SI)
2	Exploring liquids (SI); buoyancy and boats (PST); magnetism (SI); hot and cold temperature (SI); small crawling and flying animals (SI)
3	Rocks and minerals (SI); building with a variety of materials (PST); testing materials and designs (SI); hearing and sound (SI); animal life cycles (SI)
4	Waste and our world (SI); wheels and levers (SI); building devices that move (PST); light and shadows (SI); plant growth and changes (SI)
5	Electricity and magnetism (SI); mechanisms using electricity (PST); classroom chemistry (SI); weather watch (SI); wetland ecosystems (SI)
6	Air and aerodynamics (SI); flight (PST); sky science (SI); evidence and investigation (SI); trees and forests (SI)
7	Interactions and ecosystems (S&E); plants for food and fiber (S&T); heat and temperature (S&E); structures and forces (S&T); planet Earth (NoS)
8	Mix and flow of matter (S&T); cells and systems (NoS); light and optical systems (NoS); mechanical systems (S&T); freshwater and saltwater systems (S&E)
9	Biological diversity (S&E); matter and chemical change (NoS); environmental chemistry (S&E); electrical principles and technology (S&T); space exploration (S&T)
Science 10	Energy and matter in chemical change (NoS); energy flow in technological systems (S&T); cycling of matter in living systems (NoS); energy flow in global systems (SEC)
Science 14	Investigating properties of matter (NoS); understanding energy transfer technologies (S&T); investigating matter and energy in living systems (S&T); investigating matter and energy in the environment (SEC)
Science 24	Applications of matter and chemical change (S&T); understanding common energy conversion systems (S&T); disease defense and human health (SEC); motion, change, and transportation safety (NoS)
Science 20	Chemical changes (SEC, S&T); changes in motion (S&T); the changing Earth (NoS); changes in living systems (SEC, NoS)
Science 30	Living systems respond to their environment (SEC, NoS); chemistry and the environment (SEC, NoS, S&T); electromagnetic energy (S&T, NoS); energy and the environment (SEC, NoS)
Biology 20	Energy and matter exchange in the biosphere (SEC, NoS); ecosystems and population change (SEC, NoS); photosynthesis and cellular respiration (S&T, NoS, SEC); human systems (S&T, NoS, SEC)
Biology 30	Nervous and endocrine systems (NoS, SEC); reproduction and development (SEC); cell division, genetics, and molecular biology (NoS, SEC); population and community dynamics (NoS, SEC)
Chemistry 20	The diversity of matter and chemical bonding (NoS); forms of matter: gases (NoS); matter as solutions, acids, and bases (S&T, SEC); quantitative relationships in chemical changes (S&T)
Chemistry 30	Thermochemical changes (S&T); electrochemical changes (S&T); chemical changes of organic compounds (SEC); chemical equilibrium focusing on acid-base systems (S&T, NoS)

(continued)

Table 3.2 (continued)

Grade/course	Topics (emphases)
Physics 20	Kinematics (NoS); dynamics (S&T, NoS, SEC); circular motion, work, and energy (NoS); oscillatory motion and mechanical waves (S&T, NoS)
Physics 30	Momentum and impulse (S&T); forces and fields (S&T, NoS); electromagnetic radiation (NoS); atomic physics (NoS)

Note. *SI* = science inquiry, *PST* = problem solving through technology, *NoS* = nature of science, *S&T* = science and technology, *S&E* = social and environmental, *SEC* = social and environmental contexts of science and technology (Alberta Education 1996, 2014a, 2014b, 2014c, 2014d, 2014e, 2014f)

program of study in the sciences to explicitly take up the requirement was Science 10 in 2005 (Alberta Education, 2014e); it was followed by the Grades 11 and 12 programs for biology, chemistry, physics, and general science in 2007 (Alberta Education, 2014a, 2014b, 2014c, 2014f). In the front matter to each program of study, a section called Aboriginal Perspectives lays out how FNMI peoples' understandings of the natural world are integrated in science curricula to "support relational thinking by integrating learning from various disciplines of science [and] develop the concept of our connectivity to the natural world and the importance of caring for the environment" (Alberta Education, 2014e, p. 2). Framing ideas in this way offers the potential to take engagement with Indigenous perspectives beyond mere curricular content add-ons; however, there are a limited number of suggestions with regard to what incorporation of Indigenous perspectives might mean or look like in terms of teaching of specific science learning outcomes.

Neither the Science 1–6 nor the Science 7–8–9 programs of study contain any explicit reference to engagement with Indigenous perspectives (Alberta Education, 1996, 2014d). Even though Science 7–8–9 has twice undergone minor revisions (i.e., 2009 & 2014) since its initial publication in 2003, in neither instance was engagement with Indigenous perspectives addressed. Despite the silence of these documents on Indigenous perspectives, the requirement remains an overarching goal of provincial programming that teachers are expected to meet. These limitations and the manner in which they impact implementation of the mandate are discussed later in this chapter.

3.3.2 Francophone and French Immersion Curriculum

In Alberta, there are four Francophone education regions of 41 schools that offer full academic programs for Francophone students; each region reports to Alberta Education in a manner similar to English language school boards. The regions are autonomous but have created the Fédération des conseils scolaires francophone de l'Alberta (2017) to enhance collaboration and advocacy for Francophone education in the province. The predecessors to these regions were created in 1994 in response to rights to Francophone education established by the Charter of Rights and

Freedoms and upheld in the Supreme Court of Canada in 1990 (Alberta Learning, 2001). Prior to that decision, rights to Francophone education were either sometimes nonexistent (e.g., in the 1950s) or at other times in the hands of local schools who could petition to offer certain allowable percentages of courses in French (Alberta Learning, 2001). In addition to Francophone education, many school boards throughout the province offer French Immersion programs that can include science instruction in French.

For much of the 20th century, programs of study were created in English, and schools that chose to offer instruction in French were responsible for meeting those expectations through French language teaching. More recent curricula, including those in science, have been created by teams that include Francophone representation. Current programs of study are identical in both languages. Because of the important role of specialized language in the sciences and the need to scaffold students to appropriate vocabulary use, in 2015 Alberta Education began publishing lexicon resources (both French to English and English to French) for biology, chemistry, and physics by providing appropriate translations and vocabulary to support students and teachers in Francophone and French Immersion settings. Similar to school boards, the Francophone school regions have the authority (as enshrined in the Canadian Charter of Rights and Freedoms) to create locally-developed courses and resources and to make decisions about which courses and programs will be offered (Goreham, 1998). In Francophone schools, all courses, except second languages, are taught in French. In French Immersion contexts, the use of French as a language of instruction for science is variable across the province. For example, within the Calgary Board of Education, French Immersion programs only offer French language science until the end of Science 9; all Grades 10–12 sciences are taught in English (Calgary Board of Education, 2016). In Edmonton Public Schools, the programs vary with some schools making high school science courses available to students in French (Edmonton Public Schools, 2013).

3.3.3 Authorized Resources

Alberta Education (2017b) provides an online list of authorized resources that have been reviewed to ensure alignment with the programs of study. Authorized resources include textbooks and teacher guides with lesson activities, videos, and interactive CD-ROMs. Although two textbook series were originally published for specific use with the Alberta elementary science program of studies, they are currently listed in the authorized resources database as out-of-print teacher resources, not student textbooks.

For Grades 7–12, each course has one or two authorized textbooks published between 2001 and 2007. These texts are specifically aligned with the Alberta curriculum and have included Alberta science teachers as co-authors. Interestingly, of the 598 authorized resources for Grades 1–12, only two were published after 2010, suggesting that the list has not been updated to include more recent resources for teaching science (Alberta Education, 2017b).

3.3.4 Provincial Science Assessments

Students in Alberta take a science Provincial Achievement Test (PAT) in Grades 6 and 9 and Diploma Examinations in Grade 12. The purpose of PATs is to determine if students are learning what is expected of them, to report on student achievement, and to monitor and improve student learning at the school, district, and provincial level (Alberta Education, 2017e). The Grade 6 science PAT consists of 50 multiple-choice questions. In 2015/2016, 22% of the questions related to inquiry and problem solving, and 78% related to the specific units from the Grade 6 program of studies. The Grade 9 science PAT consists of 50 multiple-choice questions and 5 numerical response questions that are equally distributed among the five topics in the Grade 9 program of studies. Both knowledge and skill questions are included for each topic.

The Science Diploma Examinations (Grade 12) are constructed according to an approved blueprint that is based on the program of studies. They consist of 50–60 multiple-choice and numerical response questions. Examination items are created by item-writing working groups that include teachers; are validated by teachers, curriculum representatives, and postsecondary experts; and then field-tested in volunteer classes to ensure reliability and validity. Up until 2015, 50% of each student's final course grade was based on the diploma examination results (Alberta Education, 2015). Since entrance into Alberta university programs is based on final grades in these courses, the heavy reliance on the examination as a component of the course grade made it high stakes for students intending to pursue postsecondary study. In 2015, the weighting of these examinations was reduced from 50% to 30% of the final course mark in order to reduce students' stress, increase the emphasis on classroom work and evaluations made by teachers, and acknowledge that not all outcomes from the programs of study can be assessed in one examination (Alberta Education, 2015).

3.4 Science Teacher Education

Before the late 1880s, there were no mechanisms for teacher education or certification in Alberta. Any teacher who was certified would have obtained that credential from elsewhere. At that time, union schools—integrated secondary and teacher training schools—were established in Edmonton, Calgary, Medicine Hat, and Lacombe (Fig. 3.1); as well, an examination structure was set to award certificates to teachers. The importance of science in teacher education was evident from the beginning with students seeking certification required to pass examinations in botany, chemistry, physics, and statics and hydrostatics (Chalmers, 1967). But these were merely certifications in subject knowledge (equivalent to high school leaving examinations) with no connection to pedagogy. Students from these teacher training schools were expected to learn about teaching methods and practices during their practice teaching in schools (Hollihan, 1997).

In 1905, along with the founding of province, the first normal school opened in Calgary. Two others opened in the following decades: Camrose in 1912 and Edmonton in 1921. As in other provinces, normal schools offered dedicated teacher training programs (ranging from a few months to a year in length), which later provided the foundation for university faculties of education. With the creation of the normal school system, the focus shifted from certifying that teachers held appropriate content knowledge to ensuring that they had studied the methodology of school subjects such as hygiene and agriculture. The first recognizable curriculum and instruction course was introduced in the mid-1920s; *Subjects of the public school (teaching methods and review): Elementary science* included teaching methods in geography, nature study, agriculture, physiology, and hygiene (Chalmers, 1967). The normal schools focused primarily on preparation of elementary school teachers during 4-month programs. When the first school of education opened at the University of Alberta in 1942, it differentiated itself by offering a yearlong secondary education program. Science education was part of the program, but, due to the importance of training rural teachers for teaching in the one-room schools that dominated the provincial system, students took courses in all subject areas (Chalmers, 1967). Teacher education in both elementary and secondary science is now offered by universities across the province.

3.4.1 Description of Institutions and Programs

There are four public and five private postsecondary institutions in Alberta that offer education degrees (Table 3.3). Information on the teacher education programs was retrieved from university websites (Mount Royal University, 2017; University of Alberta, 2017; University of Calgary, 2017; University of Lethbridge, 2017) and through information received by the authors from faculty and staff members familiar with the programs. It is important to note that the programs are continually changing and the information in this chapter is based on the design of the programs for the 2016–2017 school year.

The types of programs offered include 4-year Bachelor of Education (BEd), 5-year combined/concurrent Bachelor of Science (BSc)/BEd, and post-degree (consecutive) BEd. The post-degree programs are typically 2 years in length. The 5-year programs allow students to complete a BEd and a bachelor's degree from another faculty (e.g., Science) concurrently. In addition, students may start their postsecondary programs at 2-year colleges and then transfer into one of the BEd programs. The majority of these programs provide students with the option of specializing in

Table 3.3 Alberta institutions that offer education degrees

	Programs		
	4-year BEd	5-year combined BEd	Post-degree BEd
Public universities			
University of Alberta	Elementary, middle years, and secondary	Elementary and secondary	Elementary and secondary
University of Calgary	Elementary, secondary, and K–12	Elementary and secondary	Elementary and secondary
University of Lethbridge	–	K–12	K–12
Mount Royal University	Elementary	–	–
Private/religious universities			
Ambrose University	–	–	Elementary
Burman University	Elementary and secondary	–	Elementary and secondary
Concordia University	–	–	Elementary
King's University College	–	–	Elementary and secondary
St. Mary's University	–	–	Elementary

science, with the exception of the elementary and middle years 4-year and post-degree programs at the University of Alberta.

In addition to regular on-campus programs, Alberta institutions offer alternative format programs. The University of Calgary's 4-year BEd can be completed in a community-based program that includes a combination of on-campus summer courses and online fall/winter courses, allowing students to remain in their rural/remote communities for the majority of their program. The University of Alberta offers collaborative cohort programs in which students enrolled in colleges around the province can complete a BEd through courses offered on-site at the college. The programs offered at Keyano College and Grande Prairie Regional College prepare elementary teachers. The program at Red Deer College is a middle years program that focuses on teaching students in Grades 4–9; it is the only middle years program in the province. The University of Alberta's Aboriginal Teacher Education Program is an off-campus, community-based, cohort program in elementary education that is offered in partnership with tribal and community colleges.

In describing the specific requirements for teacher education programs in Alberta, we focus on the four public institutions since most teachers receive their degrees from them. The general education requirements are fairly similar. General education courses commonly required include Indigenous education; assessment; child development and learning theory; ethics; inclusion and diversity; general curriculum and pedagogy; language, literacy, and culture; and technology. Requirements for practica (e.g., clinical experiences, classroom observations, student teaching,

Table 3.4 Summary of science content and curriculum and pedagogy course requirements in teacher education programs at Alberta public universities

University	Program	Science content	Science curriculum and pedagogy
University of Alberta	Elementary and middle years (4-year and post-degree BEd)	2 courses[a] (4-year BEd; not required at entry for post-degree)	1 course (optional)
	Secondary (4-year and post-degree BEd—science specialization)	12 courses (science majors); 6 courses (science minors)	2 courses in major area; 1 course in minor area
	Secondary (5-year combined BSc/BEd)	14 courses in major area; 9 courses in minor area	2 courses in major area; 1 course in minor area
University of Calgary	Elementary, secondary, and K–12 (4-year BEd)	1 course; 8 courses (science specialists)	2 courses (science specialists); 2 courses integrative STEM/design
	Elementary and secondary (5-year concurrent BSc/BEd)	All course requirements for a BSc in natural sciences	2 courses (science specialists); 2 courses integrative STEM/design
	Elementary and secondary (post-degree BEd)	Elementary: none required at entry; Secondary: 10 courses in major area required at entry	2 courses (science specialists); 2 courses integrative STEM/design
University of Lethbridge	K–12 (post-degree BEd)	8 courses from a single science discipline or 11 courses from a general science degree (science majors)	1 course (science majors, optional for non-science majors)
	K–12 (5-year combined BSc/BEd)	16 courses	1 course
Mount Royal University	Elementary (4-year BEd)	2 courses in numeracy and scientific literacy; 6 courses (general science minors)	1 course

[a]Course refers to the equivalent of 3 credit units or approximately 27–36 instructional hours

etc.) are variable across the institutions; they range from two practicum experiences totaling 14 weeks at the University of Alberta to four practicum experiences totaling approximately 27 weeks at the University of Lethbridge.

There is also variability in the program requirements for science content courses and science curriculum and pedagogy courses (Table 3.4). At the elementary, middle years, and K–12 levels, three programs offer the opportunity for students to specialize in science; it should be noted that the University of Alberta's program was designed as a generalist program. In terms of science content courses, the University of Alberta 4-year BEd program requires all students to take two science content-focused courses, the University of Calgary requires one, and Mount Royal

University requires two courses in numeracy and scientific literacy; the other programs have no explicit requirement for students who are not specializing in science (e.g., University of Lethbridge K–12 and post-degree programs). Required science content courses for science specialists range between 6 and 16 courses.

The elementary program requirements for science content and pedagogy courses are also quite variable. The University of Calgary and Mount Royal University require all students to take science or science, technology, engineering, and mathematics (STEM) pedagogy courses. At the University of Alberta, a science curriculum and pedagogy course is optional although it is taken by most students; at the University of Lethbridge, it is required only for science specialists. The variability in requirements stems in part from the Alberta Teacher Qualification Service that requires 3 semester credits of science for certification, which can be satisfied by taking either science content or science pedagogy courses (see section on teacher certification below). This flexibility, along with other minimal requirements for certification, has resulted in the wide range of ways that institutions have designed their programs that prepare elementary teachers to teach science.

In addition to the K–12 focused programs, only the University of Alberta and University of Calgary have programs specifically designed for preparing secondary science teachers. The University of Calgary program has a STEM focus and requires all students to take curriculum and pedagogy courses related to STEM and design thinking in addition to the science curriculum and pedagogy courses taken by science specialists. In the University of Calgary secondary program, students' curriculum and pedagogy coursework is organized around a single major specialization. At the University of Alberta, secondary program students choose a teachable major and minor (certified teaching area); only students with a major or minor in science are required to take science content and pedagogy courses.

3.4.2 Requirements for Science Teacher Certification and Preparation

The current certification structure—an interim certificate followed by a permanent certificate after a period of professional practice—has been the policy in Alberta since at least the beginning of the normal school era in 1906 (Chalmers, 1967). Interim Professional Certificates are issued for 3 years, and extensions may be granted. An Interim Professional Certificate is replaced by a Permanent Professional Certificate when a teacher completes the requirements contained in the *Teaching Quality Standard Ministerial Order*, which include teaching the equivalent of 2 full school years in a setting approved by the Minister (Government of Alberta, 2016b). Education requirements for Interim Professional Certificates are either (a) a BEd degree or (b) a degree in another field approved by the Minister, as long as it includes or is supplemented with a teacher preparation program that meets the requirements for professional teacher certification. The minimum requirements include 48 credits (approximately 16 courses of 36 hrs each) in a professional teacher education program, including 10 weeks of practicum experience. The requirements for Interim Professional Certificates for elementary teachers include a minimum of 3 credits (approximately 36 hrs) in each of the following: science, mathematics, Canadian studies, and English/French literature and composition (Alberta Education, 2017c). The requirement for science can be met by taking a single science content course or science pedagogy course. Secondary teachers are required to complete a minimum of 24 credits (approximately 8 courses of 36 hrs each) in a teachable subject area (e.g., physics) and 6 credits (approximately two courses of 36 hrs each) in English/French literature and composition.

3.5 Professional Development

Teachers in Alberta have access to a range of professional development (Pro-D) opportunities offered at the local, regional, and provincial level (e.g., Alberta Regional Professional Development Consortia); however, few of these opportunities are specific to science teaching. All teachers in Alberta are required to attend a 2-day convention organized by the Alberta Teachers' Association (ATA), as mandated in the *School Act* (Government of Alberta, 2015). The availability of science-specific sessions at these conventions varies from year to year. In addition, all teachers are required to develop and implement an annual professional growth plan that outlines the Pro-D activities that they will engage in during the year (ATA, 2017).

The ATA Science Council holds an annual conference that includes a range of science-specific sessions. Attendance at this conference is not required for science teachers; however, the conference is typically attended by 200–250 annually out of a total number of 1,222 teachers registered with the science council as of May 2017 (ATA, personal communication, May 11, 2017). The 2016 conference had 37 sessions where presenters shared resources, lesson ideas, and instructional approaches for teaching science. Past keynote speakers have included internationally known personalities such as Bill Nye and Jane Goodall. There are also a number of organizations within the province that provide Pro-D opportunities, some of which may be science specific. For example, Alberta Education recently offered Pro-D sessions on the science diploma examinations. In southern Alberta, science-specific Pro-D is available through the Galileo Network, which is an independent organization housed within the Werklund School of Education at the University of Calgary. The Alberta Science Network offers teacher workshops for Grades 1–9. Teachers may apply for Pro-D opportunities outside of the province or country with approval by the school and/or the ATA.

3.6 Discussion

This section aims to identify particular characteristics of science teaching, learning, and teacher education in the province that are noteworthy or may differentiate Alberta from other provinces. Specifically, we explore the relationship between Alberta science curriculum goals and classroom practice, the integration of Indigenous perspectives in the science curriculum, science in Francophone schools, and teacher certification.

3.6.1 Science Curriculum

Although the Alberta science programs of study are well aligned with the philosophy and goals of the *Common Framework* (CMEC, 1997), research has consistently identified a gap between these well-articulated goals and classroom practices. This misalignment is surely not an issue confined to Alberta, but it has been widely studied at all levels of Alberta science education.

Rowell and Ebbers (2004), for example, examined the inquiry language used in the introduction section of the elementary program. They argued that the introduction espouses a deep integration of open inquiry opportunities, where student questions should guide classroom activities and students should become deeply invested in engaging in the processes of science. However, they noted that the organization of the individual units heavily emphasizes mandated skills and knowledge, leading teachers toward activities that begin with teacher questions and proceed through unproblematic confirmation activities. The purpose for engaging in inquiry activities becomes oriented toward student acquisition of specific knowledge and skills. Moreover, they argued that the language used to express these expectations (e.g., describe, identify, provide) is suggestive of a framework of accountability rather than one of authentic science inquiry. In practice, they found that the knowledge and skill statements became an authoritative voice in the classroom in the same way that a mandated textbook might.

Gustafson, Macdonald, and d'Entremont (2007) noted a similar mismatch in the relationship between science and technology in the elementary program. Their literature review, commissioned by Alberta Education, highlighted a problem in the way that technological problem solving is positioned in the curriculum. Rather than being organized in an integrated science-technology-society sense, each grade has one unit of the science program designated as "Problem solving through technology." In Grades 2–6, the topic is related to one of the other units (e.g., "Science inquiry: Air and aerodynamics" and "Problem through technology: Flight"). This organization has been argued to be insufficient to help students understand interconnections between science, technology, and society and may instead contribute to building on the misconception that technological problem solving is merely applied science (NGSS Lead States, 2013, Appendix I; Rowell, Gustafson, & Guilbert, 1999). Rowell et al. (1999) suggested that this organization pattern may emphasize design skills and products as valued outcomes in and of themselves rather than as opportunities and vehicles for conceptual understanding and critical thinking.

Julien and Barker (2009) and Barker and Julien (2012) noted similar gaps between curriculum intentions and practice in relation to information literacy in high school biology programs. They argued that the narrative of the Alberta Biology 20–30 curriculum very strongly encourages nuanced and refined skills for evaluating sources, gathering evidence, and integrating and synthesizing across sources (Julien & Barker, 2009). In practice, however, there is much stronger emphasis on what information students find than on how they access, evaluate, and work with that information. Students tended to equate information-seeking practices with the use of typical authoritative sources (e.g., gathering factual information from websites and textbooks) rather than engaging in assessing the quality of data and information (Barker & Julien, 2012). They suggested that assessment practices, especially in standardized assessments such as the provincial diploma examinations, are a key constraint (Julien & Barker, 2009). Concerns around teacher autonomy and pressure to teach in ways that ensure diploma examination success have consistently been perceived by Alberta teachers (McDonald, 2002). Those examinations emphasize factual and conceptual knowledge and rarely address the processes of evaluation of that knowledge, leading to pressure on students and teachers to maintain the same focus in their classroom activities despite the narrative presented by the curriculum documents.

Chu (2012) surveyed perceptions of the Physics 20–30 curriculum emphases among preservice teachers, inservice teachers, and a curriculum leader from Alberta Education. There was a significant difference in perceptions between the teachers and the curriculum leader. Where the teachers' view emphasized student understanding of the structure of science and correct explanations, the curriculum leader's view emphasized the student as knower and explainer—a view more in line with the front matter of the curriculum documents but perhaps undermined by the organization of the individual units. Chu (2012) underscored the way in which the diploma examinations mediated teachers' use of the curriculum documents as well:

> In some classrooms the measure of success for teachers and students is not necessarily how well the program-of-study was taught, but how students perform on the summative Alberta Diploma exam. … For some teacher participants, the message of the diploma exam is heard much louder than the intent/s of the program-of-study even though the exam is made to support the program. (p. 98)

There has been a strong and ongoing tradition of research into the impact of the curriculum on students and ongoing dialogue between researchers and Alberta Education—as evidenced by the literature reviews that have contributed and continue to contribute to curriculum change processes. This research suggests that there are still gaps between the science education experience that curriculum leaders wish to create and the experiences that students and teachers have in classrooms across the province.

3.6.2 Indigenous Perspectives and First Nations, Inuit, and Métis Education

Another area where gaps persist is the integration of Indigenous perspectives in science curricula. While Alberta Education has explicitly expressed a commitment to infuse Indigenous perspectives within provincial curricula for 15 years (Alberta Learning, 2002), there are ongoing challenges to implementation in the sciences. In high school, the Aboriginal Perspectives section (e.g., Alberta Education, 2014e) in the front matter of science programs of study for Grades 10–12 opens up potential for deep consideration of Indigenous ways of knowing, being, and doing that fits well with program commitments arising from the *Common Framework* (CMEC, 1997), such as relationships, interdependencies, and stewardship. At the same time, there is no explicit direction or explanation for teachers in terms of philosophical or pedagogical grounding with respect to infusion of Indigenous perspectives. While program outcomes and expectations include some explicit reference to Indigenous people, peoples, communities, and/or their ways of knowing, being, and doing, the vast majority of these references appear only in italics as suggested content. In fact, there are only two instances where teachers and students must engage with Indigenous perspectives; both appear in the same unit of Science 30 (Alberta Education, 2014f). Many of the examples provided have the potential to lead to ongoing conversations and rich explorations. For instance, in the Biology 20 (Alberta Education, 2014a) unit on Ecosystems and Population Change, one outcome states:

> [Students will] explain how conventions of mathematics, nomenclature and notation provide a basis for organizing and communicating scientific theory, relationships and concepts
>
> - *research the historical development of the modern classification system*
> - *research plant and animal systems of classification developed by Aboriginal peoples in their cultural practices.* (p. 28, italics in original)

Classification is an interesting location for exploring Western and Indigenous perspectives in science; Western approaches tend to focus on unobservable, genetic relationships between organisms and Indigenous approaches on the place of an organism within a more dynamic web where relationships (e.g., trophic interactions) are implicit (CMASTE, 2017). However, because the example is only a suggestion, teachers who are experiencing tension around infusion can opt out of using it, leading to "death by suggestion" (Wiseman, 2016, p. 163)—a situation where provincial/territorial governments can technically meet the commitments made in broad policy with respect to integration of Indigenous perspectives in K–12 science curricula while morally abandoning them (Paquette & Fallon, 2010).

At the elementary and middle school levels, the situation is more challenging. Current programs do not include explicit reference to Indigenous perspectives in either front matter or content outcomes. As such, it is challenging for teachers to consider how the mandate for infusion should be taken up. At the same time, the lack of specifics in the K–9 programs opens up the potential for interesting and rich explorations of infusion, provided teachers are willing to develop their own lessons. Research indicates that such self-directed development of learning opportunities is challenging for teachers due to, among other things, perceived lack of resources, time, and understanding of Indigenous perspectives (Blood, 2010; Donald, 2009; Kanu, 2011; Wiseman, 2016). While teachers express the need for Pro-D in this regard, it can be challenging for them to access opportunities related to Indigenous perspectives due to difficulty getting approval from administrators to pursue Pro-D that may not be seen as directly relevant to their teaching assignment (Wiseman, 2016).

3.6.3 Francophone Schools

Students in Francophone schools sometimes face additional obstacles in comparison to their Anglophone counterparts. These challenges are often apparent in the results of international tests, such as PISA, where Francophone students in Alberta score consistently lower in all three test area subscales: competency, knowledge, and content area (O'Grady et al., 2016). These lower results may be because science learning is inextricably a language-oriented process. In Francophone minority language communities where students are often immersed in English popular culture, their needs are not well represented in the models for engaging with scientific language that are appropriate for native speakers nor those developed for English Language Learners (Rivard & Cormier, 2008). In minority language situations, Francophone students often experience limited opportunities for diverse literacy and conceptual opportunities in their first language (Rivard & Cormier, 2008). However, Gustafson et al. (2007) noted that there is scant research specifically addressing the needs, strengths, and challenges of Francophone students in Alberta. It will be important for future research to address the gaps experienced by Alberta's Francophone students.

3.6.4 Teacher Education

In Alberta, students can attain teacher education degrees with an emphasis on the elementary, middle years, secondary, or K–12 level. However, there is no *typical* teacher education program in the province. Elementary teacher education programs range from specialist programs in which students may select science as a teaching area focus or minor (e.g., University of Calgary) to more generalist programs where students take content and curriculum and pedagogy courses in a wide range of subject areas, including science (e.g., University of Alberta). Therefore, the elementary programs are quite variable in regard to requirements for taking science pedagogy and science content courses. Of the four public institutions, only the University of Alberta and the University of Calgary offer programs specifically focused on secondary science teaching.

Even though program and certification requirements are different for elementary and secondary teachers, the Interim and Permanent Professional Certificates do not specify grade level or teachable subject area; therefore, Alberta-certified teachers can be hired to teach any subject and any grade level. This flexibility allows schools to hire teachers who are the best fit for the positions independent of the specific program route that they followed during their teacher education program. On the other hand, it can provide challenges for teachers hired to teach outside of the area for which they were educated. For example, teachers who studied to be elementary teachers—possibly with only one science content or science pedagogy course—could be asked to teach secondary science, or someone educated as a secondary science teacher could be asked to teach all subjects at the elementary level.

3.7 Concluding Thoughts

Science education in Alberta has been influenced by a complex past, including an agricultural- and resource-based economy, shifts between progressive and populist governments, and relationships with Indigenous and Francophone peoples and communities. This complexity has resulted in pushes and pulls between progressive educational philosophies (e.g., enterprise approach) and content-heavy curricula (e.g., Biology 20–30). Influences of this history can be seen in the lack of specificity in the teacher certification requirements and a resultant diversity in science teacher education programs. It has resulted in a strong commitment to infusing Indigenous perspectives in the curriculum, but it has encountered challenges in the implementation. As Alberta is poised for a new round of curriculum revision "unlike any seen in Alberta" (French, 2016, para. 1), it is yet to be determined in what direction these complex influences will lead.

Acknowledgments We would like to acknowledge everyone who contributed to this chapter by sharing their expertise, experiences, and knowledge. Thank you to Stan Bissell, Brenda Gustafson, Frank Jenkins, Richelle Marynowski, Bob Ritter, and Gladys Sternberg.

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Chapter 4
Science Education in Saskatchewan: Inquiry and Indigenizing

Tim A. Molnar, Dean Elliott, and Janet McVittie

Abstract Science education in Saskatchewan involves unique challenges borne of having urban and rural, Indigenous and non-Indigenous, and immigrant populations dispersed across a large geographical area. This context impacts the crafting of science curricula, provision of cohesive and comprehensive science educator programs and professional development, and consistency in assessment. Publically funded education occurs through public, separate, and Francophone school divisions with federal involvement on Indigenous reserves. Science teacher education occurs through two public universities; both offer direct entry and post-degree programming with similar course requirements. Other organizations under the auspices of these universities also deliver teacher education. Primary challenges for those involved in advancing science teaching and learning involve employing inquiry approaches, engaging in Indigenous ways of knowing, and advancing a variety of assessment approaches.

4.1 Introduction

This chapter provides an overview of science education in Saskatchewan. It includes discussion of the context within which science education occurs, recent curricular developments and focus, preparation of science teachers at postsecondary educational institutions, professional development, and some general commentary on what the authors perceive as the various opportunities and challenges relating to these topics.

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C. D. Tippett, T. M. Milford (eds.), *Science Education in Canada*,
https://doi.org/10.1007/978-3-030-06191-3_4

4.2 Demographics

Saskatchewan is a province with a sparse population spread over a vast geographical area of more than 650,000 km^2. The population has fluctuated around 1 million since the 1930s, reaching approximately 1.1 million as of 2016 (Statistics Canada, 2017). This combination—a small population dispersed over a wide area—has strongly influenced the structure of educational governance and funding as well as issues related to curriculum, instruction, and assessment.

Saskatchewan was a predominantly rural province until the 1970s when factors such as the changing role of agriculture led to a population shift; approximately two-thirds of its population now reside in urban areas. The two largest population centres, Saskatoon and Regina (Fig. 4.1), have 295,000 and 236,000 residents, respectively (Statistics Canada, 2017). Regina is the provincial capital. The next 10 largest population centres—Prince Albert, Moose Jaw, Yorkton, Swift Current, North Battleford, Estevan, Weyburn, Lloydminster, Martensville, and Warman—range from 5,000 to 35,000 residents (Statistics Canada, 2017).

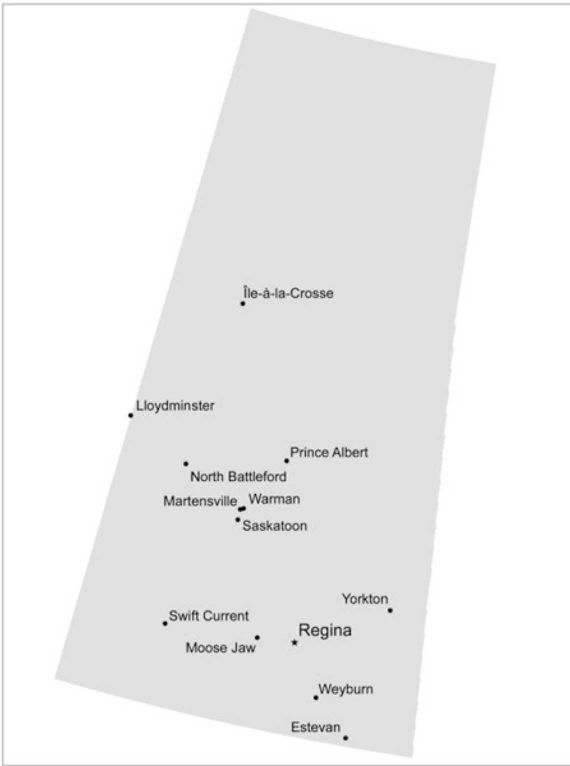

Fig. 4.1 Map of Saskatchewan

4.3 Educational Context

The structure of K–12 education in Saskatchewan has been driven by the need to provide publicly accessible education to a diverse population. Governments have grappled with the requests of various stakeholders who desired alternatives to the status quo, including Indigenous, Francophone, and religious minorities.

4.3.1 School Divisions

The authority to establish school districts, designated as either Protestant or Catholic, was first granted by the 1884 *Ordinances of the North-West Territories*, some 21 years before Saskatchewan was established as a province in 1905 (Scharf, 2006). School districts were established to provide local control over education, which in the early 1900s typically meant a single one-room school in each school district. The Saskatchewan Act of 1905 granted responsibility for education to the province while also affirming the right to form Protestant or Catholic separate schools. From a peak of over 5,000 rural school districts in the 1930s, governance changes resulted in 150 school districts by the 1980s, and then consolidations to 118 school divisions as of 1998, and a name change from school *district* to school *division* (Owen, 2006); many divisions were comprised of only a few schools.

Following the government-commissioned report on K–12 education *Finding the Balance* (Government of Saskatchewan, 2003), the government formally mandated additional school division amalgamations. In 2004, the Education Equity Task Force was established to determine boundaries for new school divisions. Subsequently, 65 school divisions were amalgamated into 14 divisions, while another 14 remained unaffected. Of the current 27 school divisions in Saskatchewan, 18 are public, eight are separate (Roman Catholic), and one is Francophone. Additionally, 70 First Nations receive education funding from the federal government for students between the ages of 4 and 21 who live on reserves (Indigenous & Northern Affairs Canada [INAC], 2010; 2017). Most recent data (Table 4.1) indicate there were approximately 192,000 K–12 students enrolled in 605 public schools, 133 separate schools, 15 *écoles fransaskoises*, and 100 First Nations-administered schools in the 2015–2016 school year (Indian & Northern Affairs Canada, 2009; Saskatchewan Ministry of Education [SME], 2015b).

The single Francophone school division—the *Conseil des écoles fransaskoises*—was established in 1995 and represents the whole province. Students enrolled in Francophone schools receive their entire instruction in French. Students enrolled in French Immersion programs in public or separate schools receive some instruction in French. Denis (2006) provides a thorough background of Francophone education in Saskatchewan.

Approximately 16% of Saskatchewan's population is classified as Indigenous: 10% First Nations, 5% Métis, and less than 0.01% self-identifying as Inuit

Table 4.1 2015–2016 K–12 student enrolment across divisions

Grade	Public schools	Separate schools	French Immersion[a]	*Conseil des écoles fransaskoises*	First Nations-administered schools
K	10,299	3,316	1,691	190	1,385
1	10,801	3,503	1,684	209	1,593
2	10,511	3,377	1,612	165	1,497
3	10,454	3,299	1,398	156	1,385
4	9,963	3,196	1,230	130	1,361
5	9,657	3,097	1,110	143	1,245
6	9,833	2,955	995	105	1,128
7	9,592	2,979	970	101	1,123
8	9,445	2,897	807	88	1,068
9	10,064	2,732	640	81	1,048
10	10,880	2,833	593	78	1,285
11	10,315	2,558	561	77	857
12	12,859	3,190	496	72	1,002
Total	**134,673**	**39,932**	**13,787**	**1,595**	**15,977**

Note. Adapted from Saskatchewan Ministry of Education (2015b)
[a]French Immersion data are included within public and separate schools data

(Saskatchewan Bureau of Statistics, 2013). The responsibility for education of Indigenous people is a complex combination of federal, provincial, and First Nations governments. There are nine Tribal Councils in Saskatchewan that coordinate and manage K–12 education programs and services in collaboration with their member First Nations bands and nine First Nations not affiliated with a Tribal Council who manage their own K–12 education programs and services (Aboriginal Affairs & Northern Development Canada, 2014).

Each of Saskatchewan's 12 urban centres is home to numerous elementary schools (Kindergarten through Grade 8 or 9) with 100–600 students and 1 or more secondary schools (Grade 8 or 9 through 12) with 400–1,900 students. Many of the 140 or so smaller communities in the province are in a rural or remote location and have a single K–12 school typically with fewer than 200 students, most of whom are bused to school. Although there are a few exceptions, the middle school or junior high school model is not common in the province.

4.4 Curriculum Development

The Ministry of Education released the policy document *Core Curriculum: Plans for Implementation* (SME, 1987), which was an articulated, aligned framework for Kindergarten through Grade 12 education (Robinson, 2006). This document included Required Areas of Study (language arts, mathematics, science, social studies, health education, arts education, and physical education), Common Essential Learnings (communication, numeracy, critical and creative thinking, technological literacy, personal and social values and skills, and independent learning), as well as locally-determined options, adaptive dimension, and time and credit allocations. Science curriculum documents for Grades 1–5 and Grade 10 were released in 1990; documents for Grades 11 and 12 Biology, Grades 11 and 12 Chemistry, and Grades 11 and 12 Physics were released in 1992; and documents for Grades 6–9 were released in 1993.

The most recent general curriculum revision began in 2005 with a review of research to determine philosophical directions for all K–12 curricula. These directions included outcomes-based curricula; simultaneous development of curricula in English and French; infusion of Indigenous content, perspectives, and ways of knowing into all curricula; a comprehensive plan to strengthen teaching and improve student learning; and collaboration with educational partners and stakeholders (D. Elliott, personal communication, October 3, 2016). As shown in Fig. 4.2, the Cross-Curricular Competencies (thinking, identity and interdependence, literacies, social responsibility) are a synthesis of the Common Essential Learnings. The Broad Areas of Learning are a synthesis of the 1984 Goals of Education. (SME, 2009). The current Saskatchewan science curriculum (SSC), with a philosophical orientation toward inquiry, was developed in consultation with K–12 teachers, school division personnel, university faculty, and stakeholders from industry (e.g., mining, agriculture), outreach organizations (e.g., Saskatchewan Science Centre, Let's Talk Science), and Indigenous communities.

Each curricular area has an overarching aim along with three to four goals. The aim for K–12 science is to develop scientific literacy for all students, where:

> Scientific literacy today embraces Euro-Canadian and Indigenous heritages, both of which have developed an empirical and rational knowledge of nature. A Euro-Canadian way of knowing about the natural and constructed world is called science, while First Nations and Métis ways of knowing nature are found within the broader category of Indigenous knowledge. (SME, 2009, p. 5)

The four goals for science mirror those of the *Common Framework of Science Learning Outcomes K–12* (Council of Ministers of Education, Canada [CMEC], 1997): understand the nature of science and science, technology, society, and the environment (STSE) interrelationships, construct scientific knowledge, develop scientific and technological skills, and develop attitudes that support scientific habits of mind.

Figure 4.3 shows the relationships between the aim, goals, and four learning contexts—scientific inquiry, technological problem solving, STSE decision making, and cultural perspectives—that provide teachers with different entry points into the curriculum for engaging students. This representation and these entry points support specific lesson planning and sequencing to ensure connections and progression amongst the knowledge, attitude, skill, and STSE learning over science courses and individual units of study.

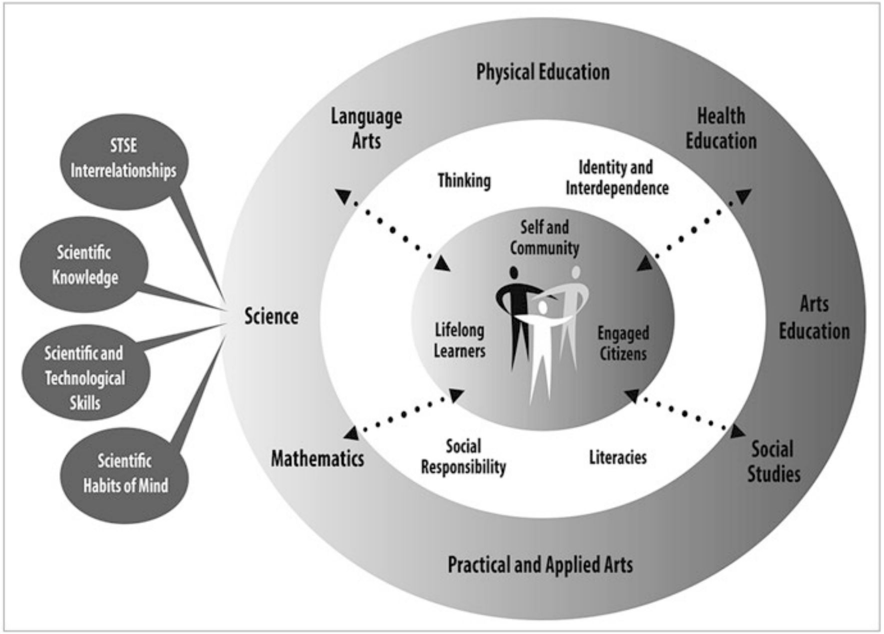

Fig. 4.2 Conceptual foundations for Saskatchewan's curriculum (SME, 2009, p. 7). The inner layer shows broad areas of learning; the middle layer lists cross-curricular competencies; the outer layer shows required areas of study. The callouts on the left are the four goals for science that mirror the foundations of the *Common Framework* (CMEC, 1997). (Copyright 2009 by the Saskatchewan Ministry of Education)

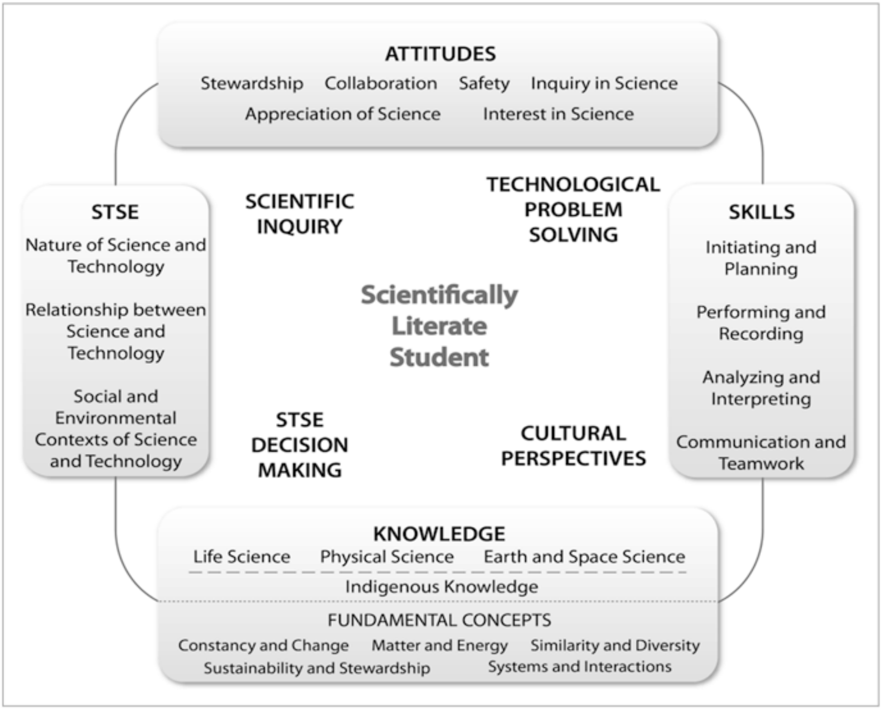

Fig. 4.3 Aim, goals, and entry points for K–12 scientific literacy (SME, 2009, p. 11). (Copyright 2009 by the Saskatchewan Ministry of Education)

Mandatory learning outcomes delineate what students should know and be able to do upon completion of the grade or course. Indicators describe ways that students might demonstrate achievement of an outcome and clarify the breadth and depth of each outcome (SME, 2010). For example, an outcome for the Grade 8 unit Cells, Tissues, Organs, and Systems is “Analyze the characteristics of cells, and compare structural and functional characteristics of plant and animal cells” (SME, 2009, p. 30). Some of the suggested indicators for this outcome include:

- Categorize organisms as single-celled and multi-cellular
- Explain how growth and reproduction of living organisms depends on cell division
- Design and carry out an experiment to demonstrate the function of selectively permeable membranes in cells (SME, 2009, p. 30)

The current SSC includes a few broad learning outcomes with a wide range of indicators, which allows teachers flexibility to tailor learning and assessment to individual learners. Teachers can also develop their own indicators as long as those indicators maintain the intent of the outcome (SME, 2010). The possibility for individualized indicators allows teachers to craft engaging and meaningful learning experiences for a diverse range of students; it also provides increased autonomy for teachers and learners in deciding how mandated learning outcomes will be met.

4.4.1 Science Curriculum: Kindergarten Through Grade 9

Science education begins in Kindergarten. In English settings, 150 minutes per week of science instruction is required in each of Grades 1–9. In both French Immersion programs and Fransaskois schools, 120 minutes per week are required for Grades 1–9, with the exception of Fransaskois Grades 4 and 5 where the requirement is 160 minutes. The topics of study for Kindergarten through Grade 9 for the English, French Immersion, and Fransaskois curricula follow the *Common Framework* (CMEC, 1997): one life science, two physical sciences, and one earth and space science (Table 4.2).

Table 4.2 K–9 science topics

Grade	Life science	Physical science	Earth and space science
K	Living things in our environment	Observing forces and energy Objects and materials	Exploring our natural surroundings
1	Needs and characteristics of living things	Using objects and materials Using our senses	Daily and seasonal changes
2	Animal growth and changes	Liquids and solids Motion and relative position	Air and water in the environment
3	Plant growth and changes	Structures and materials Magnetism and static electricity	Exploring soils
4	Habitats and communities	Light Sound	Rocks, minerals, and erosion
5	Human body systems	Properties and changes of materials Forces and simple machines	Weather
6	Diversity of living things	Understanding electricity Principles of flight	Our solar system
7	Interactions within ecosystems	Mixtures and solutions Heat and temperature	Earth's crust and resources
8	Cells, tissues, organs, and systems	Optics and vision Forces, fluids, and density	Water systems on Earth
9	Reproduction and human development	Atoms and elements Characteristics of electricity	Exploring our universe

4.4.2 Science Curriculum: Grades 10 Through 12

Science is mandatory until Grade 11 although there are a number of options for Grades 11 and 12 science courses (Table 4.3). Within the 24 credits (a 100-hour course equals 1 credit) required for graduation, 2 must be in science, meaning that all students must complete Science 10 and at least one Grade 11 science course. School divisions may also offer locally-developed electives at the high school level; examples include Astronomy, Paleontology, and Forensic Science. Although these courses do not meet the graduation requirements for science, they do count toward credits needed to graduate.

The Grade 10 topic of Climate and Ecosystems represents a synthesis of the *Common Framework* (CMEC, 1997) topics of Sustainability of Ecosystems and Weather Dynamics; the other two topics remain essentially unchanged from those in the *Common Framework*. In Grade 11, the traditional single-discipline courses of Biology, Chemistry, and Physics were replaced by interdisciplinary courses (i.e., Health Science, Environmental Science, and Physical Science) and Computer Science to more closely reflect student interests and common employment sectors; each course includes an outcome related to career exploration. The names Biology, Chemistry, and Physics were retained for Grade 12 to align with postsecondary institution prerequisite requirements; and a new earth science course was developed. All current secondary science curricula were released during 2016–2018. The French curricula have been revised along similar timelines.

4.4.3 Science Resources

Lists of recommended science resources are created through a teacher review process and are accessible through the SME website (www.curriculum.gov.sk.ca); schools are not required to follow these suggestions. Given Saskatchewan's small population, there have rarely been customized resources that align with provincial science curricula. However, in 2008, SME partnered with Pearson Education Canada to develop customized science textbooks in English for Grades 3–9 and in French for Grades 6 and 7. These resources also included Indigenous perspectives, for which they have received formal recognition nationally and internationally. Throughout the textbooks, activities and achievements of Saskatchewan women and

Table 4.3 Science courses and topics in Grades 10, 11, and 12

Grade 10	Grade 11	Grade 12
Science 10 • Climate and ecosystem dynamics • Chemical reactions • Force and motion in our world	Environmental science 20 Health science 20 Physical science 20 Computer science 20	Biology 30 Physics 30 Earth science 30 Computer science 30

men are provided in the "Ask an Elder," "Ask an Expert," and "Careers and Profiles" features. With the support of SME, Pearson Education Canada developed customized teacher resources and support materials for Grades 1 and 2. Similar partnerships for Grades 10–12 were deemed financially unfeasible.

4.5 Assessment

Saskatchewan science teachers assess their students according to the mandatory learning outcomes for each grade. They may use suggested learning indicators to help them formulate assessment. This flexibility in the structure of the SSC supports teachers' professional autonomy to develop appropriate and individualized assessment approaches, which would include assessment *of, for,* and *as* learning that address accountability, guides and informs learning, and provides unique learning opportunities. The assessing, evaluating, and reporting of student achievement of science learning outcomes is guided by school division policies. Some school divisions require teachers to report student achievement for each learning outcome; many divisions have developed outcomes-based report cards.

Some Grade 12 science students participate in provincial assessments as well as classroom assessments, and the province participates in both national and international large-scale assessments of science achievement. Saskatchewan has a unique approach to Grade 12 provincial assessments, which are currently administered in science, mathematics, and English language arts depending on school division policy and whether the responsible teacher is accredited or nonaccredited. To qualify for accreditation in Grade 12 Biology, Chemistry, or Physics, a teacher must have acquired 2 years of teaching experience, attended an accreditation seminar, completed 21 credit hours of relevant academic courses, and completed 3 credit hours in a professional education course (SME, 2015a). Accredited teachers are able to determine final marks for Grade 12 courses; however, students of nonaccredited teachers must write provincial examinations, which count for 40% of the final mark and are developed by the SME in collaboration with accredited teachers. Some school divisions do not support accreditation for their teachers and require all students to write provincial examinations.

At the national level, Saskatchewan participates in the Pan-Canadian Assessment Program (PCAP), which takes place every 3 years. In 2013, Saskatchewan scored 486 in science, significantly lower than the Canadian mean set at 500 (O'Grady & Houme, 2014). At the international level, Saskatchewan participates in the Programme for International Student Assessment (PISA). In 2015, Saskatchewan scored 496 in science, significantly below the Canadian mean of 528 but slightly above the OECD average established at 493 (O'Grady, Deussing, Scerbina, Fung, & Muhe, 2016).

4.6 Teacher Education

There are two public universities in Saskatchewan, the University of Saskatchewan (UofS) and the University of Regina (UofR); both offer education programs. Saskatchewan education degrees require the completion of 120 credit units (CU) with a minimum of 48 CUs of teacher education courses; 1 CU constitutes approximately 13 hours of contact time. An internship, or practicum placement, of approximately 16 weeks is required.

There are four pathways that can be followed to obtain a degree that leads to teacher certification: direct entry, transfer, concurrent, and post-degree programs (Table 4.4). The transfer pathway—once the only route at the UofS—allows students to enter the College of Education after completing some university courses and results in a Bachelor of Education (BEd). The post-degree pathway is an after-degree program that results in a Bachelor of Education After Degree (BEAD) as opposed to a BEd and is only available at the UofR.

Constructivist learning theory undergirds these teacher education programs, which involve coursework in educational philosophy, psychology, administration, and curriculum. Typically, this coursework includes topics such as educator identity, anti-oppressive and ethical pedagogy, place- and land-based pedagogies, and evaluation and assessment. Methods courses are offered for subject areas including English language arts and literacy, mathematics, science, and social studies. Anti-racism, cross-cultural, and Indigenous education courses are offered in addition to being frequent topics within other courses.

Table 4.4 Programs and pathways leading to teacher certification in Saskatchewan

<table>
<tr><th rowspan="2">Institution</th><th rowspan="2">Program (Grades)</th><th colspan="4">Pathways</th></tr>
<tr><th>Direct entry BEd</th><th>Transfer BEd</th><th>Concurrent combined BEd[a]</th><th>Post-degree BEAD</th></tr>
<tr><td>University of Saskatchewan</td><td>Elementary/middle years (K–8)
Secondary (9–12)</td><td>✓</td><td>✓</td><td>With kinesiology or music</td><td>–</td></tr>
<tr><td>University of Regina</td><td>Elementary
• Early elementary (preK–5)
• Middle years (6–9)
• Baccalauréat en éducation élémentaire
Secondary
• 10–12
Baccalauréat en éducation secondaire</td><td>✓</td><td>✓</td><td>With kinesiology, mathematics, or music</td><td>✓</td></tr>
</table>

Note. BEd = Bachelor of Education; BEAD = Bachelor of Education after degree
[a]Not a path to science specialization

There are a number of partner organizations that provide routes to obtaining an education degree. The First Nations University of Canada (FNUC), Saskatchewan Urban Native Teacher Education Program (SUNTEP), Northlands College, and the Indian Teacher Education Program (ITEP) all provide opportunities for people, usually of Indigenous heritage, to complete coursework that would lead to an education degree at the affiliated university. FNUC is a federated college at UofR that offers a secondary teacher education route. SUNTEP, part of the provincially-funded Gabriel Dumont Institute, offers programs for Métis students in Prince Albert and Saskatoon as part of UofS programming and in Regina as part of UofR programming. With the recent closing of the Northern Teacher Education Program (NORTEP) after 40 years, Northlands College now offers teacher education in coordination with UofS. ITEP, housed within the UofS College of Education, provides community-based programming across Saskatchewan. Each of these partnerships includes the necessary science methods courses required for the education program from their affiliated university.

4.6.1 Science Teacher Education

Given the philosophical foundation of science curricula documents in Saskatchewan, there is clear direction to provide teacher candidates with opportunities to develop inquiry pedagogy. Science methods courses emphasize *hands-on, minds-on* approaches and address problem solving, questioning, investigating *big ideas*, integrating across subject areas, and building on student interests. Indigenous knowledge systems are acknowledged as valid in their own right and in relation to Euro-Canadian or Western modern science and are explored through activities that often call on local knowledge keepers.

4.7 Elementary

A central concern in UofS elementary/middle years (K–8) and UofR elementary (preK–9) programs is helping teacher candidates to develop their confidence and reduce their anxiety about teaching science. At UofS, elementary/middle years teacher candidates are required to have both a first and second teaching area, with 18 CUs of content area coursework in the first area (e.g., science) and 12 CUs of content area coursework in the second teaching area. Students in the direct entry pathway at the UofS have a choice of taking either a science or mathematics course, in addition to science methods courses, delivered by the College of Education. In addition, they are required to take one 3-CU science methods course. In 2016, 10 of the 113 elementary/middle graduates from UofS identified science as their first teaching area (S. Bueckert, personal communication, August 11, 2017). UofR requires elementary teacher candidates to complete two 3-CU science methods courses, one on teaching science generally and the other focused on environmental education. The UofR graduates approximately 90 elementary and 30 middle years teachers annually (J. MacDonald, personal communication, October 12, 2016).

4.8 Secondary

The teaching area requirements for secondary science teacher candidates are more specific than for elementary candidates. Both UofS and UofR provide opportunities for secondary science teacher candidates to develop a foundation of pedagogical and curricular understanding. Secondary science teacher candidates typically demonstrate confidence in their science knowledge; however, they often lack experience with hands-on inquiry. Secondary science methods courses emphasize specific skills and practices in science education and encourage synthesis of concepts highlighted in other courses.

UofS secondary teacher candidates are required to have first and second teaching areas; science options are biology, chemistry, and physics. The first teaching area requires a minimum of 24 CUs of content courses; the second teaching area requires a minimum of 15 CUs. In some cases, academic advisors will assist applicants in determining whether courses count toward science content requirements; alternate acceptable courses include engineering, geology, environmental science, agriculture, kinesiology, or nutrition. Most students satisfy course requirements by completing first and second year courses; there is a current consideration to require at least one third year course in the first science teaching area. One 3-CU secondary science methods course is required for Grades 10–12. Secondary science teacher candidates also take a 3-CU post-internship inquiry course where they can focus upon science teaching pedagogy.

The UofS College of Education recently underwent major program changes to create more holistic and integrated learning opportunities while continuing to attend to traditional areas of study (i.e., language arts, science, mathematics). In secondary science education, two separate courses—one focusing on physical science and the other on life science—were merged into one general course on secondary science methods. Post-internship inquiry courses also provide opportunities for science teacher candidates (e.g., a course exploring teaching and learning through research using a synchrotron). In 2015, 50 secondary teachers graduated with science as their first teaching area (S. Bueckert, personal communication, October 11, 2016).

UofR secondary teacher candidates are also required to have two teaching areas, with 24 CUs of content courses in the first teaching area and 18 CUs in the second area; options include general science, biology, chemistry, and physics. The secondary science teacher program includes a science methods course for Grades 9–10 even though this is not a recognized grade range for schools. Teacher candidates must complete an environmental education methods course, which involves a mix of elementary and secondary teacher candidates. A 3-CU post-internship course, which is project-based and negotiated between instructors and students, covers a range of topics and activities related to instruction, assessment, resources, and use of these related to science teaching and learning. Approximately 10–16 secondary teachers graduate from UofR each year with a first teaching area in science, most commonly biology and chemistry (J. Macdonald, personal communication, September 15, 2017).

4.9 Teacher Certification

The SME was originally responsible for teacher certification, but as of 2016, an independent body—the Saskatchewan Professional Teachers Regulatory Board (SPTRB)—oversees certification and allows for self-regulation for the profession. The SPTRB sets out standards for certification, conduct, and competence. A certified teacher is considered competent to teach any subject, including science, at any level from K through 12. All teachers require a minimum of a bachelor's degree and at least 48 CUs of teacher education courses in order to be certified.

Saskatchewan teachers typically possess a Professional "A" Certificate, which qualifies them to teach all grades and all subject areas. Once a teacher has a Professional "A" Certificate, an Advanced Qualification Certificate (AQC) may be obtained by completing courses in specific programs created by UofS or UofR to address provincial needs. For example, if a need for mathematics teachers has been identified, an AQC in mathematics will likely be created. As well as being certified, teachers in publicly funded schools must also belong to the Saskatchewan Teachers Federation (STF), which was formed in 1934. Teachers in federally-funded First Nations schools are not required to be members of the STF.

Pay scales are dependent upon years of education, number of degrees, and level of degree. A BEd or a Bachelor of Science (BSc) would place a teacher in the class IV category. Having a BEd and a BSc would place a teacher in class V. Having a BEd and a BSc along with a Masters of Education would place a teacher in class VI.

4.10 Professional Development

School divisions hold the primary responsibility for providing professional development (Pro-D) for teachers. The larger divisions have the capacity to provide their own Pro-D; many of the smaller divisions and First Nations educational authorities will join neighbouring school divisions for Pro-D events. There is no provincial requirement for Pro-D for certified teachers; however, teachers are required to attend division-level staff development events during the school year. For example, large school divisions typically allot 1.5 days at the elementary level and 2 days at the secondary level per school year for division-level staff development (Saskatoon Public Schools, 2005). This time may or may not be devoted specifically to science education.

There are a variety of science-specific Pro-D opportunities that are facilitated by school divisions, STF, institutional Pro-D units, and outreach organizations. For example, during the recent science curriculum revision, most school divisions provided opportunities to engage in professional learning related to the new science curricula. These opportunities were typically collaboratively designed and delivered by science consultants from the SME, teachers who participated in the curriculum revision, and school division consultants.

The STF has a number of associated professional growth networks that it partially funds; the Saskatchewan Science Teachers Society is one of these networks. The Society offers Pro-D opportunities through its biannual Sciematics Conference that targets mainly secondary science and mathematics teachers. The Society also organizes a weeklong summer science institute consisting of workshops with a range of speakers, field trips, demonstrations, hands-on activities, instructional strategies and material resources, and other opportunities to help teachers develop their science teaching.

There are three institutional Pro-D units—affiliated with UofS, UofR, and STF—that were established to enhance educational practices in Saskatchewan. Each unit is considered at arm's length from the organization that houses it; however, the organization usually provides space and administrative support. The Saskatchewan Educational Leadership Unit at UofS contracts with school divisions to support change in teaching and programming. The Saskatchewan Instructional Development and Research Unit at UofR focuses on research and dissemination related to leadership and instructional practices. The Saskatchewan Professional Development Unit at STF offers a range of Pro-D for teachers of all grades and subject areas; recent science topics have included comprehension strategies in secondary science, inquiry approaches, and planning for instruction and assessment.

There are approximately 40 outreach organizations that support science teaching and learning, such as Agriculture in the Classroom, the Safe Drinking Water Foundation, the Saskatchewan Science Centre, the Saskatchewan Watershed Authority, and the Saskatchewan Mining Association. These organizations offer a variety of programs that address various curriculum outcomes and engage learners in activities focusing on engineering, agriculture, life sciences, and Indigenous knowledge. These outreach programs partly serve as Pro-D for science teachers although that is not their primary purpose.

4.11 Opportunities and Challenges

Science education in Saskatchewan faces unique challenges as well as opportunities for engaging learners in science. Three areas are discussed here: inquiry teaching, Indigenous perspectives, and assessment.

4.11.1 Inquiry Teaching

Saskatchewan's current science curriculum emphasizes inquiry approaches, which presents both opportunities and challenges. There is still the need for students to develop content knowledge; however, the increased emphasis on inquiry is intended to motivate and engage students, which has been identified as a challenge with a long history (Aikenhead, 2006). The SSC's explicit focus on learning through inquiry offers substantial opportunities for building student interest and engaging learners. Opportunities exist for teachers to address students' interest by focusing on local places and community problems and by allowing students to ask questions they deem to be important while pursuing scientific knowledge. Within an inquiry framework, there are opportunities for instructional approaches such as mastery learning, goal setting, cooperative learning, reciprocal teaching, think alouds, feedback, and worked examples—all pedagogical approaches that Hattie (2008) noted have a positive impact on students' achievement. In addition, broad education initiatives such as science, technology, engineering, and mathematics (STEM) that provide opportunities for inquiry are easily accommodated in the SSC.

Challenges can arise because the use of the textbook as the predominant instructional strategy (i.e., assigned readings and questions are the main mode of student learning) is not uncommon. It can be daunting for teachers with a minimum of training and experience in science pedagogy, science culture, and science inquiry to be tasked with engaging students in meaningful inquiry opportunities. A further challenge is to create meaningful inquiry experiences that build content knowledge while also leading to an understanding of the nature of science. To meet these challenges, teachers can avail themselves of the professional learning opportunities described earlier.

4.11.2 Indigenous Perspectives

Addressing Indigenous perspectives was a key driver in developing the most recent science curricula renewal in Saskatchewan. The SSC promotes Indigenous perspectives and positions teachers to actualize an inclusive science learning experience for all students**.** The intersection of Indigenous perspectives with Euro-Canadian approaches to inquiry and problem solving can offer opportunities for learners from various ethnic and cultural backgrounds to cross into the culture of science (Aikenhead, 1996). A challenge in fostering this intersection is the need for teachers, regardless of background, to develop an understanding of Indigenous cultural and instructional practices. This development can be facilitated through collaboration with Elders—individuals who have earned the respect of their community through the wisdom, harmony, and balance demonstrated in their actions and teachings. Most school divisions employ at least one Elder.

During the most recent revision of science curricula, instructional resources that included Indigenous perspectives were developed through extensive consultation with Elders. The series of textbooks developed specifically for Saskatchewan include an “Ask an Elder” feature that provides access to the wisdom of a First Nations or Métis Elder who shares an oral story related to the content of each unit. Another example of providing insight into Indigenous perspectives is the Saskatchewan Cradleboard Initiative (University of Saskatchewan, n.d.), which offers complementary resources that intertwine Indigenous knowledge with STEM. Lessons include Deadfall Trap Physics, Vitamin C in Saskatoon Berries, and Cleaning up the Traditional Way, the latter being an investigation of Métis soapmaking. There are also events such as the Federation of Sovereign Indigenous Nations Science Fair that offer opportunities for Indigenous youth to pursue their understanding of Euro-Canadian and Indigenous knowledge.

However, challenges remain for those involved in teaching and learning at the intersection of Indigenous perspectives and Euro-Canadian science. One concern involves students experiencing only a token involvement with Indigenous knowledge; another is integrating topics in an interdisciplinary manner that respects the holistic nature of Indigenous knowledge systems. Finally, there is the issue of helping Indigenous students to cross cultural boundaries by nurturing their Indigenous identity (Aikenhead & Elliott, 2010).

4.11.3 Assessment

Since assessment is such an important part of a teacher’s role, one would think that courses on assessment would be integral to teacher education programs. However, the UofR teacher education program requires only one assessment course; in the past, the UofS did not require such a course although there is now a mandatory assessment course. Employing a range of assessment approaches remains a challenge for many science teachers. For example, it was found that high school science teachers in Saskatchewan preferred assessments *of* learning that measured student recall such as quizzes, multiple-choice tests, and major examinations (Duncan & Noonan, 2007). Having additional assessment coursework in teacher education programs could lead to teachers using a wider range of assessment approaches.

School divisions, the STF, and the SPDU have been working with teachers on both assessment *for* learning approaches and on outcomes-based assessment. However, it has been argued that students should also learn to self-assess, which would enhance academic achievement through the construction, use, and evaluation of criteria (McDonald & Boud, 2003). Future professional learning opportunities could explore assessment *as* learning, which might enhance science teachers’ assessment practices.

4.12 Concluding Thoughts

This chapter has outlined the context of science education in Saskatchewan, addressing curriculum development, teacher education, and Pro-D for science teachers. Additionally, it has described how the SSC provides educators with opportunities to offer engaging learning experiences through inquiry while outlining some of the challenges that teachers may face as they embrace those opportunities. If teachers are to fully implement inquiry pedagogy as envisioned in the SSC, both preservice and inservice support is required. For example, one significant challenge is incorporating Indigenous ways of knowing and engaging with such knowledge as valid in its own right. Science teacher educators need to involve teacher candidates in experiences that interweave authentic science inquiry in a wide array of contexts (e.g., sustainability, Indigenous knowledge).

Government at all levels needs to recognize that science is a fundamental aspect of student learning, equal in importance to mathematics and language and literacy. Science needs to be prioritized when developing resources and, perhaps more importantly, when providing Pro-D for teachers. Recognizing science as a priority could result in students becoming more scientifically literate—whether this is measured by local, national, or international assessments—and thus better able to discern the validity of knowledge claims they encounter. Perhaps more students would pursue postsecondary science education. An increase in scientific literacy, with or without additional coursework at the postsecondary level, is a benefit to the society at large.

Acknowledgments We would like to thank the following people for sharing their knowledge and ensuring accuracy in this chapter: Shelley Bueckert (University of Saskatchewan), Mark Edmonds (Prairie School Division), Jolene Holtvogt-Briens (Saskatchewan Ministry of Education), Krishan Kapila (First Nations University of Canada), Phil Langford (Saskatchewan Science Teachers Society), Stephenie Leito Csada (Saskatchewan Ministry of Education), John Macdonald (University of Regina), Shelly Tootoosis (Saskatchewan Teachers Federation), and Dawn Wallin (University of Saskatchewan).

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Chapter 5
Science Education in Manitoba: Collaborative Professional Communities

Dawn Sutherland

Abstract Manitoba is the province at the longitudinal centre of Canada, bordered by Ontario to the east and Saskatchewan to the west. It is one of the three prairie provinces (along with Alberta and Saskatchewan) and Canada's fifth most populous province. Its population is diverse and includes the largest percentage of First Nations, one of the largest Francophone communities outside of Québec, as well as significant German, Ukrainian, Icelandic, and Filipino populations. Manitoba was one of the lead provinces for the implementation of the *Common Framework* and develops curricula using government consultants, lead writers, and teacher teams. In Manitoba, there are five postsecondary institutions that offer science education teacher programs. A great strength is that science educators are strongly connected through the Manitoba Education Research Network and often collaborate in research projects that involve government, universities, and school divisions. As well, in the past sustainability education has been strongly emphasized and supported by the provincial government and has led to many integrated programs with science content included.

5.1 Introduction

Two recent publications of the Council of Canadian Academies—*Science Culture: Where Canada Stands* (2014) and *Some Assembly Required: STEM Skills and Canada's Economic Productivity* (2015)—describe the state of science and mathematics knowledge, both nationally and internationally, as fairly strong. One point on which the two expert panels agree is that, in order to strengthen Canada's innovation and productivity in the future, more investment needs to be made in the elementary and secondary educational system. However, what would this investment look like?

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C. D. Tippett, T. M. Milford (eds.), *Science Education in Canada*,
https://doi.org/10.1007/978-3-030-06191-3_5

This chapter explores the potential for promoting science and innovation in the province of Manitoba by first examining demographic features of the public school population and then looking at provincial and university-based initiatives to develop science and science, technology, engineering, and mathematics (STEM) skills.

5.2 Manitoba Context

Manitoba is the province at the longitudinal centre of Canada, bordered by Ontario to the east and Saskatchewan to the west. It is one of the three prairie provinces (along with Alberta and Saskatchewan) and Canada's fifth most populous province. The name *Manitoba* originates from the languages of the Cree and Assiniboine First Nations; Manitou, or Great Spirit (in Ojiibway, *Manito-bau*), is the unique sound made by the waves washing against the limestone rocks at Lake Manitoba Narrows (Government of Manitoba, n.d.). Manitoba's economy is based largely on natural resources, particularly mining, forestry, hydroelectric, and agriculture. Much of its natural ecosystem is protected in more than 80 provincial parks, where hiking, biking, canoeing, camping, and fishing are all popular activities.

In 2016, Manitoba had a population of nearly 1.3 million, which was an increase of 5.8% from 2011 (Statistics Canada, 2017). Winnipeg (Fig. 5.1), the largest city in the province, has a population of just over 800,000 and is incredibly diverse. It has one of the largest urban Francophone populations outside of Québec totalling just over 110,000 as well as significant German (121,000), Ukrainian (115,000), and Filipino (59,000) populations (Manitoba Immigration & Multiculturalism, 2007). In recent years, Manitoba has been growing as a result of increased immigration; as a result, the school population has also been growing. Predictions put forward in *Impacts of Demographic Change in Manitoba* (Manitoba Bureau of Statistics, 2016) are that the Grades 5–8 population will increase significantly in the next 5 years.

Manitoba's population includes the highest percentage of Indigenous peoples in Canada, at 17% of the province's population, an increase of 13% between 2006 and 2011 (Statistics Canada, 2016). Additionally, Winnipeg has the largest urban Indigenous population of all cities in Canada at just over 78,000 people. As a comparison, the city of Edmonton in the province of Alberta, with a population of 1.3 million, has the second largest urban Indigenous population at just under 62,000 people (Indigenous & Northern Affairs Canada, 2016).

5.3 Manitoba's Education System

The provincial student population from Kindergarten through Grade 12—which was just over 202,000 in 2014, up 0.8% from 2013—is distributed throughout 37 school divisions (districts) with 691 schools (Manitoba Education & Advanced Learning, 2016). These data do not include the 16,000 students attending 56

Fig. 5.1 Map of Manitoba. Names in brackets are the Anishinaabe First Nations names

Manitoba First Nations schools that are under federal jurisdiction. In 2016, the Manitoba First Nations School System was established, with 10 participating First Nations and 2,160 students (Manitoba First Nations Education Resource Centre [MFNERC], 2016a). In 2016, the high school graduation rate was 78.3% (Manitoba Education and Training [MET], n.d.).

At the beginning of the millennium, there were several reports published criticizing MET for its inability to provide a satisfactory education to inner-city Indigenous students (Silver, Mallett, Greene, & Simard, 2002). Since these reports, the provincial government has responded with initiatives to improve the educational experiences of Indigenous students, such as requiring teacher candidates to complete Indigenous education courses and increasing the number of Indigenous teachers in the elementary system. The Manitoba government funds programs that support Indigenous elementary preservice teachers such as Brandon University's Program for the Education of Native Teachers and the University of Winnipeg's ACCESS Education Programs that include the Education Centre and the Community-Based Aboriginal Teacher Education Program. Indigenous secondary preservice teachers are also supported by the provincial government but to a lesser degree.

5.3.1 Science Curriculum

Manitoba was one of the lead provinces for the implementation of the *Common Framework of Science Learning Outcomes, K to 12* (Council of Ministers of Education, Canada [CMEC], 1997). The science curricula based upon the *Common Framework* were rolled out over a 5-year period: *Kindergarten to Grade 4 Science* (MET, 1999), *Grades 5 to 8 Science* (MET, 2000a), *Senior 1 Science* (Grade 9; MET, 2000b), *Senior 2 Science* (Science 10; MET, 2001), and Grades 11 and 12 science courses (MET, 2003, 2005, 2006, 2010, 2011, 2013a, 2013b). All science curricula were created by committees that consisted of teacher experts as well as a designated writer and a government consultant. For each science curricula, the province produced two documents: a framework document and a foundation document. The framework document contains the outcomes for each grade level, and the foundation document is a collection of learning experiences that are meant as suggestions for implementing the science curriculum.

All students are required to take science from Kindergarten through Grade 10. In K–10, outcomes for science skills are presented separately from outcomes for content knowledge (Fig. 5.2). There are approximately 15 science skills outcomes that increase in complexity every 2 years, with new outcomes introduced in Kindergarten/Grade 1, Grade 3, Grade 5, Grade 7, and Grade 9. All curricula include science

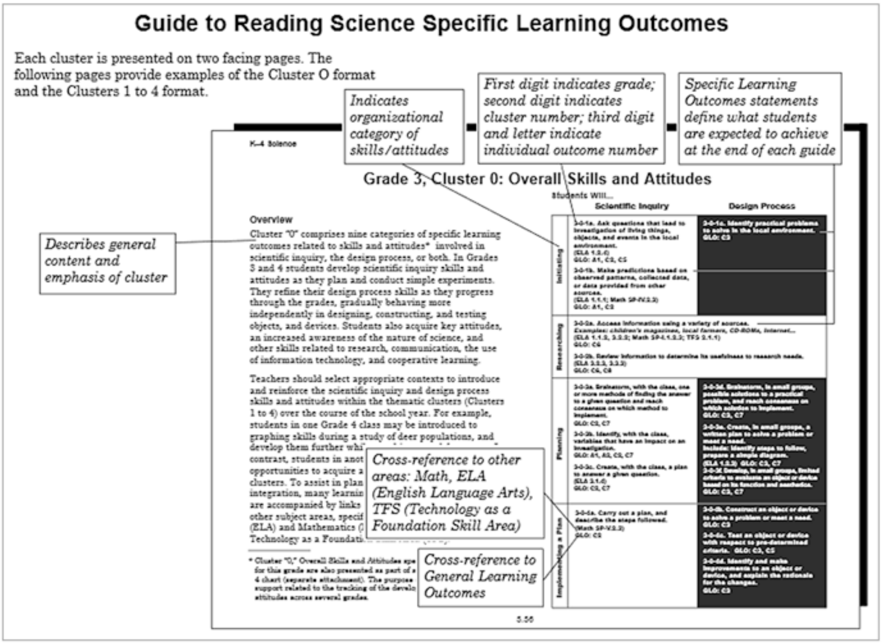

Fig. 5.2 Organization of specific learning outcomes related to skill development in science (MET, 1999, p. 3.4)

inquiry skills; early and middle years' curricula include design process skills, while Grades 9 and 10 curricula include science, technology, society, and environment (STSE) issues skills. Students' mastery of skill and content outcomes are reported separately on the provincial report card for Grades 1–10. However, the science skills outcomes are to be integrated into the content topics in each grade.

The content topics from K–10 are very similar to the ones identified in the *Common Framework* (CMEC, 1997). A notable exception is the topic heat capacity, which was in the curriculum before the implementation of the framework and was retained in Grade 8 (Table 5.1). Topics are organized in four clusters that are related to life sciences, physical sciences, and earth and space sciences. Particular science resources or textbooks are not mandated. In K–6, teachers use a variety of resources to build their own units for each of the prescribed science topics. For Grades 7–10, two textbook series that were created based on the *Common Framework* (CMEC, 1997)—*Science and Technology* (Nelson) and *Science Power* (McGraw-Hill Canada)—are frequently used in the classroom.

Students in Manitoba are not required to take science courses after Grade 10 in order to graduate; however, most postsecondary institutions require upper-level science courses as prerequisites into some programs. Science is an elective in Grades 11 and 12 when Biology, Chemistry, and Physics are offered as separate courses;

Table 5.1 Manitoba science topics for Kindergarten through Grade 10 by cluster

Grade	Cluster 1 Life sciences	Cluster 2 Physical sciences I	Cluster 3 Physical sciences II	Cluster 4 Earth/Space sciences
K	Trees	Colours	Paper	–
1	Characteristics and needs of living things	The senses	Characteristics of objects and materials	Daily and seasonal changes
2	Growth and changes in animals	Properties of solids, liquids, and gases	Position and motion	Air and water in the environment
3	Growth and changes in plants	Materials and structures	Forces that attract and repel	Soils and the environment
4	Habitats and communities	Light	Sound	Rocks, minerals, and erosion
5	Maintaining a healthy body	Properties of and changes in substances	Forces and simple machines	Weather
6	Diversity of living things	Flight	Electricity	The solar system
7	Interactions within ecosystems	Particle theory of matter	Forces and structures	Earth's crust
8	Cells and systems	Optics	Fluids	Water systems
9	Reproduction	Atoms and elements	Nature of electricity	Exploring the universe
10	Dynamics of ecosystems	Chemistry in action	In motion	Weather dynamics

Note. Adapted from MET (1999, 2000a)

skills and content outcomes are no longer separated and teachers are not required to report on skill mastery. The curricula for these courses are shown in Table 5.2. In addition to the core science courses, Interdisciplinary Topics in Science courses may be offered in Grades 11 and 12. MET contracted a writer to create a sample Grade 12 interdisciplinary course about Lake Winnipeg that included lesson plans, black-line masters, and assessment tools (MET, 2013a, 2013b).

Many Grades 11 and 12 science teachers do not use a single textbook but develop their courses using a variety of resources. The reasons are partly historical. MET had approached textbook companies about the feasibility of textbooks to address Grades 11 and 12 biology curricula, but the companies declined because of the relatively small student population and predicted lack of profit. Textbooks that are used in Manitoba typically are developed for other provinces.

5.3.2 Assessment

MET does not conduct any province-wide standardized testing in science. However, Manitoba does participate in national and international assessments such as the Pan-Canadian Assessment Program (PCAP) and the Programme for International Student Assessment (PISA) as one approach to monitoring progress in science education. Manitoba's mean 2013 PCAP science score was 465 ± 3.1, below the national average of 500 ± 1.9 (O'Grady & Houme, 2014, p. 107). Manitoba's mean 2015 PISA science score was 523 ± 6.4, below the national average of 534 ± 4.0 but above the international average of 501 ± 0.5 (O'Grady & Houme, 2014, p. 17). Despite lower scores on both PCAP and PISA compared to the national average, the province has not recently devoted any additional resources to science education.

Table 5.2 Manitoba science topics for Grades 11 and 12 by course

Grade	Biology	Chemistry	Physics
11	Wellness and homeostasis Digestion and nutrition Transportation and respiration Excretion and waste management Protection and control Wellness and homeostatic changes	Physical properties of matter Gases and the atmosphere Chemical reactions Solutions Organic chemistry	Waves Nature of light Mechanics Fields
12	Genetics Biodiversity	Reactions in aqueous solutions Atomic structure Chemical kinetics Chemical equilibrium Acids and bases Electrochemistry	Mechanics Fields Electricity Medical physics

Note. Adapted from MET (2000b, 2001)

5.4 Teacher Education

There are five institutions in Manitoba that offer degrees in education: Brandon University (BU), Collège Universitaire de Saint-Boniface (CUSB), University College of the North (UCN), the University of Manitoba (UofM), and the University of Winnipeg (UWinnipeg). Depending upon the institution, preservice teachers can choose one of the following streams:

- Early years (EY): K–Grade 4, a generalist program
- Early/middle years (E/MY): K–Grade 8, a generalist program
- Middle years (MY): Grades 5–8, a generalist program
- Senior years (SY): Grades 9–12, a subject-specific program that requires greater content

Admission requirements include credits for teachable major and minor subjects which are identified in Table 5.3. EY, E/MY, and MY teacher candidates require 18 credit hours (the equivalent of six full-semester courses) in a teachable major, 12 credit hours in a teachable minor, and 6 credit hours in each of mathematics, physical or biological sciences, English or French, and geography or history. SY teacher candidates require 30 credit hours in a teachable major and 18 credit hours in a teachable minor.

Pathways for earning a Bachelor of Education (BEd) degree differ by institution and are described in the following sections. The required science courses vary according to institution and stream (Table 5.4).

Table 5.3 Acceptable major and minor teachable areas according to stream

Early, early/middle, and middle years		Senior years	
Major areas (18 credit hours)	Minor areas (12 credit hours)	Major areas (30 credit hours)	Minor areas (18 credit hours)
Art, biology, chemistry, computer science, English, French, general science, geography, other approved language, history, human ecology, industrial arts, mathematics, music, native studies, physical education (health), physics, theatre	All major teachable areas are accepted as a minor teachable area except general science	Art, biology, business education, chemistry, computer science, English, French, general science, geography, other approved language, history, human ecology, industrial arts, mathematics, music, native studies, physical education (health), physics, theatre, vocational industrial	All major teachable areas are accepted as a minor teachable area
Early/middle and senior years' subjects acceptable as a minor area only: Anthropology, classics, dance, developmental studies, earth science, economics, environmental studies, law, philosophy, sociology, political science, psychology, religious studies			

Note. According to the *Education Administration Act* (Government of Manitoba 2017)

Table 5.4 Science methods courses offered in Manitoba education faculties

Institution	Stream			
	Early years	Early/middle years	Middle years	Senior years
Brandon University	Science methods (EY)	–	Science methods (MY)	Science methods (MY) Science methods (SY)
Collège Universitaire de Saint-Boniface	–	Didactique élémentaire	–	–
University College of the North	–	Science methods	–	–
University of Manitoba	Pedagogy for sustainable well-being: science, mathematics, and social studies (6 credit hours)	–	Teaching science in MY	SY teaching general science *Prerequisite*: SY curriculum and instruction: sciences *Electives*: SY teaching biology SY teaching chemistry SY teaching physics
University of Winnipeg	EY curriculum, instruction, and assessment: science SY curriculum, instruction, and assessment: science	EY curriculum, instruction, and assessment: science MY curriculum, instruction, and assessment: science	EY curriculum, instruction, and assessment: science MY curriculum, instruction, and assessment: science	*Prerequisite*: SY curriculum, instruction, and assessment: theory of science teaching *One or two of:* SY curriculum, instruction, and assessment: biology SY curriculum, instruction, and assessment: chemistry SY curriculum, instruction, and assessment: geography SY curriculum, instruction, and assessment: physics

Note. *EY* = early years, *MY* = middle years, *SY* = senior years. Unless otherwise indicated, courses are 3 credit hours or approximately 36 class hours

5.4.1 Brandon University

BU offers both consecutive (post-degree) and direct-entry degrees in education. The consecutive program requires 2 years of study in education after completing an undergraduate degree in a teachable major. Candidates in the direct-entry program enter after high school and complete 5 years of study that includes their teachable major and course requirements as well as education courses.

A variety of specialized programs have been offered at BU to meet the needs of specific communities. For example, the Brandon University Northern Teachers Education Program was a northern community-based program. The Brandon University Hutterian Education Program was established because many of the province's Hutterite colonies found it more suitable to have teachers from their own colonies; this program has been discontinued. Currently, the Project for the Education of Native Teachers provides Indigenous individuals working as educational assistants in northern communities the opportunity to obtain a BEd by completing summer courses at the BU campus. None of these programs were structured to lead to undergraduate teacher candidates becoming secondary science specialists.

5.4.2 Collège Universitaire de Saint-Boniface

CUSB offers the only French language preservice teacher program in the province and is the only program that offers an extended 7-month practicum experience. Admission to this after-degree program is based upon grade point average, suitable courses in teachable areas outlined by the province, professional suitability, and language competency. There are two streams: E/MY and SY. Each year approximately 40 candidates are admitted to this certification program. Candidates complete most of their course work in the first year, spending 21 weeks in classes and 4 weeks in practicum blocks. In the second year, candidates are in practicum blocks for 7 months (September–March) and meet once per week at CUSB for seminars on professional issues and methods courses. Science methods courses are taught during second year.

5.4.3 University College of the North

UCN has two main campuses located in The Pas and Thompson. As well, there are 12 regional centres. Previous locations for the community-based programs have been Easterville (Chemawawin), Churchill, Cross Lake (Pimicikamak), Flin Flon, Grand Rapids (Misipawistik), Norway House, Nelson House (Nisichawayasihk), Oxford House (Bunibonibee), Split Lake (Tataskweyak), Mathias Colomb (Pukatawagan), St. Theresa Point, and Swan River. UCN's BEd program is unique because of the college's mandate to include Indigenous and northern perspectives in both theory and practice.

UCN's Council of Elders selected the Kenanow Learning Model (UCN, n.d.) as the organizing framework for the BEd program. This model incorporates identity, sense of place, community history, and responsibility in the context of teaching. The model bridges the link between Western education perspectives and the Aboriginal perspectives in the transmission of knowledge. *Kenanow* is a word drawn from the Cree language. Translated literally, it usually reads 'all of us, all of us who are here' which includes all our relations as described in the model. In this model, the kinship system is envisioned as an organically functioning system into which education is naturally and harmoniously integrated and transmitted. The BEd incorporates Indigenous cultural knowledge with best practices in pedagogical approaches into all courses, including science, while emphasizing collaboration among Elders, faculty, local educators, community members, and students. Another unique aspect of the program is that education students attend a culture camp prior to graduation to incorporate land-based teachings to their educational practice. Science requirements for the program are shown in Table 5.4.

5.4.4 University of Manitoba

UofM offers an after-degree undergraduate program that is similar in structure to those of BU and UWinnipeg. In this program, prospective teachers select a specific stream (i.e., EY K–4, MY Grades 5–8, or SY Grades 9–12). Each stream has specific characteristics. The EY program uses an immersion delivery model where many of the university classes are conducted in the same school. The MY stream has a focus on the physical, social, emotional, and intellectual development and needs of adolescents. The SY stream places teacher candidates into classrooms related to their major and minor teachable subjects to develop their instructional capabilities at the upper high school level. The UofM Faculty of Education has an Office of Indigenous Initiatives with a director who provides leadership and support and who connects the faculty with the Indigenous communities in the province.

5.4.5 University of Winnipeg

UWinnipeg offers both a 2-year post-degree and a 5-year direct-entry integrated program. Because of an inner-city focus in these programs, teacher candidates are required to do one placement in an urban setting. The different program streams are distinguished by the grade levels of each of the four placements (Table 5.5). In EY, E/MY, and MY streams, teacher candidates take the same two 3 credit hour science methods courses in the certification years; in SY, teacher candidates take methods courses in their science major and minor teachable areas (Table 5.4).

UWinnipeg has three off-campus ACCESS programs, which are funded by the provincial government and designed for marginalized or nontraditional students such as northern residents, inner-city residents, single parents, and immigrants.

Table 5.5 Practicum grade level placements by stream at the University of Winnipeg

	Stream			
	Early years	Early/middle years	Middle years	Senior years
Practicum 1	K–4	K–4	K–4	5–9
Practicum 2	K–4	K–4	5–8	9–12
Practicum 3	5–8	5–8	5–8	9–12
Practicum 4	K–4	5–8	5–8	9–12

- At the Winnipeg Education Centre, cohorts of about 20 teacher candidates from the inner city take classes together for a 5-year period. Upgrading and tutoring supports are provided, and all practicum placements are in the inner city.
- The Community-based Aboriginal Teacher Education Program is a partnership between the university and two school divisions: Seven Oaks and Winnipeg. This BEd program allows Indigenous educational assistants to work in their respective school division from September to April while attending classes part-time and then be released from their position to attend classes full time from May to July.
- The Immigrant Teacher Education Program is a partnership between several school divisions and the university that supports teachers educated internationally as they gain experience in the Manitoba school system. These teachers work in partner schools during the day and complete coursework during evenings and weekends.

None of the ACCESS programs are specifically designed to lead to a specialization in science.

5.5 Professional Development for Science Teachers

The provincial government takes a leading role in professional development (Pro-D) and has implemented programs to support the introduction of new curricula, created an educational research network, and established an online learning community. Pro-D for Manitoba teachers is also provided by teacher associations and specialized organizations. Pro-D for teachers of science exists within these more general opportunities. For example, when the current science curricula were introduced (i.e., 1999–2004), MET provided funding for teams of expert teachers—individuals who had piloted the new curricula—to create a resource with suggested activities for the specific learning outcomes in each topic. For two summers, the expert teacher teams facilitated grade-specific workshops intended to help teachers implement the new curriculum.

Another professional learning opportunity funded by MET is the Manitoba Education Research Network (MERN; http://www.mern.ca/), which has a full-time director who initiates collaborative research projects by connecting teachers and researchers with similar interests. Teachers work together while following an inquiry approach and identify questions they are most interested in exploring in their own pedagogy, and researchers assist in the design of research projects. A science collaborative group that included 10 teachers was established in 2015; it is anticipated that an additional 10 teachers will be involved in subsequent years. MERN also hosts four or five forums a year in various regions of the province, with an average of 16 presentations in each forum. The forums are an opportunity for university and teacher researchers to present to colleagues and develop a professional network. Between 2007 and 2015, three forums focused on science education.

In 2013, MET created the Manitoba Professional Learning Environment (MAPLE; http://mapleforem.ca/en/), an online educational community that provides a virtual space where educators across the province can access resources and services (MET, 2017b). There is a specific science educators' MAPLE group where teachers share lesson ideas and discuss classroom issues. MET uses MAPLE as an official means of communicating initiatives, curricula, and programs.

Professional learning opportunities supported by teacher associations include an annual province-wide Pro-D day. Special Area Groups, such as the Science Teachers' Association of Manitoba (STAM; http://stam.mb.ca/), host conferences on this day. STAM presentations and topics usually highlight senior-level science content. Teachers may also present innovative science units and projects.

Specialized organizations such as MFNERC also provide Pro-D for teachers of science. In 1998, the Assembly of Manitoba Chiefs created MFNERC to provide support in administration, technology, language, and cultural education for First Nations schools in Manitoba. MFNERC's science team has developed an astronomy curriculum that incorporates local Indigenous knowledge; it has invested in a portable astronomy laboratory that travels to First Nations throughout the province to teach about the night sky from an Indigenous perspective. Since 2003, MFNERC has hosted an annual science fair for Indigenous students. In 2016, more than 490 students took part in the event, presenting over 200 projects, with winners going on to compete in the Canada-Wide Science Fair (MFNERC, 2016b). As well, MFNRC has hosted a national science camp for Indigenous and Inuit students. The camp is a chance for students to participate in science programs and learn about possible science careers in science, while networking with like-minded youth from across the country.

5.6 Strengths in Science Education in Manitoba

A current strength in Manitoba science education is that the science education community is relatively small and members are typically very supportive of one another. MERN is unique to Manitoba and has resulted in some very strong collaboration between the government, universities, and school divisions and have led to several initiatives that are described next.

5.6.1 Manitoba Centre for Research in Youth, Science Training and Learning (CRYSTAL)

In 2005, the UofM became host to one of five Canadian university-based Centres for Research in Youth, Science Training and Learning. CRYSTAL Manitoba (http://umanitoba.ca/outreach/crystal/) was supported by a 1 million dollar grant from the Natural Sciences and Engineering Research Council of Canada. For 5 years, a CRYSTAL team composed of researchers from UofM, UWinnipeg, CUSB, and BU, as well as University of Regina, University of Saskatchewan, and Lakehead University—in the neighbouring provinces of Saskatchewan and Ontario—worked with government and community partners to investigate science education from four perspectives: the learner, the learner as part of a classroom and school community, the learner as part of a local community, and the learner as part of a global community.

Sixteen separate research projects led to the development of more than 100 teacher resources, many of which are still in use. Topics of these resources include contextualizing science through story and historical narrative (http://sci-ed.org), integrating Inuit knowledge to provide two-way learning experiences (http://umanitoba.ca/outreach/crystal/nunavut.html), and sustainability in secondary science (http://umanitoba.ca/outreach/crystal/sustainability.html). Another lasting impact of CRYSTAL Manitoba was the collaborative groups that were created—many of which continue to work together on new and exciting projects.

5.6.2 Education for Sustainable Development (ESD)

Manitoba is a global leader in the promotion of ESD (Manitoba Education & Advanced Learning, n.d.). ESD initiatives fall under MET's priority area of citizenship, sustainability, and well-being; every school in Manitoba is encouraged to have an ESD plan by 2019 (MET, 2017a). To support ESD, MET has established the ESD Leadership Council that is comprised of senior-level representatives from various educational sector groups, faculties of education, and government departments. The council has six goals: ensure quality education for all, infuse ESD pedagogy into teacher education, integrate ESD into curricula and learning (preK through Grade 12 and teacher education), establish ESD school plans, strengthen ESD capacity building at all levels through training and professional learning opportunities, and reorient technical and vocational education and training in support of a green economy. MET has taken a whole-school approach to ESD—meaning that not only is the curriculum reflective of ESD principles, but schools themselves become a model learning environment demonstrating how sustainability can be embedded into school policies, operations, and management.

From 2004 to 2006, a considerable amount of effort to integrate ESD into the curriculum was invested by MET. Huppé, Creech, and Buckler (2013) reviewed all

Manitoba curricula so as to identify sustainability themes already present and gaps that existed to create a baseline on where to move forward in sustainability education. The review was completed in 2006, and subject area correlation charts with ESD themes were posted on the EDS government website (http://www.edu.gov.mb.ca/k12/esd/correlations/index.html). ESD is important to mention here because, although it is integrated into every subject and grade in Manitoba, it receives particular emphasis in science education, social studies, and physical education/health education. As a result, there are many locally-created resources for teachers to use that help them teach science using a more integrated approach.

5.6.3 Design It

Engineering design is part of Manitoba's K–8 science curriculum. To complement this aspect of the curriculum, Design It, an engineering outreach initiative based at UWinnipeg, was started in 2009 with a team of three preservice teachers (Sutherland, Thomson, Claudio, & Lumbera, 2014; http://dsutherlan4.wixsite.com /designit). The Design It team provides design-based workshops that include a problem context; instruction on science concepts and technical drawing; time for planning, building, and testing designs; and discussions on design thinking. The team has created more than 15 different workshops that are available for Winnipeg classroom teachers and afterschool programs. Recently, the Design It team has offered a weeklong summer camp. In 1 year, the Design It team can reach more than 1,500 students and currently has 13 staff members during the school year and four in the summer.

Design It has become a vehicle for strengthening the science teaching skills of team members who are not science specialists, helping them to become leaders in science education. In the process of developing workshops, the Design It team forms a collaborative group whose members brainstorm possible design challenges, create and teach the lessons to the rest of the team, and critique and refine lessons. This iterative workshop development process has led to a group of preservice teachers who participate in conferences and other dissemination opportunities to explain how their confidence in science teaching has been enhanced as a result of working with Design It.

5.7 Challenges in Science Education in Manitoba

Some of the challenges in teaching science in Manitoba are challenges that can be found nationally. Many generalist teachers do not have the science background to feel comfortable teaching science content and may not have much confidence in teaching science even at the lower grades. In addition, there are many Francophone communities in Manitoba where science is taught in French. National assessments in science achievement and interests show that Francophone students, outside of Québec, score lower than their English counterparts (O'Grady & Houme, 2014). The national assessments seem to suggest that teaching science in French in small Francophone communities in Manitoba has additional challenges. Although science content can be contextualized using a cultural or sustainability lens or taught in a way that assists students in becoming active citizens regarding science issues, it often is not.

Teacher self-efficacy in science instruction at the elementary level is a common challenge to science education programs. Research associated with professional adequacy, professional interest and motivation, and professional science knowledge has found these factors to be impediments to science program delivery (Lewthwaite, 2007). These issues are prevalent in Manitoba elementary schools as well. In Manitoba science is not a required course after Grade 10, and entry into the Faculty of Education at UWinnipeg from high school, for example, requires only 5 credits at the Grade 12 level which include 1 credit of English and 1 credit of mathematics. Once in a program, teacher candidates are required to take only one 6 credit hours science course; most students take biology, astronomy, or physical geography to fulfil this requirement. In addition, EY, E/MY, and MY education programs attract a disproportionate number of humanities and language specialists. For example, more than 80% of the teacher candidates in EY and MY science methods courses at UWinnipeg have a language major. To address the challenges of inadequate science knowledge and low confidence in teaching science, teacher inquiry projects and collaborative learning communities in science have been established and funded by MERN. These collaborations have resulted in some promising findings in mathematics (Betts, Rosenberg, Kammerlock, & Birse, 2015) and perhaps will help in science teaching.

Teachers in small Francophone communities who teach science face similar challenges, as well as some challenges more specific to their teaching context (Lewthwaite, Stoeber, & Renaud, 2008). Science teachers in these communities have the additional challenge of teaching science in French to students who may not have strong French language skills. Within these contexts, the "priority placed on French language development often compromise[s] the attention given to science as a curriculum area" (Lewthwaite et al., 2008, p. 39).

Another challenge is that, in general, science education in Manitoba does not demonstrate to students how they can use scientific knowledge to enhance their ability to participate in Canadian society. Many of Manitoba's current socioscientific issues require technical information as well as scientific and traditional perspectives about energy, air, land, and water. These issues have the potential to create a political and economic nexus between Indigenous communities and provincial or federal governments. For example, the slogan *Idle No More* has been taken up by a group opposed to the removal of Indigenous people from decision-making processes concerning their land, water, and treaty rights. An implication of the Idle No More movement for science education is its new way of thinking about science knowledge, in that it is not passive or objective but rather contextual and experiential. Science educators can be a support network for those who question, explore, and challenge their local, provincial, and federal governments in order to take an active role in determining their own future.

5.8 Concluding Thoughts

The Council of Canadian Academies (2014, 2015) described the state of science and mathematics knowledge, nationally and internationally, as fairly strong and pointed out that, in order for Canada to remain strong in innovation and productivity, more investment needs to be made in science education in elementary and secondary schools. In Manitoba, the government has invested in supporting collaborations between government consultants, university professors, and professional educators to research best practices in science education. This investment has resulted in strong relationships among stakeholders in science education across the province and a greater understanding of the science education needs of the province. Next steps involve enacting best practices findings into Manitoba classrooms through collaborative inquiry and other forms of professional development, supporting science teachers within Francophone communities, and providing opportunities for science teachers to create contextualized and integrated science lessons.

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Chapter 6
Science Education in Ontario: Profile and Perspectives

Xavier E. Fazio and Astrid Steele

Abstract Ontario is the fourth largest and most populous jurisdiction in Canada with proportionally a highly diverse population. Elementary and secondary education is governed by the Education Act, which sets out the responsibilities of the Ontario Ministry of Education, school boards, educators, and students. Science curriculum is prescribed by the ministry for all K–12 students in publicly funded schools. Science curricula are organized according to grade groupings: K, 1–8, 9–10, and 11–12. Curricula topics include learning expectations found in biology, chemistry, physics, and earth and space sciences, along with scientific investigation and career areas. Unique to the elementary science curriculum are technological knowledge and design topics. Teacher education is regulated by the Ontario College of Teachers, which was created to license teachers, set professional standards and qualifications, and accredit university teacher education programs. The 16 university teacher education programs in the province vary by their admission standards, courses, and practicum arrangements, but they must meet the same accreditation standards. Professional development for science teachers are wide-ranging and are provided by various science teaching and learning organizations, along with school district and ministry-supported initiatives. Contemporary issues important to science education in Ontario include teaching science to cultural and language-diverse learners, environmental education, and the importance of quality science education for all students.

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C. D. Tippett, T. M. Milford (eds.), *Science Education in Canada*,
https://doi.org/10.1007/978-3-030-06191-3_6

6.1 Introduction

The name *Ontario* has its origins in part from an Iroquois word for beautiful or precious water or lake (Government of Ontario, 2017). It is Canada's fourth largest province or territory geographically, covering more than 1 million square kilometres—an area almost twice the size of France. Ontario's many lakes, rivers, and streams played a central role in the province's history and development both culturally and economically. For Indigenous peoples and European settlers, lakes and rivers were a means of transportation and sources of food, which helped determine patterns of settlement and industrialization. While Ontario boasts about one-fifth of the world's fresh water, its terrestrial landscape is varied with ancient rocky shield, extensive coniferous and deciduous forests, farmland, and grassy lowlands. Manufacturing, agriculture, science and technology, health, tourism, and financial services contribute to its diverse communities (Government of Ontario, 2015, 2017).

6.2 People and Places in Ontario

As of July 1, 2015, Ontario's population was 13,792,052, making it the most populous province with over 38.5% of Canada's total population (Statistics Canada, 2015a). The largest concentration of urbanization is in the area called the *Golden Horseshoe*, which includes the western shore of Lake Ontario, the Greater Toronto area, and the cities of Hamilton, St. Catharines, and Niagara Falls; there are more than 9 million people in this area alone (Fig. 6.1). Ontario's capital city, Toronto, has more than 2.7 million people, making it the fourth most populous metropolitan area in North America after Mexico City, New York, and Los Angeles. Moving away from Lake Ontario and Toronto, to the west is the Kitchener-Waterloo area, north is Barrie, and northeast is Oshawa and Peterborough. Population centres in southwestern Ontario include London, Windsor, and Sarnia. In eastern Ontario, Ottawa (Canada's capital) and Kingston are the major cities. In northern Ontario, key municipalities include Greater Sudbury, Thunder Bay, Sault Ste. Marie, North Bay, and Timmins (Government of Ontario, 2017).

Ontario's population is highly diverse according to demographic information obtained in the *2011 National Household Survey* (NHS; Statistics Canada, 2015b). Indigenous peoples—First Nations, Métis, and Inuit (FNMI)—comprise over 2% of Ontario's population (~20% of all Indigenous persons in Canada) with two-thirds being First Nations, approximately one-third Métis, and a small number of Inuit. First Nation peoples in Ontario include the Cree, Oji-Cree, Algonquin, Ojibwa, Odawa, Potawatomi, and Delaware, plus the Iroquois-speaking Six Nations: Mohawk, Oneida, Onondaga, Cayuga, Seneca, and Tuscarora (Government of Ontario, 2017). Of importance to science education programs, because of the

Fig. 6.1 Map of Ontario

school-age population, the NHS indicated that the Indigenous population is younger than the non-Indigenous population, with over 32% consisting of youth aged 19 and younger as compared to 24% for the non-Indigenous population (Ontario Ministry of Finance, 2014).

Compared to other provinces, Ontario has the highest proportion of foreign-born individuals, who represent over 28% of its population (Statistics Canada, 2016). Citizens primarily report English, Scottish, and Irish ethnic or cultural origins; other highly reported ethnic origins are French, German, Italian, Chinese, East Indian, and Dutch. In total, more than 200 ethnic origins have been reported. About 26% of Ontarians identified themselves as a member of a visible minority population, with South Asian being the single largest group identified in the survey. Overall, this proportion represents more than half of Canada's total visible minorities, with the vast majority living in Toronto and surrounding suburban areas. Recent immigrants are mainly from Asia and Europe (including Middle Eastern countries), with the remainder from Africa, the Caribbean, and Central and South America (Ontario Ministry of Finance, 2014). Toronto continues to be a major immigrant gateway for Canada with 40% of new immigrants coming to the Greater Toronto Area.

6.3 Overview of Education in Ontario

Public elementary and secondary education in Ontario is governed by the *Education Act* and its regulations, which set out the duties and responsibilities of the Minister and Ministry of Education, school boards, school board supervisory officers, principals, teachers, early childhood educators, parents, school councils, and students. The Ontario Ministry of Education (OME) has authority and responsibility for developing curriculum; allocating funds to school boards; setting policies and guidelines for school trustees, directors of education, principals, teachers, and other school board officials; setting requirements for student diplomas and certificates; and identifying approved textbooks and other learning resources (OME, 2016a).

Unlike some other provinces and territories, Ontario operates four publicly funded school systems based on the *Constitution Act* of 1867 provision and the *Canadian Charter of Rights and Freedoms*: an English-language public school system, a French-language public school system, an English-language separate (Roman Catholic) school system, and a French-language separate (Roman Catholic) school system. The 1867 provision originally applied to Ontario, Québec, Saskatchewan, Alberta, and Newfoundland and Labrador since these jurisdictions had pre-existing separate schools. This constitutional provision was repealed by some provinces in the late 1990s; however, Ontario has maintained this unique structure for its public education system. English is Ontario's official language although there are several French-speaking communities across the province. French-language rights extend to Ontario's public education system (OME, 2016a). Ontario is the only province in Canada that has full funding for Catholic-supported education. In Catholic secondary schools (Grades 9–12), multi-faith students can attend but not at the elementary level (Grades K–8).

There are 72 district school boards in Ontario: 31 English public, 29 English Catholic, 4 French public, and 8 French Catholic. Across all school districts and authorities, there are 3,974 elementary and 919 secondary schools (OME, 2016b). Each school that is in a territorial district but not in a district school board is part of the OME's Provincial Schools Authority. Most provincial schools offer specialized programs and residences for students with severe physical or learning exceptionalities. There are 10 school authorities: four geographically isolated school boards and six hospital-based school authorities. Finally, in remote and rural areas, there are 118 band-operated schools (80 elementary and 38 secondary) on First Nations reserves. Approximately three-quarters of the band-operated schools serve 500 or fewer students (Lewington, 2013; Statistics Canada, 2012).

In general, an elementary school consists of early learning-Kindergarten (ELK) through Grade 8 and a secondary school of Grades 9 through 12. Other elementary school configurations include ELK through Grade 8, ELK through Grade 5, and Grades 5 through 8. There are a few schools (generally in low population areas) that have both elementary and secondary grades in the same building.

As of 2014–2015, the number of students in publically funded schools was 2.0 million, of whom over 1.3 million were elementary students (Grades ELK–8) and over 640,000 were secondary students (Grades 9–12). Of this population, over 101,000 students are found in 12 French-language school districts, with over 425 schools (OME, 2016b). Approximately 78,000 students self-identified as FNMI with about 14,000 students attending schools on reserves (Gallagher-Mackay, Kidder, & Methot, 2013).

In addition, there are over 900 private schools that operate as businesses or non-profit organizations, independent of the OME and in accordance with the requirements under the *Education Act.* Private schools in Ontario do not receive any funding from OME. The number of students in private schools is about 5% of the total student population (OME, 2016b).

6.4 Science Education in Ontario

Science curriculum documents for ELK through Grade 12 are prescribed by OME. All publicly funded schools are required to follow these documents and to develop courses of study from them. OME develops policy and guidelines related to assessment of academic achievement and associated programs of study; as well, it approves science textbooks and other learning materials (OME, 2016a).

The curricular emphases throughout the Ontario science curricula are guided by Visions I and II for scientific literacy, premised by the *Common Framework of Science Learning Outcomes, K–12* (Council of Ministers of Education, Canada [CMEC], 1997). In Vision I, the purpose of school science is to support the development of future scientists and to build curriculum from scientific knowledge and processes. Vision II looks outside of science and examines how science interacts with society, technology, and the environment, which is seen as important for all citizens regardless of their occupation or vocation (Roberts, 2007, 2014). The science curricula are positioned to accomplish both by representing a blend of these respective visions for scientific literacy. The current science curricula may be considered a *version 2.0* of the curricula for elementary and secondary students that were released in 1999–2000 in response to the *Common Framework*.

Students begin with science-based early learning (age 4) and Kindergarten (age 5) integrated programs. The document *The Kindergarten Program, 2016* (OME, 2016c) contains age-appropriate science learning expectations and is organized differently from the curricula for Grades 1–12. The science and technology outcomes of the program provides a broad context including descriptions of play-based science learning and of the Kindergarten team role in creating a classroom environment that supports children's scientific inquiry and engagement in technological objects and the natural environment. The program lays the foundation for elementary and secondary students to participate in the provincially-prescribed science (and technology) program.

The current English science curricula for Grades 1–12 are detailed in three documents: *The Ontario Curriculum, Grades 1–8: Science and Technology, 2007; The Ontario Curriculum, Grades 9 and 10: Science, 2008; The Ontario Curriculum*, *Grades 11 and 12: Science, 2008* (OME, 2007c, 2008c, 2008d). These same documents are available in French; thus, Francophone teachers and students follow the same science curricula using *Le curriculum de l'Ontario, de la 1re à la 8e année – Sciences et technologie, 2007*; *Le curriculum de l'Ontario, 9e et 10e année – Sciences, 2008*; and *Le curriculum de l'Ontario, 11e et 12e année, Sciences, 2008* (OME, 2007a, 2008a, 2008b).

The Pan-Canadian science foundations for scientific literacy provided a conceptual framework (CMEC, 1997) for organizing these curricular documents. The three goals of these science curricula focus on relating science and technology to society and the environment (STSE), science-specific skills, strategies and habits of mind, and scientific concepts that science students should know and be able to demonstrate in today's society. Further, each document's introduction briefly identifies the importance of the nature of science and technology in learning science (Science Teachers' Association of Ontario, 2006). Nonetheless, there are essentially no learning expectations about the nature of science and technology in the documents.

The curriculum documents articulate how fundamental concepts in science provide a framework for a deeper understanding so that students can utilize a scientific knowledge base to see patterns and connections across disciplines. The fundamental concepts addressed in these curricula are common to many science curricula in Canada and globally (OME, 2008c, 2008d). These fundamental concepts are further organized into *big ideas*, that is, a way of representing these fundamental concepts into broad understandings for planning and instruction in science (Wiggins & McTighe, 2005) for each topic of study (Fig. 6.2).

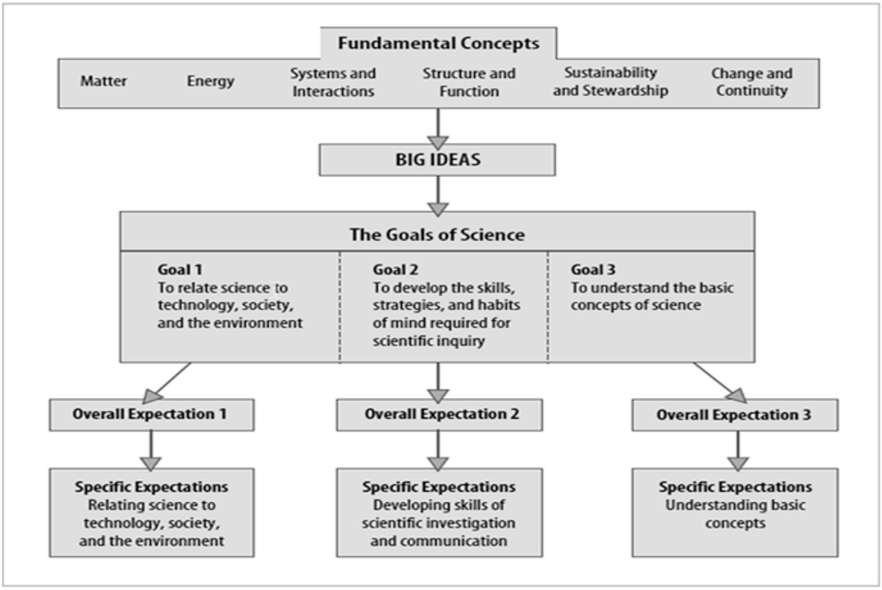

Fig. 6.2 Relationship between fundamental concepts, big ideas, goals of science, and expectations (OME, 2008c, p. 6)

6.4.1 Elementary Science and Technology Curriculum: Grades 1–8

The program goals for Grades 1–8 are to relate science and technology to society and the environment; to develop the skills, strategies, and habits of mind required for scientific inquiry and technological problem solving; and to understand the basic concepts of science and technology (OME, 2007c). The elementary science and technology curriculum identifies technological knowledge and problem solving in its goals (i.e., goals 2 and 3). It should be noted that Grades 9–12 technological learning outcomes are under the auspices of the secondary school technological education curriculum (e.g., OME, 2009c) rather than the science curriculum. While technology can have various connotations (e.g., computers, engineering), in the Ontario elementary science and technology document, technology is described as:

> a form of knowledge that uses concepts and skills from other disciplines (including science) and the application of this knowledge to meet an identified need or to solve a specific problem using materials, energy, and tools (including computers). Technological methods consist of inventing or modifying devices, structures, systems, and/or processes. (OME, 2007c, p. 4)

These technology expectations align with the Next Generation Science Standards' engineering core ideas, crosscutting concepts, and science and engineering practices (NGSS Lead States, 2013).

The Grades 1–8 science and technology curriculum topical expectations are organized into four strands that identify the major areas of knowledge and skills: Understanding Life Systems, Understanding Structures and Mechanisms, Understanding Matter and Energy, and Understanding Earth and Space Systems (Table 6.1).

Each topic of study has three overall expectations along with clearly delineated specific expectations representing learning outcomes for the overall expectation. For example, in the Grade 5 Conservation of Energy and Resources topic, the overall expectations state that students will:

1. Analyze the immediate and long-term effects of energy and resource use on society and the environment, and evaluate options for conserving energy and resources
2. Investigate energy transformation and conservation
3. Demonstrate an understanding of the various forms and sources of energy and the ways in which energy can be transformed and conserved (OME, 2007c, p. 108)

As an example, one specific expectation subsumed under the third overall expectation above states that by the end of Grade 5 students will:

> identify a variety of forms of energy (e.g., electrical, chemical, mechanical, heat, light, kinetic) and give examples from everyday life of how that energy is used (e.g., electrical energy for cooking; chemical/electrical energy to run our cars; mechanical energy to hit a baseball; light energy for managing traffic on the roads; heat energy to warm homes and schools). (p. 109)

Table 6.1 Prescribed science topics for each strand in Grades 1–8 (OME, 2007c, p. 19)

Grade	Understanding life systems	Understanding structures and mechanisms	Understanding matter and energy	Understanding Earth and space systems
1	Needs and characteristics of living things	Materials, objects and everyday structures	Energy in our lives	Daily and seasonal changes
2	Growth and changes in animals	Movement	Properties of liquids and solids	Air and water in the environment
3	Growth and changes in plants	Strong and stable structures	Forces causing movement	Soils in the environment
4	Habitats and communities	Pulleys and gears	Light and sound	Rocks and minerals
5	Human organ systems	Forces acting on structures and mechanisms	Properties of and changes in matter	Conservation of energy and resources
6	Biodiversity	Flight	Electricity and electrical devices	Space
7	Interactions in the environment	Form and function	Pure substances and mixtures	Heat in the environment
8	Cells	Systems in action	Fluids	Water systems

6.4.2 Secondary Science Curriculum: Grades 9–12

The Ontario secondary science curriculum shares many features with the elementary science and technology curriculum. Nevertheless, specific differences, highlighted in this section, have implications for science education and for science teacher education. There are two curriculum documents that contain the learning expectations for secondary school students: The Ontario Curriculum, Grades 9 and 10: Science and The Ontario Curriculum, Grades 11 and 12: Science (OME, 2008c, 2008d). Courses in the Grades 9 and 10 science curriculum are organized into five strands: scientific investigation skills, biology, chemistry, earth and space science, and physics; in Grades 11 and 12, separate courses are offered in biology, chemistry, earth and space science, environmental science, and physics. Scientific investigation skills apply to all science courses and topics and must be developed by the science teachers in conjunction with content.

Aside from scientific literacy emphases and delineated learning expectations described earlier in this chapter, the science curriculum is informed by other education deliberations. For example, in order to have a provincial standard for assessment and evaluation, an achievement chart that identifies four categories of knowledge and skills (i.e., knowledge and understanding, thinking and investigation, communication, application) guides science teachers' planning, instruction, and assessment (OME, 2008d). Science-specific criteria are articulated within each category. Other general program considerations for science include health and safety, students with special needs, English Language Learners, environmental education, diversity (including Indigenous perspectives), critical thinking, literacy and numeracy integration, information communication technology (ICT), and career education. Many of these program considerations have separate educational policies, guidelines, and resources, for example, *Learning for All* (OME, 2013).

Since all secondary school programs begin in Grade 9, the intention of Grades 9 and 10 science is to provide a transition in terms of topics and skills from the K–8 elementary science and technology programs. However, the Grades 9–12 technological education curriculum (OME, 2009c) is distinct from the science curriculum. Some courses (e.g., Computer Technology, Construction Technology, Hospitality and Tourism, Manufacturing Technology, Technological Design, Hairstyling and Aesthetics, and Green Industries) reside under the jurisdiction of the technological education curriculum. Therefore, the secondary science curriculum does not have many technology-based learning expectations, which does not align with current curricular reforms in other countries.

The science courses in Grades 9 and 10 are offered in two course types: academic and applied (Table 6.2). The intent of the academic courses is to develop students' knowledge and skills through the study of more abstract topics, focusing on the essential concepts of the topic, exploring related concepts, and incorporating practical applications as appropriate. The applied courses focus on the essential concepts of a subject and develop students' knowledge and skills through practical applications and concrete examples (OME, 2008c). Students who successfully complete academic or applied courses in Grade 9 may proceed to either the academic or applied Grade 10 science course. However, the choice in Grade 10 of academic or applied courses may impact admission to senior secondary (Grades 11–12) science courses and influence pathways for particular postsecondary destinations (university, college, or workplace).

Table 6.2 Grades 9 and 10 science courses and topics, by strand (OME, 2008c, p. 18)

Course	B. Biology	C. Chemistry	D. Earth and space science	E. Physics
Grade 9 Academic	Sustainable ecosystems	Atoms, elements, and compounds	The study of the universe	The characteristics of electricity
Grade 9 Applied	Sustainable ecosystems and human activity	Exploring matter	Space exploration	Electrical applications
Grade 10 Academic	Tissues, organs, and systems of living things	Chemical reactions	Climate change	Light and geometric optics
Grade 10 Applied	Tissues, organs, and systems	Chemical reactions and their practical applications	Earth's dynamic climate	Light and applications of optics

There are four types of courses in the Grades 11–12 program: university preparation, university/college preparation, college preparation, and workplace preparation (OME, 2008d). University preparation courses, in principle, are designed to meet general entrance requirements to a university, whereas university/college preparation courses are designed to meet the entrance requirements for general science programs offered by universities and colleges. College preparation courses are designed to meet admission requirements to college programs in Ontario, such as a dental hygiene diploma program. Finally, workplace preparation courses are broadly aimed to meet expectations of employers or for apprenticeship and training programs, such as plumbing. The Grades 11–12 program includes the major science disciplines (i.e., biology, chemistry, and physics) based on the original Pan-Canadian framework as well as general science courses (e.g., Environmental Science, Earth and Space Science). The general science courses are designated as hybrid university/college or workplace destination courses.

Prerequisites are an important consideration for students pursuing Grades 11 and 12 courses. Depending on the Grade 10 or 11 science course completed, students may not be able to enrol in a subsequent Grade 11 or 12 science course; for example, the college stream Grade 11 biology course is not a valid prerequisite for the university stream Grade 12 biology course. Many of the university/college and workplace courses in Grades 11 and 12 are not highly subscribed by secondary students due to either postsecondary school admission requirements or the lack of course room in student timetable schedules because of other secondary school diploma requirements. Table 6.3 provides a summary of some science courses and respective topics from each discipline area offered in Grades 11 and 12.

The Ontario Secondary School Diploma requires that students take 18 compulsory and 12 optional full-year course credits. The compulsory credits must include two Grade 9 or 10 and one Grade 11 or 12 science courses. However, students may substitute their Grade 11 or 12 science course requirement with courses in other subject areas, including technology education, cooperative education, computer science, and French as a second language (OME, 2015). Therefore, students can graduate with only 2 science credits. Students can choose to take a variety of Grades 11 and 12 science courses as part of their optional course credit requirements. School districts may develop their own courses (i.e., a locally-developed course) to address student needs not met by courses provided in the curriculum policy documents that do not duplicate existing courses (OME, 2004).

6.4.3 Large-Scale Assessment of Science Education

Large-scale provincial assessment is the responsibility of the Educational Quality and Accountability Office (EQAO)—an arms-length agency of the OME. Language (i.e., reading and writing) and mathematics are tested every year in Grades 3 and 6, along with mathematics in Grade 9, and a language literacy test in Grade 10 that students must pass in order to obtain a secondary school diploma (EQAO, 2017). Nonetheless, science is *not* assessed using province-wide accountability tests. There is some

Table 6.3 Sample Grades 11 and 12 science courses and respective topics

Course	Strand B	Strand C	Strand D	Strand E	Strand F
Environmental Science, Grade 11, University/ college	Scientific solutions to contemporary environmental challenges	Human health and the environment	Sustainable agriculture and forestry	Reducing and managing waste	Conservation of energy
Physics, Grade 11, university	Kinematics	Forces	Energy and society	Waves and sound	Electricity and magnetism
Biology, Grade 12, University	Biochemistry	Metabolic processes	Molecular genetics	Homeostasis	Population dynamics
Chemistry, Grade 12, College	Matter and qualitative analysis	Organic chemistry	Electro-chemistry	Chemical calculations	Chemistry in the environment

Note. Adapted from OME (2008d, p. 18)

evidence that literacy and numeracy accountability policies in Ontario have had an adverse impact on elementary science education programs (Fazio & Karrow, 2013).

Grade 8 students (age 13) participate in the Pan-Canadian Assessment Program (PCAP). The 2013 PCAP results indicate that Ontario students performed statistically better than the Canadian average (CMEC, 2014). Additionally, Ontario participates in the Programme for International Student Assessment (PISA); Canada's results were consistent with those of other top-ranked countries, with Ontario performing at the Canadian average (O'Grady, Deussing, Scerbina, Fung, & Muhe, 2016). Ontario also participates in the Trends in International Mathematics and Science Study (TIMSS) assessment for elementary students and is considered a benchmark jurisdiction in Canada (EQAO, 2012). Data from TIMSS suggest that since 2003 there has been a decrease in the number of students in Grades 4 and 8 meeting international benchmarks (Fazio & Karrow, 2013).

6.5 Science Teacher Education in Ontario

Beginning in the 1950s, Ontario had a comprehensive system of teacher education run by the Department of Education (Fiorino, 1978). In the 1970s, responsibility for teacher preparation was transferred to universities as part of decentralization in the Ontario Department of Education, which resulted in a shift from teacher training to teacher education (Kitchen & Petrarca, 2013). In addition to academic studies at university, prospective teachers were expected to study foundations of education, curriculum, and instruction and to undertake practice teaching in schools. In 1974, *Regulation 269* of the Ontario Teachers Qualification legislation divided teacher qualification into Primary/Junior (Grades K–6), Junior/Intermediate (Grades 4–10), and Intermediate/Senior (Grades 7–12) (Fiorino, 1978). Twenty years later, the Ontario Royal Commission on Education (1994) issued the report entitled *For the*

Love of Learning that recommended teachers join other professions (e.g., doctors, nurses) in self-regulation. Subsequently, the Ontario College of Teachers (OCT) was created with a mandate to license teachers in Ontario, set and maintain professional standards and qualifications for the teaching profession, implement a disciplinary process, and accredit university teacher education programs (Government of Ontario, 2016; OCT, 2015). To teach in a publicly funded school, a teacher must be a certified member in good standing with the OCT. In 2014–2015, there were approximately 115,000 full-time equivalent teachers, consisting of 75,000 elementary and 40,000 secondary teachers (OME, 2016a).

According to the OCT, there are 13 publicly assisted university institutions that offer accredited teacher education programs and that have elementary and/or secondary science teacher education. Two institutions offer teacher education programs in French. Furthermore, there are three independent universities in Ontario, one of which has a campus in the United States. Table 6.4 outlines all teacher education programs that lead to a recommendation to OCT for science teacher certification (according to 2015–2016 institutional websites and the online Ontario Teacher Education Application Service). *Concurrent* programs are defined as integrated undergraduate programs where students complete a Bachelor of Education (BEd) degree program while earning an undergraduate degree in science. Typically, students apply directly from secondary school into these programs. *Consecutive* programs, the most common pathway, are baccalaureate-type programs where students are admitted to a teacher education program upon completion of a university degree program (e.g., Bachelor of Science/BSc or Bachelor of Arts/BA).

General requirements for acceptance into a consecutive program include completing a minimum 3-year postsecondary degree from an accredited postsecondary institution. Three-year degrees are becoming an uncommon offering by many Canadian universities; 4-year degrees are the standard degree for most teacher education applicants. In addition, a prospective teacher must successfully complete a four-semester university teacher education program.

In 2015, Ontario's teacher education program changed from a two-semester program, with a minimum of 40 days of practicum (field experience), to a four-semester program, with a minimum of 80 days of practicum. Additional teacher education program changes included an enhanced focus on areas such as curriculum, pedagogy and assessment, special education, technology-enhanced teaching, and diversity (OCT, 2017). Variations still exist in terms of time to completion, with institutions' programs ranging from 18 to 24 months. Successful completion of a teacher education program results in a BEd degree and a recommendation by the institution to OCT for certification. The one exception to this is OISE, which offers a Masters of Teaching instead of a BEd program that leads to recommendation for certification.

The OCT identifies broad core content that should be included in a four-semester teacher education program for all education students regardless of subject specialization, as outlined in the *Accreditation Resource Guide* (OCT, 2017). Coursework foundations include educational law, history, philosophy, sociology, special education, and educational psychology. Other common—though not ubiquitous—courses

Table 6.4 Ontario universities offering teacher education programs leading to science teacher certification

University	Primary/ Junior (ELK–Gr. 6)	Junior/ Intermediate (Gr. 4–10)	Intermediate/ Senior (Gr. 7–12)	Concurrent program	Consecutive program
Brock (2018)	✓	✓	✓	✓	✓
Lakehead (2016)	✓	–	✓	✓	✓
Laurentian/ Laurentienne (n.d.)	✓ English/ French	✓ English/ French	✓ French	✓	–
Niagara–Ontario campus[a] (2016)	✓	–	✓	–	✓
Nipissing (2016)	✓	✓	✓	–	✓
Ontario Institute of Technology (2016)	✓	–	✓	✓	–
Ottawa (2016)	✓ English/ French	✓ English/ French	✓ English/ French	–	✓
Queen's (n.d.)	✓	–	✓	✓	✓
Redeemer[a] (2016)	✓	✓	–	✓	✓
Toronto, Ontario Institute for Studies in Education (OISE) (2015)	✓	✓	✓	–	✓
Trent (2016)	✓	–	✓	✓	✓
Tyndale[a] (2013)	✓	✓	–	–	✓
Western (2016)	✓	✓	✓	–	✓
Wilfrid Laurier (2016)	✓	✓	–	–	✓
Windsor (n.d.)	✓	✓	✓	–	✓
York (2016)	✓	✓	✓	–	✓

Note. Programs are offered in English unless otherwise indicated
[a]Independent is not publicly funded in Ontario

examine varied aspects of literacy, numeracy, assessment, diversity, environmental education, Indigenous perspectives, and ICT.

6.5.1 Pathways and General Requirements for Science Teacher Education

The only previous reviews of science teacher preparation programs in Ontario were completed by Epp and Epp (2000) and by Fazio and Niemczyk (2009). These two reviews identified considerable variation in the province with respect to delivery of science education and foundations courses, along with practica content and length.

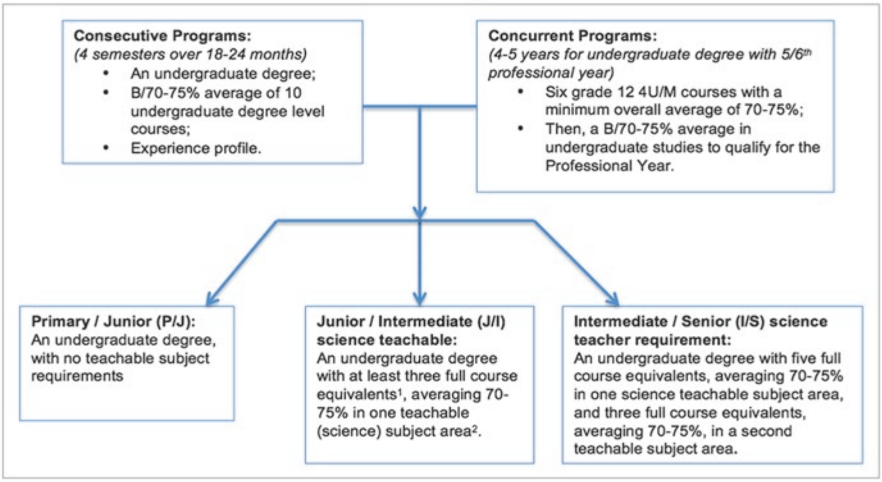

Fig. 6.3 Ontario science teacher education pathways. [1]A full course equivalent is understood to represent (approximately) a 72-hour degree-level course. [2]Teachable subject areas are biology, chemistry, physics, and general science

These results reflect the non-subject-specific guidelines for such courses by the OCT. Figure 6.3 shows the generic pathways for both elementary and secondary teacher candidates for obtaining science teaching certification.

Primary/Junior teachers (ELK–Grade 4) are generalists and do not require a teachable subject certification in any subject area. Junior/Intermediate teachers (Grades 4–10) must be prepared to teach all subjects but need to be qualified in one subject area or teachable subject (e.g., general science). Intermediate/Senior teachers (Grades 7–12) must hold qualifications in two teachable subjects (e.g., biology and chemistry, physics and mathematics) according to OCT regulations. Nevertheless, any teacher can be allowed to teach science (or any other subject) without holding a qualification to teach in that subject area if deemed necessary and by mutual agreement with the school principal.

There is a disconnect between the designation of elementary and secondary schools and the OCT's certification levels. That is, both the Junior/Intermediate and Intermediate/Senior divisions span the elementary and secondary realms, which lead to vagueness and even confusion when describing teacher education programs. Two examples of elementary and secondary science teacher education programs with respect to admissions, curriculum and instruction courses (science pedagogy courses), foundations courses, and field experiences (practicum) are provided, according to 2015–2016 institutional websites (Table 6.5). The nomenclature variations describing these two programs are symptomatic of the generic guidelines from the OCT in terms of course requirements and the autonomy of universities in designing teacher education programs. While Brock uses Elementary and Nipissing separates the program into Primary/Junior and Junior/Intermediate divisions, both education programs consist of similar foundations courses; however, differences exist in credit value for science education courses.

Table 6.5 Two Ontario examples of general requirements for science teacher education programs

Institution	General course requirements	Science-specific course requirements	Practicum days
Brock University	12 Credits[a] including assessment, cognition, social/emotional perspective, special education, ICT in education, professionalism and law, social and equity issues in Ontario context, teacher as researcher	Elementary: 0.5 course in teaching science and technology at the P/J or J/I level (regardless of teachable specialization)	105
	P/J and J/I have an integrated teaching, learning, and assessment course	Secondary: 1.5 course equivalent for each of two science-specific subjects (biology, chemistry, physics, general science)	
	I/S have special topic electives (e.g., Aboriginal education, environmental education)		
Nipissing University	P/J: Seven foundations courses[b] covering legal issues, professionalism, special education, curriculum design, assessment and evaluation, ICT, and diversity topics	P/J: One course in teaching science and technology	100
	J/I curriculum courses as P/J above but without a course in emergent literacies	J/I: One course in teaching science and technology; one course in intermediate general science	
	I/S: Foundations courses as above with two additional curriculum courses covering language and mathematics	I/S: Two courses in each of two science-specific subjects (biology, chemistry, physics, general science)	

[a]At Brock University, 1 credit is considered one full equivalent course (72 hrs) or two half courses each with a credit value of 0.5 (36 hrs)
[b]At Nipissing University, one course is 36 hours and worth 3 credits (equivalent to 0.5 credit value at Brock University); thus, a 6-credit course is 72 hours

In order to meet the requirements for elementary science teacher preparation, teachers need to demonstrate the requisite knowledge and skill reflected in their pedagogy courses. These courses rely on the principle that teachers of science should have a clear understanding of general and science-specific curriculum learning outcomes, instructional and assessment strategies, and developmental and social considerations of students in Ontario. For example, at Nipissing University the 2018 course description in the academic calendar the 36-hour, 3-credit course Science and Technology for the Junior and Intermediate Divisions states:

> Teacher candidates explore the structure, framework, and concepts of the science and technology program in the junior and intermediate divisions. Candidates focus on the development of personal science attitudes, skills, and knowledge while investigating the current approaches and instructional strategies that link scientific understanding to child development, (through, for example: inquiry, problem solving, critical thinking, hands-on, in-, and out-of classroom experiences). (Nipissing University, 2018, n.p.)

All Ontario secondary science teacher education programs include (a) minimum grade admission requirements in a previous degree, based on a selection of science courses appropriate to the science teachable subject (i.e., biology, chemistry, general science, physics) and (b) an experience profile or statement regarding working with adolescents in schools or informal educational programs. The minor variations that exist among admission requirements for secondary science teacher education programs include differences with respect to grades, prior teaching-related experience, and exclusion or inclusion of certain undergraduate science courses for specific science teachable subjects. Table 6.6 provides an example of one university's program admission requirements, including admission differences for four teachable secondary science subjects.

Secondary science teacher candidates are required to complete a combination of coursework and field experiences based on the generic core content areas specified by the OCT. In addition, they are required to take a science-specific pedagogy (e.g., methods) course commensurate with their teachable subject(s). However, there is considerable variation within programs. A review of institutional course calendars revealed the following themes in secondary science pedagogical course content: instructional strategies, laboratory methods and materials, issues and research in teaching science, ICT and science teaching, curriculum guidelines, nature of science (NOS), lesson and unit plan development. Most of these themes are evident in a majority of secondary science teacher programs. For example, the Lakehead University calendar description for Intermediate/Senior science-biology teachable basic qualification includes a number of these themes:

> Provides a foundation for the development of knowledge and understanding in the teaching of biology, based upon current research and best practices in teaching and learning science. Focuses upon pedagogical content knowledge and instructional strategies for teaching Biology within the context of the relevant Ontario Ministry of Education curriculum and policy documents. (72 hrs). (Lakehead University, 2016, n.p.)

In contrast, issues and research in science education and NOS were explicitly included in only a few course descriptions.

Table 6.6 Example of admission requirements for a consecutive secondary science program

Brock University admission requirements
• An undergraduate degree, with 5 full undergraduate credits, averaging 75%, in one teaching subject area and 3 full undergraduate credits, averaging 70%, in a second teaching subject area
• Two 100-hour teaching-related experience profiles
• *Science-biology*: Maximum of 1 undergraduate credit in anatomy, physiology, biochemistry, or biomechanics
• *Science-chemistry*: Five full undergraduate courses in chemistry as a first subject; three as a second teachable subject
• *Science-general science*: 3 Undergraduate credits must be from biology, chemistry, or physics (including astronomy) with a minimum of 2 credits in one subject and 1 credit in one of the remaining science subjects
• *Science-physics*: All 5 undergraduate credits must be in physics related to: forces and motion; energy, work, power, matter, and energy; waves – light and sound; electricity, magnetism, gravitation; hydraulic and pneumatic systems

Some teacher education programs offer elective or specialty courses related to science education. For instance, in their concurrent program, Brock University offers the course Higher Level Thinking in the Sciences and Mathematics; Western University offers a specialty course called Introduction to STEM Education; and York University's concurrent education program offers an elective course called Global Issues and Education. Other variations include practicum options. Some teacher education programs offer alternative practicum placements in international or informal (e.g., museum or outdoor education) settings. Some institutions that have both concurrent and consecutive teacher education program pathways may have combined courses for science teacher candidates in the various sciences. These blended courses are offered because of low enrolment numbers and the need to sustain course offerings for the science teachable subjects.

6.6 Professional Development in Ontario

Once certified, teachers are not legally required to engage in further professional development other than that mandated by the district school board on professional development (Pro-D) days or to acquire specific qualifications to teach particular science courses in schools. School boards generally support teacher professional development on specific Pro-D days by providing online and text resources along with various levels of funding to participate in local or provincial initiatives.

Teachers can earn additional qualifications (AQs) in a wide variety of subject teachables and general educational areas. AQ courses are overseen and accredited by the OCT and facilitated by various providers, primarily faculties of education but also some district school boards and teacher federations (OCT, 2016a, 2016b). AQ courses are 125 hours in length, are offered both face-to-face and online, and can lead to an increase in salary and/or career advancement. Dependent on their teaching assignment, teachers may be required to successfully complete specific AQ courses in order to teach science. Current AQs pertinent to science education include Honour Specialist in Biology, Chemistry, General Science, or Physics; Environmental Science; Environmental Studies Specialist; and Outdoor and Experiential Education.

Science teachers can often choose the direction of their Pro-D and, within limitations of time and funding, have access to a considerable breadth of science Pro-D. Professional learning opportunities specific to science education that do not result in professional qualifications are numerous and varied in content and scope. Some science Pro-D providers are listed in Table 6.7.

There is a trend, supported by the OME, away from workshop offerings and toward learning communities where a group of teachers may develop their understanding of a science teaching topic that is particularly relevant to their school and students. A *professional learning community* is a collective of teachers who share a common vision and goal for collaborative work using inquiry, experimentation, and innovation to improve teaching and student learning. The professional learning community model has evolved into the collaborative inquiry model (OME, 2014)

Table 6.7 Examples of science Pro-D available in Ontario

Format of Pro-D	Provider and URL
Lesson plans, teacher learning co-ops, and leadership and management skills (not exclusive to science teaching and learning)	Ontario Teachers' Federation http://www.otffeo.on.ca/en/ learning/
A yearly conference; a virtual library; ScienceWorks workshops for K–12 teachers	Science Teachers' Association of Ontario (STAO/APSO) https://stao.ca/cms/
Science centres and museums with programming, resources, and workshops for teachers and students	Ontario Science Centre, Toronto http://www.ontariosciencecentre.ca/School/ Canadian Science and Technology Museum, Ottawa Resources/Teacher/ http://cstmuseum.techno-science.ca/en/ Science North/Dynamic Earth, Sudbury http://www.sciencenorth.ca/schools/teacher-resources/
Teacher workshops that focus on the smarter science framework	Smarter Science https://smarterscience.youthscience.ca/
Workshops and resources	The Canadian Ecology Centre http://www.canadianecology.ca/professional-development/
Workshops, special programs, and resources	Perimeter Institute for Theoretical Physics https://www. perimeterinstitute.ca/outreach/teachers

with a strong focus on teacher-directed research into practice. The collaborative inquiry model of Pro-D requires support from school administration in the form of time in the school schedule and access to resources. Collaborative inquiry groups may work within a single school, with colleagues amongst schools, or with outside participants such as faculties of education.

6.7 Contemporary Issues in Science Education for Ontario

In this section, a few contemporary issues regarding science education in Ontario are introduced to raise awareness and prompt conversations for future priorities in science education. While not comprehensive, the following four sections highlight what the authors consider emerging issues that are important for Ontario.

6.7.1 Indigenous Perspectives

Numerous scholars agree that science education, as enacted in North America, is founded on Western paradigms that privilege science knowledge and skills, and valorize industrialization and globalization (Aikenhead, 1996). This is a viewpoint that likely serves many Ontario teachers and their students well. However, the cultural disconnect that arises when Indigenous students enter science classrooms has been described as akin to crossing a border into unknown territory; and interpretations of data repeatedly show an achievement gap where Indigenous students are significantly less successful in their education, including their science studies, than their non-Indigenous counterparts. Not only do Indigenous students score significantly lower on EQAO test scores (Gallagher-Mackay et al., 2013), they also demonstrate a higher dropout rate than non-Indigenous students (42% vs. 29%) with many Indigenous students never achieving requirements for high school graduation (OME, 2007b).

The ongoing issues of education for these students are being addressed in the Aboriginal Education Strategy through the FNMI Education Policy Framework (OME, 2007b). This strategy calls for developing and supporting teachers' understandings of Indigenous cultures, historical perspectives, and learning preferences and to develop appropriate curriculum and teaching strategies, that is, to connect science curriculum to the lived experiences of Indigenous students. Supporting the Framework is the online Teacher's Toolkit with accompanying guide (OME, 2009a) that identifies curricular expectations across subject curricula and provides teaching strategies to effectively address those expectations. There are a handful of indirect references to Indigenous perspectives in science expectations, for example, from Grade 3: "describe ways in which humans from various cultures, including Aboriginal people, use plants for food, shelter, medicine, and clothing" (OME, 2007c, p. 72).

A number of universities offer teacher education programs specifically for Indigenous teacher candidates. For example, Lakehead and Trent universities offer Bachelor of (Aboriginal) Education degrees, while Brock, Lakehead, Nipissing, Queen's, and Ottawa universities offer Aboriginal/Native Teacher Certification Programs. The comprehensive programming infuses traditional values, culture, and art into curriculum areas, including science (Lewington, 2013). In addition, many faculties of education provide specific training and/or courses in Indigenous education for all teacher candidates.

6.7.2 Environmental Education

The position of environmental education (EE) in science was redefined in 2007 when Ontario's Curriculum Council examined the state of environmental education in the province and produced a report titled *Shaping Our Schools, Shaping Our Future* (Bondar, 2007). This report defined EE as "education *about* the environment, *for* the environment, and *in* the environment" (p. 6). A subsequent report, *Acting Today, Shaping Tomorrow; A Policy Framework for Environmental Education in Ontario Schools* (OME, 2009b), supported the STSE learning expectations in the K–12 science curricula (OME, 2007a, 2008a, 2008b), such that EE continues to develop as an acknowledged component within the science curriculum. The intentions of both STSE and EE are quite similar in their shared focus on a healthy environment and the health of those who inhabit it. More specifically, STSE and EE overlap in areas such as NOS, environmental science and technology, eco-justice, environmental and social justice, and becoming informed citizens capable of making wise choices locally and globally (Steele, 2014).

In response to calls for EE in the curriculum, many Ontario teacher education programs offer a variety of opportunities for professional learning in EE beyond addressing the STSE expectations in the science curriculum (Inwood & Jagger, 2014). For example, Nipissing University has offered educating for environment (E4E) weekend workshops and has added elective outdoor and EE courses in their 2-year program. Trent University offers eco-mentoring weekend workshops and has included a requisite course in EE for all teacher candidates (DiGiuseppe et al., 2016).

6.7.3 Diverse Perspectives

Ontario has the highest rate of immigration amongst all provinces, which is particularly evident in the urban and surrounding areas of Toronto, Ottawa, Hamilton, and London. A growing cultural and linguistic diversity represents pedagogical challenges for science teachers. For instance, cognitive and linguistic demands of learning science, particularly by new immigrants who are English Language Learners (Cummins, 2012), are neither well-researched nor advanced by many Ontario science education programs. New conceptual perspectives on science education will need to be researched and developed (e.g., Calabrese-Barton, Tan, & O'Neill, 2014). For instance, more science teachers will be working with students from cultural and economic backgrounds that differ from their own. Acknowledging cultural diversity within science classrooms and leveraging classroom practices that support scientific career and citizenship goals that can be attained by *all* students will be an important science education priority for Ontario.

6.7.4 Elementary Science Education

The tradition of a single teacher delivering all subjects to elementary students goes back to the days of the one-room schoolhouse. Unfortunately, with many subjects—and science in particular—this practice is problematic. Elementary teachers require a significant level of science pedagogical content knowledge to teach science effectively. Yet most elementary teachers do not have an undergraduate science background and have had little science education preparation during their teacher education program (Dow, 2015). Elementary teachers, faced with multiple subjects, can find it challenging to remain current with new pedagogies and content in science. Additionally, the de-emphasis of science in high-stakes testing manifests itself in elementary schools through reduced instructional time for science and curtailed learning opportunities to promote higher-order thinking (i.e., scientific inquiry and technological design) (Fazio & Karrow, 2013). Regardless, curricular and societal expectations for science education remain high, leading to the concern that many elementary teachers may be underqualified to teach science and to prepare their students for further study in science and technology.

6.8 Conclusion

As science education in Ontario orients to the realities of the 21st century, addressing the above issues is essential to support science learning for *all* students. Local and specific data collection is required to create a more accurate picture of what is happening in science classrooms across Ontario. Both aggregate and case-specific data on the enactment of science curriculum are needed. While school districts have autonomy to design pedagogical innovations and promote science leadership, collaboration with community stakeholders such as parent groups, science NGOs, and science and technology industries can be enlisted to support these initiatives via involved educational leadership. Valuing science education and engaging in discussions with practitioners on how to improve science outcomes for all students will help reprioritize and reenergize Ontario science education.

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Chapter 7
Science Education in Québec: La science et la technologie pour tous

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Abstract This chapter overviews science education in Québec, highlighting its educational policies, the science and technology (S&T) curriculum, and teacher education in particular. Québec is a unique province; its Charter of the French Language, vast immigrant population, and diverse Indigenous population can lead to disparities in education in metropolitan centres and rural communities. The reform of educational policies and the most recent revision of S&T curricula have led to a renewed interest in studies of science education and its implementation. This chapter explores ongoing challenges in Québec: difficulties inherent in integrating S&T at the secondary level, a low priority of science at the elementary level, declining student interest in S&T, gender and equity in science education, the under-representation of Indigenous youth in science, and the role of language in science. Also presented are innovative approaches to teacher education and professional development, such as school and university partnerships, development of learning communities, and collaborative design of engaging S&T curricula.

7.1 Introduction

Yousra:	*We like it*
Marina:	*We like science*
Yousra:	*We like to know more about science* [giggle]
Both:	*It's not a joke!*

An exchange between youth involved in a video project (Rahm, Boulanger, Hébert, Journet, & Lachaîne, 2015; original in French)

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C. D. Tippett, T. M. Milford (eds.), *Science Education in Canada*,
https://doi.org/10.1007/978-3-030-06191-3_7

These lines are the opening to a video about recycling that was produced by two students in a science club in a Québec secondary school. Yousra (all names are pseudonyms), an immigrant from Morocco, and her friend Marina, an immigrant from Lebanon, document the decomposition of different forms of plastic. They interviewed teachers, asking them to define recycling and describe their recycling practices at home, and then edited the interviews and other content into a coherent short story about recycling that was shared on the school website. Yousra was at ease with science projects given her participation in *Les Scientifines*, a neighbourhood afterschool science program for girls in which she participated during her last 2 years in elementary school. Through her involvement in *Les Scientifines*, she had pursued two different science fair projects and engaged in other science activities, exploring questions grounded in her own interests (Rahm et al., 2015).

This brief anecdote highlights many dimensions of Québec science education. As elsewhere, children and youth are interested in science and have many opportunities to engage with science in and out of school. However, the contributions of these unique opportunities to science education and a scientifically literate society have yet to be fully documented. Interest in science does not necessarily lead to the pursuit of a science career either, which is often how success in science education is measured (Roy, Mujawamariya, & Lafortune, 2014). The anecdote also refers to afterschool programs that offer students additional opportunities outside the classroom to engage with science and technology (S&T) driven by their interests. In current discussions of science education, provincial comparisons tend to centre on achievement in science, technology, engineering, and mathematics (STEM) related subjects or on meeting the labour demands in STEM (Conseil Supérieur de l'Éducation [CSE], 2013). However, such a focus overlooks the richness of science education at large, which includes formal and informal science education taking place in a range of settings and disciplines among children, youth, and adults engaged with science for multiple reasons, yet each contributing to their science literacy development.

The example at the beginning of this chapter is also illustrative of ways S&T can be integrated as emphasized in the current Québec curriculum (CSE, 2013; Ministère de l'Éducation du Loisir et du Sport du Québec [MELS], 2001, 2004, 2007). Understanding S&T in Québec requires contextual information about the province, an overview of its school science curriculum and science teacher education programs, and a summary of the current issues that are, in part, specific to Québec. Furthermore, a selective summary of innovative science practices and projects points to next steps, needs, and challenges for Québec science education.

7.1.1 Provincial Context

Québec is unique in Canada due to its language policy, which in 1977 led to the adoption of the Charter of the French Language, commonly known as Bill 101 (Behiels, Hudon, & Millette, 2013/2015), making French the province's only

Fig. 7.1 Map of Québec

official language. Québec is the largest province in Canada; with a total of 1.5 million km^2, it comprises over 15% of the country's surface area. In 2015, its population was estimated at just under 8.25 million (Girard, 2015), which ranks second among all provinces and territories. Approximately 19% of the population live in rural areas, while close to 49% live in and around Montréal (Fig. 7.1) and 9% live in Québec City, the provincial capital. There are 11 distinct Indigenous groups in Québec; these 10 First Nations (i.e., Abenaki, Algonquin, Atikamekw, Cree, Huron-Wendat, Innu, Malecite, Mi'kmaq, Mohawk, Naskapi) and the Inuit communities account for 2% of the population. Approximately 40% of the Indigenous population is under the age of 25, compared to approximately 29% of the non-Indigenous population.

Québec's long history of immigration brings issues tied to French Language Learners (FLLs) such as struggles related to experienced discontinuities in language and culture. Currently, about 25% of the students in the school system were either born outside of Canada or have one or two parents born outside of Canada. For example, in some Montréal schools, over 60% of students were born outside of Canada.

7.1.2 Education

Historically, Catholics and Protestants have had their own schools, overseen by the first Ministry of Public Instruction established in 1868 and abolished in 1875 due to pressures from the Catholic Church. The Ministry of Public Instruction was subsequently taken over by the Department of Public Instruction that was comprised of a Catholic and Protestant Committee that oversaw educational policies (Corbo, 2002). However, the public education system was secularized in the early 1960s, resulting in over 1,500 school boards. The 1963–1966 Parent Commission emphasized the need to make education accessible to all children in Québec and led to an overhaul of the system. The Ministry of Education was established in 1964, the number of school boards was reduced, and the curriculum was standardized.

Currently, there are 60 French, nine English, and three multilingual (i.e., Indigenous languages and bilingual French and English) school boards in the province. They include 2,738 public schools and 320 private schools, all of which are overseen by MELS (2015a). There are an additional 29 special schools overseen by the federal government, and three overseen by the Government of Québec, that serve both French- and English-speaking students in the Côte-Nord region (Commission scolaire du Littoral) and Indigenous students in the Nord-du-Québec region (Cree School Board and Kativik School Board; MELS, 2015a).

7.1.2.1 Language

In 2011–2012, 76% of K–11 students had French as their first language, 9% had English, 1% had an Indigenous language, and a further 14% had other first languages, which in order of frequency were Arabic, Spanish, Creole, Italian, and Chinese (Mandarin and/or Cantonese; MELS, 2014b). Access to English schools, by law, is reserved to children whose parents received an education in English in Canada, while others are required to pursue their education in French (Bourhis & Foucher, 2012). Indigenous students living on reserves are exempt from the Charter of the French Language. In practice, these students are sometimes taught in Cree or Inuktitut, for example, during the first 3 years of elementary school, and then continue in French or English while still receiving some Indigenous language instruction (National Assembly of Québec, 2007).

An overview of student enrolment, cultural background, and school categories is provided in Table 7.1. It should be noted that especially in the greater Montreal area, where possible, parents send their children to private high schools. That practice has become a hidden form of injustice, and its implications for children and youth became a tension that the CSE brought to the forefront of issues it intended to address in 2016.

Table 7.1 Student enrolment by level, language of instruction, and school category in 2011–2012

Level (age)	Total enrolment	Language of instruction (%)			School category (%)	
		French	English	Indigenous	Private	Public
Preschool (4–5 years)	99,483	90.5	8.7	0.8	5.5	94.5
Elementary (6–11 years)	465,943	89.1	10.4	0.5	7.0	93.0
Secondary (12–17 years)	432,178	88.6	11.1	0.3	20.3	79.7
CÉGEP (18–19 years)	186,827	83.4	16.6	–	7.4	92.6

Note. Based on data from MELS (2014a, p. 138)

7.1.2.2 Instructional Organization

The current school system from Kindergarten (K) through Grade 11 is organized into cycles. There are three elementary cycles—Cycle One (K–Grade 2), Cycle Two (Grades 3–4), and Cycle Three (Grades 5–6)—and two secondary cycles—Cycle One (Secondary I and II; Grades 7–8) and Cycle Two (Secondary III, IV, and V; Grades 9–11). Secondary Cycle Two may be followed by *Collège d'enseignement général et professionnel* (CÉGEP, similar to Grades 12 and 13 elsewhere), which offers both vocational or terminal education and general education in preparation for university programs (MELS, 2007).

At the elementary level, classroom teachers are generalists who teach all subjects "except for second language, Physical Education and Health, and arts education" (MELS, 2015b, p. 3). Suggested time allocations for this level are language of instruction (7 hrs/week), mathematics (5 hrs/week), and physical education and health (2 hrs/week) with the remaining 11 hours apportioned at the discretion of the teacher for second language, arts education, ethics and religious culture, geography, history and citizenship education, and S&T (Éditeur officiel du Québec, 2017).

At the secondary level, teachers are specialists in one or two of the subject areas that are included in required courses for graduation. In Cycle One (Grades 7–8), suggested time allocations are language (language of instruction and second language, 600 hrs), mathematics (300 hrs), S&T (200 hrs), geography (150 hrs), history and citizenship education (150 hrs), arts education (200 hrs), physical education and health (100 hrs), and ethics and religious culture (100 hrs). In Cycle Two (Grades 9–11), students follow either a *general education* or an *applied general education* path. Regardless of path, suggested time allocations for subject areas are similar for each grade although the actual courses will vary (Éditeur officiel du Québec, 2017, pp. 15–16).

7.1.2.3 Curriculum Structure

Recently, a major reform in the educational system led to structural changes in how schools and the curricula are organized as well as changes in pedagogy. This reform began in 1997 at the elementary level and was fully implemented across the entire

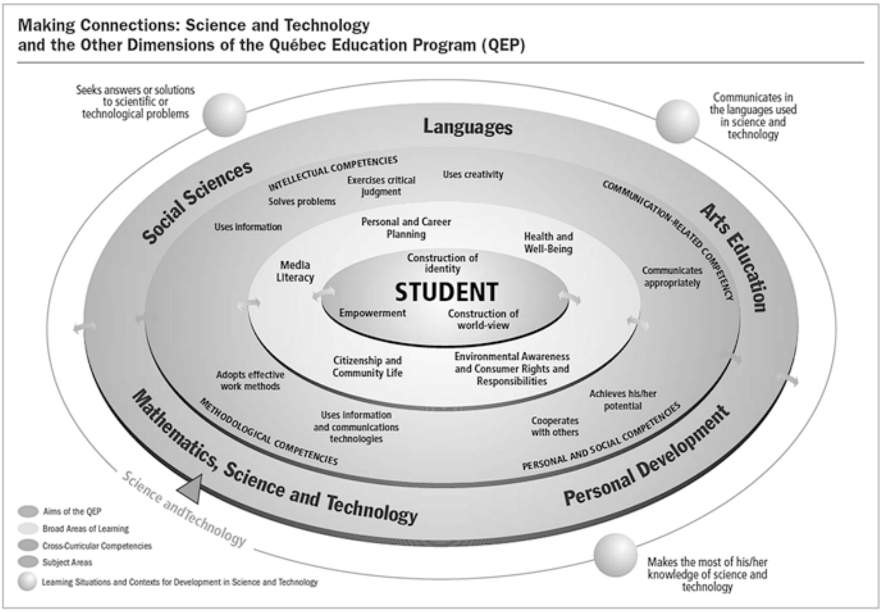

Fig. 7.2 The structure of the current educational program in Québec—Science and Technology. Reproduced from the Québec Education Program, secondary school education, Cycle One (MELS, 2004, p. 224)

education system by 2010. Committed to equality and opportunity, the curriculum is competency-based and student-centered with an emphasis on development within five subject areas: languages; mathematics, science, and technology; social sciences; arts education; and personal development (Fig. 7.2). There are nine cross-curricular competencies grouped into four categories—intellectual, methodological, personal and social, and communication-related—and connected to students' everyday, real-life concerns. The competencies are contextualized across the five broad areas of health and well-being, personal and career planning, environmental awareness and consumer rights and responsibilities, media literacy, and citizenship and community life. These broad areas are intended to support students' development of integrated ways of knowing that transcend subject areas. Hence, the broad areas of learning offer a means to develop cross-curricular as well as subject-specific competencies that are developed in and out of school across the lifespan.

7.1.3 Science and Technology Education

Science education is integrated with technology education to form the curricular area known as *science and technology*. According to the elementary curriculum document:

> Science and technology are distinct, yet complementary fields of endeavour, and their development is closely interrelated. Science attempts to describe and explain the world. It looks for relationships that allow us to make predictions and determine the causes of natural phenomena. For its part, technology applies the discoveries of science, while contributing to its development by providing it with new tools or instruments as well as new challenges and topics for research. Technology attempts to change the world so it can be adapted to meet humanity's needs. (MELS, 2004, p. 160)

Across all grade levels, the curriculum is grounded in socioconstructivism calling for teacher-guided student engagement with science through authentic problem solving, discussions, and products that support the development of competencies and scientific and technological literacy. The S&T curriculum includes complex learning scenarios that require the development and application of content and cross-disciplinary knowledge while making students' scientific reasoning evident. In most cases these scenarios require some laboratory work. Overall, emphasis rests on the development of S&T literacy, which implies ways of knowing, doing, and being in real-life S&T situations.

S&T is not mandatory until Grade 3 although teachers in Grades K–2 (Cycle One of elementary school) are encouraged to have children "explore the world of science and technology" (MELS, 2001, p. 160) via observations and hands-on manipulations. S&T in the elementary grades aims to offer students opportunities to develop three competencies:

- To propose explanations for or solutions to scientific or technological problems
- To make the most of scientific and technological tools, objects, and procedures
- To communicate in the languages used in science and technology (MELS, 2001, p. 161)

The first competency involves students posing questions and finding solutions through observations, hands-on activities, measurements, construction of models, and experimentation in either the real world or the laboratory. The second competency focuses on students' ability "to use the objects, tools and procedures of science and technology to construct tangible representations of the world around us or to refine our understanding of that world" (MELS, 2001, p. 168). It makes the link to real life and contexts. The third competency centres on the development of scientific language for both posing and solving problems as well as for articulating and sharing solutions. In terms of content, there are three broadly defined areas with a list of concepts (see http://www1.education.gouv.qc.ca/progressionPrimaire/science/index_en.asp) to be mastered within each: *The Material World* (e.g., matter, fluids, waves), *The Earth and Space* (e.g., sources of energy, seasonal changes, soil), and *The Living World* (e.g., cell division, digestive system). The program aims to contextualize the teaching of S&T through cultural referencing, which implies an exploration of history, values, ethics, impact, and limitations.

At the secondary level, the same three competencies are developed in the S&T curriculum, with a slight rewording of the first competency, to "seek answers or solutions [as opposed to merely] propose explanations" (MELS, 2007, p. 2). *The Technological World*, which refers to objects, systems, products, and processes,

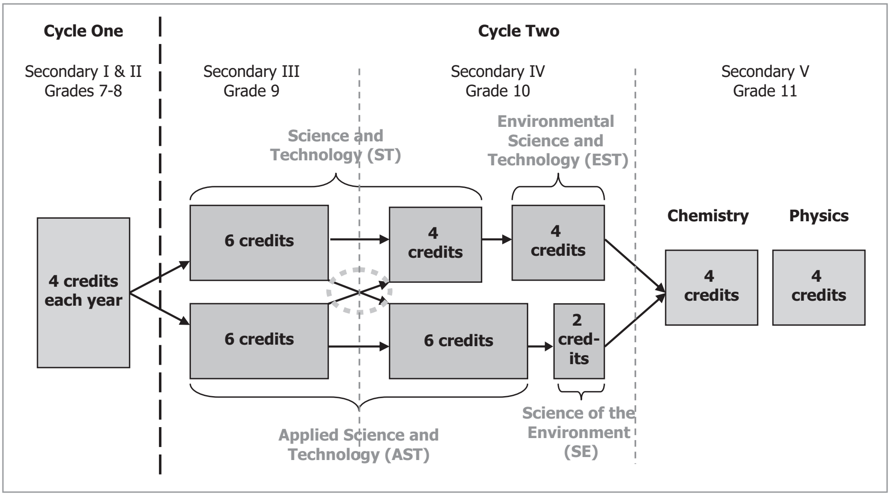

Fig. 7.3 The sequence of secondary science courses. (Adapted from a 2010 PowerPoint presentation developed by the Educational Services Department, Lester B. Pearson School Board, Dorval, PQ)

appears as a fourth area in the secondary curriculum. Four different approaches are recommended in teaching secondary S&T:

> The technocratic approach focuses on scientific skills. The democratic approach is more concerned with developing citizenship skills. The humanist perspective aims to help students develop their intellectual potential, while the utilitarian approach is based on the everyday uses of science and technology. (MELS, 2007, chapter 6, p. 2)

Another feature of the S&T curriculum at the secondary level is the presence of a school science technician who works together with the science teachers, preparing the materials for laboratory investigations.

A total of 200 hours is devoted to S&T over the 2 years of Secondary Cycle One and 100–250 hours over the 3 years of Secondary Cycle Two (Éditeur officiel du Québec, 2017). Students in Cycle Two have a choice between the general and applied paths, with the main difference being the emphasis given to technology and the application of S&T to real-world problems. There are two 100-hour science courses in Secondary V (Grade 11)—Chemistry (gases, reactions, chemical equilibrium) and Physics (kinematics, dynamics, geometrical optics)—required to pursue a CÉGEP degree in the sciences. As such, the system is very flexible. Figure 7.3 illustrates the sequence of courses in secondary science, and Table 7.2 provides an overview of the science concepts that are covered.

Students are asked to make connections with broad areas of learning and develop cross-curricular competencies; scientific fields such as astronomy, biology, chemistry, geology, physics, physical geography, and technology are explored in an integrated manner. For example, availability of drinking water could be explored through the living world (ecosystems), through earth and space (climate and the role of the hydrosphere and atmosphere), through the technological world (functioning

Table 7.2 Science and technology content in secondary Cycles One and Two

	The Living World	The Material World	The Earth and Space	The Technological World
Cycle One (Secondary I and II; Grades 7–8)	Diversity of life forms Survival of species Life-sustaining processes	Properties of matter Changes Organization	Characteristics of the Earth Geological and geophysical phenomena Astronomical phenomena	Engineering Technological systems Forces and motion
Cycle Two (Secondary III, IV, and V; Grades 9–11)	Hierarchical organization of life Systems: nutrition, relationships, reproduction	Properties of matter Changes in matter Organization of matter Fluids Waves	The Earth Space	Graphical language Engineering Materials Biotechnology

Note. Adapted from MELS (2004, 2007)

of a drinking water treatment plant or an aqueduct), and through the material world (pH scale and electrolytic dissociation). Student competency is assessed at the school level, with the exception of Ministry-administered uniform examinations for Secondary IV/Grade 10 students in S&T and Applied S&T (see MELS, 2015). These uniform examinations are not competency-based but are instead paper-and-pencil tests, with most of the items entailing multiple-choice questions focusing on the recall of scientific knowledge. A passing grade on these examinations is required for graduation.

7.2 Teacher Education in Québec

Teacher education (i.e., a university professional program leading to teacher certification) is compulsory for anyone wanting to teach at the elementary or secondary level (MELS, 2015a). All teacher education programs are structured around 12 core professional competencies that are developed through course work and practicum placements in diverse educational settings (Ministry of Education in Québec, 2001). To ensure equivalency across institutions, teacher education programs are regularly accredited by the Committee for the Accreditation of Teacher Education Programs (CATEP), which is composed of university professors, teachers, and school board personnel. MELS has developed a complex system of equivalence requirements for people holding teaching degrees from outside Québec, resulting in seven potential paths to becoming a teacher (see MELS, 2015b, for elaboration).

Within the province, one of the more common paths to teaching is a CÉGEP diploma followed by a 4-year, 120-credit hour university Bachelor of Education (BEd) program. Programs in English are offered at Bishop's University, Concordia University, and McGill University. Programs in French are offered at Université de Sherbrooke (UdeS), Université Laval (UL), Université de Montréal (UdeM) and at six of the 10 campuses of L'Université du Québec, including its largest, L'Université du Québec á Montréal (UQAM). These programs include one practicum placement each year as well as foundations courses and content area courses in art education, English, French, ethics and religious culture, mathematics, music, natural sciences, physical education, and social sciences. At the secondary level, a teaching diploma in general education implies specialization in one or two subjects that require 45 credit hours (MELS, 2015a). Furthermore, all university students must pass a French language test; this test can be taken during the first 2 years of a teacher education program.

7.2.1 Science Teacher Education

Although certification is not discipline-specific, there are three pathways leading to a degree that would include teaching science: an elementary BEd (Grades K–6), a secondary BEd (Grades 7–11), or a masters in secondary teaching (Grades 7–11). A general CÉGEP diploma is required for entry into most elementary BEd programs. These programs typically include only one 45-hour science methods course that combines science teaching with science content; it is not uncommon for preservice teachers' most recent science course to have been in Grade 10/Secondary IV (Chastenay, 2014). An exception is the UdeM program, which requires one science content and one science methods course; both are taught within the School of Education. Science methods courses are typically taught in a university laboratory and involve practical science work and the development of science learning situations. Pedagogical approaches in these courses may involve partnerships with science museums, explorations of hands-on science, and specific approaches to encourage girls' and minority students' engagement in science (Dionne & Couture, 2010b; Dionne & Deblois, 2011; Potvin & Dionne, 2007; Roy et al., 2014).

Entry requirements for secondary science teacher BEd programs include a CÉGEP diploma in science, which typically includes three courses each in biology, chemistry, and physics. Most secondary science BEd programs include a number of content courses often taken through science departments or faculties. The rest of the program includes teaching placements in secondary schools and courses that address learning theory, classroom management, school system organization, evaluation, and science methods. Typically these courses reflect reform-based curricula, constructivist teaching and learning, and the role of science teachers as guides in creating authentic learning situations, helping students to appropriate ways of knowing and talking science and to develop an identity as a science insider (M. Legendre, 2008).

Masters programs in secondary science teaching are offered at McGill, UdeM, UdeS, UQAM, and UL. These programs are designed for people holding a bachelor's degree in a relevant field or for teachers certified in other countries or other Canadian jurisdictions.

7.2.2 Certification

A teaching licence that indicates level (elementary or secondary) and language (French or English) but not a specific subject area is required to teach in Québec (MELS, 2015a). For general education there are three types of licences (Gouvernement du Québec, 2017). A *teaching diploma*, which can be obtained upon completion of a BEd or a Master of Education, is a permanent licence. A *teaching permit*, which is valid for 5 years, may be obtained if someone does not meet all the requirements for a teaching diploma, for example, is not a Canadian citizen. A provisional *teaching authorization* is valid for 2 years and may be obtained, for example, after completion of three of the four required practicum placements or at the discretion of the Ministry of Education. Judgment about a teacher's competencies in a specific field (e.g., mathematics or science) is left to the employer to assess by examining the individual's qualifications.

7.2.3 Professional Development

Professional development (Pro-D) for teachers is recommended by MELS but is not required. Yet, studies indicate important gains for teachers engaged in ongoing Pro-D (Dionne & Couture, 2010a; Dionne, Couture, Savoie-Zajc, & Paris, 2015). For example, Dionne and Couture (2010a) found in a learning community for female Grades 5 and 6 teachers that cognitive, affective gains manifested in an increased interest and motivation to teach S&T and increased senses of professional autonomy and empowerment. In a subsequent analysis of this community of learners over a 2-year period, Dionne et al. (2015) found that the sharing of ideas and co-creation of science activities led to increased self-efficacy in science teaching.

Most school boards employ pedagogical consultants who organize Pro-D opportunities such as the presentations of materials and activities and new developments in teaching and evaluation practices; some of these opportunities may be related to science. Pro-D opportunities may also be sought through local organizations. The Association for the Teaching of Science and Technology in Québec (http://www.aestq.org/index.php) has approximately 600 active members; it produces the journal *Spectre* and holds an annual meeting where teachers can share innovative practices and participate in conference workshops on various topics.

Another important resource for teachers of science is *Science pour tous*, which is a network of scientific programs in Québec that was formed in 1997. *Science pour tous* has been actively involved in the shaping of Québec's scientific culture; it contributed to the government document *Politique québécoise de la science et de l'innovation* (Québec science and innovation policy; Gouvernement du Québec, 2001) as well as other policy documents that address formal and informal science education. A third important resource is *L'île du savoir* (Island of knowledge; n.d.); it develops activities that can be integrated into the elementary classroom such as robotics or fab lab-related projects. Teachers are encouraged to take advantage of such opportunities, not simply to outsource science teaching but to learn to implement such projects in their teaching.

An additional area of support for Pro-D is provided by university-based S&T research centres and outreach programs, including:

- Centre de recherche sur l'enseignement et l'apprentissage des sciences (Centre for Research in Teaching and Learning in Science; https://www.usherbrooke.ca/creas/) at UdeS
- Équipe de recherche en éducation scientifique et technologique (Research Team in Science and Technological Education; http://erest.uqam.ca/) at UQAM
- Chaire de recherche sur l'intérêt des jeunes à l'égard des sciences et de la technologie (Research Chair on Youth Interest in Science and Technology; http://www.crijest.org/) at UQAM and UdeS
- Laboratoire mobile pour l'étude des cheminements d'apprentissage en science (Mobile Laboratory for the Study of Learning Pathways in Science; http://recherchesnumeriques.ca/regroupement/laboratoire-mobile-pour-letude-des-cheminements-dapprentissage-en-sciences-labmecas) at UQAM
- The WOW Lab (https://www.mcgill.ca/wowlab/) at McGill
- Let's Talk science (http://outreach.letstalkscience.ca/mcgill-university)
- EducArt (https://educart.ca/en/about/) at the Montreal Museum of Fine Arts

The role of the university in Pro-D and the kind of school-university collaborations are the focus of much-needed research (Samson, Hasni, Gauthier, & Potvin, 2011).

Suggestions are that *top-down* reforms and training should be avoided; instead, professional learning communities should be developed (Dionne et al., 2015; Perrenoud, 2005) as well as collaborative research projects between universities and teachers (Lacasse & Barma, 2012). This type of Pro-D and professional learning would benefit science teachers, helping them to engage more deeply with the structural changes and challenges implicit in science education reform (Lacasse & Barma, 2012; R. Legendre, 2002). The development of learning communities to address challenges associated with science teaching reform has proven promising (Dionne et al., 2015; Samson et al., 2011).

7.3 Ongoing Challenges

This section highlights some of the key issues facing S&T education in Québec: the difficulties inherent in integrating S&T at the secondary level, the low priority of science at the elementary level, declining student interest in S&T, gender and equity in science education, the underrepresentation of Indigenous youth in science, and the role of language in science.

7.3.1 Secondary Education: The Integration of Science and Technology

The S&T reform within Québec called for a pedagogy theoretically grounded in a constructivist epistemology (M. Legendre, 2008) that required teachers to engage with new, fundamental ideas about what the teaching of science implies, what counts as knowledge in science, ways of assessing knowing and doing science through a focus on competencies, and integration of science with technology. Additionally, the integration of technology—in the sense of engineering or the application of science—with science has been perceived as a burden given the already crowded curriculum.

According to the policy document, *Teacher Training: Orientations, Professional Competencies* (Ministry of Education in Québec, 2001), future science teachers are expected to fit the following exit profile:

> The science and technology exit profile covers a broad range of knowledge. The teacher training program should not be designed as a patchwork of courses from various subject areas, but should instead be developed with a view to training future teachers of an integrative subject, namely science and technology, who will work with fellow teachers to develop student competencies. The subject-specific knowledge for the teacher training program must be designed to identify the contribution made by science and technology to the understanding and resolution of various problems. The program must also link the subject to other subject areas and promote teaching from a cultural perspective. (p. 163)

In practice, universities struggle to offer truly integrated S&T teacher training. The topic of technology itself is a challenge, given teachers' reservations about their engineering abilities or what they have summarized as a lack of handyman abilities and engineering spirits (Charland, Riopel, Fournier, & Potvin, 2009). The two domains of S&T seem to call for different postures and underlying processes in problem solving. Lacasse and Barma (2012) pointed out that the level of support and resources required for secondary science teachers to develop meaningful and authentic S&T learning situations, such as the creation of a wind turbine, are very demanding and lacking in many schools**.** Even secondary teachers with training in multiple disciplines of S&T (e.g., biology, physics, chemistry, technology) may find it challenging to conceive integrated transdisciplinary projects.

7.3.2 Elementary Education: The Low Priority of Science

Historically, the shortcomings of science education at the elementary level have been widely reported; for example, the amount of time allocated to S&T in the curriculum was described as deplorable (CSE, 1982). The lack of importance placed on mandatory examinations in science may have reinforced the subordinate status of S&T—with teachers considering S&T to be less important than mathematics and French. Elementary teachers were described as being unable to or uninterested in teaching science and therefore neglecting to teach science and exhibiting an overall lack of competence (CSE, 1982). Subsequent reports suggest that little has changed (CSE, 2004, 2013); in fact, the disappearance of minimum S&T teaching times in 2000 (MELS, 2004) may have been a step backwards for science education.

The cultural politics of Québec's S&T funding structure has favoured a strong out-of-school culture of outreach activities, such as science fairs, museums, and science clubs (Dionne, Trudel, & Reis, 2013). However, programs that offer pedagogically sound science practices are the exception (Dionne et al., 2013; Rahm, 2010; Rahm, Gorry, Lachaîne, & Kanouté, 2013). Hence, the common practice of elementary teachers outsourcing science teaching to the informal sector is potentially problematic (Hasni, 2005). One way to address some of the problems identified in informal science could be university-community collaborations, such as a partnership involving a museum offering workshops to elementary preservice teachers (Dionne & Deblois, 2011). These workshops would allow prospective teachers to strengthen their disciplinary knowledge and explore innovative hands-on investigative methods in science. A second example would be practicum placements in science museums, a context that allows student teachers to develop self-efficacy in science teaching, scientific communication skills, and scientific content knowledge (Deblois & Dionne, 2014; Dionne & Deblois, 2013).

7.3.3 Declining Student Interest in S&T

Educational change in Québec was initiated to respond to an increasing disinterest in science and science careers (CSE, 2013). However, Hasni and Potvin (2015) found that interest in science from Grades 5 to 11 declined in those dimensions that were linked to school (e.g., school S&T, self-concept in science), while interest in out-of-school dimensions increased (e.g., use of S&T for society, out-of-school science). The largest decline in interest occurred at the transition between elementary and secondary school (Grades 6 and 7). The lowest level of interest in school science occurred in Grade 8. Almost a quarter of the students considered themselves to perform fairly well in S&T, yet they presented themselves as reluctant to consider S&T careers. Hasni and Potvin (2015) concluded that very few students seriously consider pursuing S&T careers and suggested that pedagogical methods that are challenging and intellectually engaging, like scientific inquiry, could help increase interest in S&T.

Interest in science is also tied to students' and teachers' understanding of what science is (Désautels & Larochelle, 2004). School science can be seen as disjointed from the ways in which science figures in daily life (Gonsalves, Rahm, & Carvalho, 2013). Désautels and Larochelle (2004) identified the need for opportunities to engage with science in ways that are tied to real-world problems. Currently, real-world problems are addressed in environmental education, which figures prominently in Québec schools, leading to projects related to climate change, biodiversity, and green schools (Sauvé, 2013). Yet, these learning projects are often offered in the context of service learning or the Ethics and Religious Culture program (Rahm et al., 2015).

7.3.4 Gender and Equity in Science

Much research in Québec has focused on gender and equity in science education. There are notable gender differences in preference for subdisciplines of science, with girls preferring biology and other human-related subdisciplines (Hasni & Potvin, 2015). Attempts to support girls in their pursuit of careers in the physical sciences have had little positive effects (Lafortune, Deschênes, Williamson, & Provencher, 2008; Roy et al., 2014). Since 2003, L'Association de la francophonie à propos des femmes en sciences, technologies, ingénierie et mathématiques (French Association of Women in Science, Technology, Engineering, and Mathematics; http://www.affestim.org/accueil/) has been demystifying science careers for girls, proposing pedagogical initiatives to foster girls' interests in science, and developing initiatives to inform parents about ways to support their daughters in the pursuit of science.

Other outreach efforts include *Les Scientifines*, an afterschool science program serving girls from two elementary schools in an underserved and ethnically diverse community of Montréal. *Les Scientifines* is often presented as exemplar because it offers long-term exposure to science, participation in science fair projects, and the production of a scientific newsletter (Rahm, 2010; Théorêt & Garon, 2003). Yet, longitudinal case studies make evident just how challenging it can be for girls because they often struggle with cultural discontinuities and expectations that are difficult to combine with careers in the physical sciences (Rahm et al., 2015). While programs like *Les Scientifines* offer girls a safe space to develop a science identity, maintaining that identity requires ongoing mentoring and coordinated actions between schools and out-of-school programs (Rahm, 2012; Rahm, Lachaîne, & Mathura, 2014; Rahm, Mathura, & Lachaîne, 2016).

7.3.5 Underrepresentation of Indigenous Youth

Indigenous youth are underrepresented in the sciences within Québec. That state of affairs is tied to their underrepresentation in higher education in general, with 30% of Québec's Indigenous population having no trade school, college, or university certificate or degree in comparison with 15% of the non-Indigenous population (Statistics Canada, 2016). However, there is movement towards Indigenous science outreach efforts such as the Québec Aboriginal Science Fair (http://www.

esaquebec.ca/home/) held annually since 1998 or afterschool programs managed by Youth Fusion (https://fusionjeunesse.org/en/).

Science monitoring projects in northern communities have also become popular. For instance, Inuit youth in Nunavik (Fig. 7.1) have opportunities to work in collaboration with teams of scientists and contribute to the blending of Inuit and Western ways of knowing and doing science in the context of archaeology (Desrosiers & Rahm, 2015). Another example is Avativut, a citizen science program in Nunavik, where high school students monitor their environment, experience science as it applies to their community and way of life, have opportunities to work at the elbows of scientists from the south, and learn about careers in the sciences (Gérin-Lajoie et al., 2014). Another initiative is the Kiuna Institution, a college that is a project of the First Nations Education Council in Québec that represents the Abenaki, Algonquin, Atikamekw, Cree, Huron-Wendat, Innu, Malecite, Mi'kmaq, Mohawk, and Naskapi. It offers different college-level degrees that are open to Indigenous and non-Indigenous students.

Unfortunately, the current education system does not support the nonlinear education pathways that would facilitate Indigenous students' pursuit of science. Additionally, northern students who wish to study science are obligated to leave their communities to study in the south—in a system with a history of colonialism and a singular view of science (Rodon, Lévesque, & Dalseg, 2016).

7.3.6 The Role of Language in Science

Throughout this chapter, Québec's unique language situation—its immigrant population, its French language charter, and its diverse Indigenous population—has been tangentially mentioned. However, issues of language are more problematic for some groups than others (McAndrew et al., 2015; Sandilands, McKeown, Lyons-Thomas, & Ercikan, 2014). On a recent iteration of the Pan-Canadian Assessment Program (O'Grady & Houme, 2014), Québec students who wrote in French scored at the Canadian mean in science, and students who wrote in English scored below the Canadian mean. Furthermore, science achievement has been noted as particularly problematic in minority Francophone communities (Mujawamariya & Lirette-Pitre, 2004). Reading and writing in science is not simply literacy but is decoding and using different text genres that enrich students' scientific knowledge and their culture (Rivard, 2009); however, little research has unpacked the issues that FLLs face in the context of science literacy development.

The authors see science as a promising yet under-researched tool to support French language learning. For instance, work with immigrant youth producing videos in an afterschool science club clearly indicated that science was a means to develop French literacy skills (Rahm et al., 2015). Students recorded themselves talking science and juxtaposed that video with additional footage, making the science content more personal and coherent. Similarly, the production of a science newsletter in *Les Scientifines* entailed many communication challenges for girls whose first language was often neither French nor English (Rahm et al., 2013). These girls struggled to understand science terminology used in online resources and to translate the science content in ways appropriate and meaningful for their audience of elementary students. Clearly, FLLs will experience many challenges with school content; at the same time, science is an engaging tool for learning language (Rahm et al., 2013).

7.4 Concluding Thoughts

Several important issues need further exploration in science education in Québec. Issues of language and S&T are important, given the number of immigrant students in the province (Rahm et al., 2015). Ethnic diversity among teachers and students and its impact on the development of science literacy and on minority students' interest in science careers should be explored (Mujawamariya, Gaudet, & Lapointe, 2014). Ways to adapt science teaching for students with exceptionalities who are integrated into regular classrooms warrant additional investigation. *Desettling science*—which might involve the blending of approaches from Western, Indigenous, or other cultures—has been given little attention to date. The complementary nature of formal and informal learning in S&T and the development of science literacy in multiple settings should be examined.

This chapter began with a brief exchange that made evident students' interest in science. Yet, it has been noted that science education is a practice far removed from the regular practices of scientists (Désautels & Larochelle, 2004; Hasni & Potvin, 2015; Roy et al., 2014). It has also been noted that students lack the S&T literacy needed to engage in current debates about issues such as sustainability and climate change. Pro-D and teacher education could play an important role in addressing these issues. Collaborative projects and engagement in transdisciplinary professional learning communities are promising practices. Alternative practicum placements can provide opportunities for preservice teachers to be immersed in science in meaningful and empowering ways. Hence, the future of teacher education may entail a model that spans multiple settings and brings together scientists, teacher educators, and the community.

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Chapter 8
Science Education in New Brunswick: Canada's Only Officially Bilingual Province

Grant Williams, Michel T. Léger, Ann Sherman, and Nicole Ferguson

Abstract This chapter on science education explores a complex set of conditions that make New Brunswick unique from other Canadian jurisdictions. The Department of Education and Early Childhood Development has two distinct units—one for Francophone education and one for Anglophone education—which means there are two complete sets of curricula, offices, assessments, etc. There are four Anglophone school districts and three Francophone school districts in New Brunswick. Provincial universities offer English BEd degree programs, French BEd programs, and programs for bilingual teaching. New Brunswick has been home to one of the million-dollar NSERC Science Education projects (2005–2010) that forged a number of research and learning collaborations, which are still ongoing today. This chapter describes how these different complexities result in a variety of programs that are meant to support the work of educators of science at all levels throughout both Francophone and Anglophone New Brunswick.

8.1 Introduction

New Brunswick is one of the four Atlantic provinces and is the third smallest province in Canada, both geographically and demographically, with a population of approximately 750,000. Approximately one third of the population is Francophone and two thirds are Anglophone. The province is home to 15 Indigenous

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C. D. Tippett, T. M. Milford (eds.), *Science Education in Canada*,
https://doi.org/10.1007/978-3-030-06191-3_8

Fig. 8.1 Map of New Brunswick

communities of mainly Mi'kmaq and Wolastoqey (Maliseet) peoples, whose total population is approximately 23,000 (Statistics Canada, 2012). New Brunswick has three urban areas situated around Moncton, Saint John, and the capital Fredericton, but most areas are fairly rural with large agricultural regions and forests (Fig. 8.1). It is Canada's only officially bilingual province with all government services offered in both English and French. The New Brunswick Department of Education and Early Childhood Development (NBDEECD) is structured with one minister who heads a dual system with deputy ministers and complete administrative staffs for each official language. Most decisions in each of the Anglophone and Francophone branches are made independently of each other, and curriculum documents are created separately in each language. There is a practice not to translate from one language into the other because of the constitutional commitment to duality and language conservation. In other words, curriculum documents in each language are created through separate processes. Another example of the distinctive nature of education in New Brunswick is the fact that schools fall into three categories in the Anglophone districts—elementary school, K–5; middle school, 6–8; and high school, 9–12—while the Francophone districts categorize schools as either primary (K–8) or high school (9–12).

There are approximately 69,000 students currently enrolled in K–12 in Anglophone schools and 29,000 students in Francophone schools (NBDEECD, 2016c). There is little recognition of the Indigenous communities as far as representation in the NBDEECD since the education of Indigenous students living on-reserve is funded and administered by the federal government. Nine Indigenous communities have their own band-operated elementary schools and, in some cases, middle schools; there are no Indigenous high schools in New Brunswick, so all Indigenous high school students attend public schools.

The demographics of New Brunswick are changing. In 2012, the number of deaths in the province outnumbered the number of births (Statistics Canada, 2012). Despite this demographic reality, many schools in the three main urban centres have experienced an influx of students since 2006 due to a noticeable migration of population from the province's northern towns and villages. These three urban centres are also the preferred destination of immigrants who choose to make New Brunswick their home. At the same time, New Brunswick has experienced a large migration of skilled tradespeople to western Canada. It should be noted that many of the immigrants eventually move out of the province to larger urban areas such as Toronto, Montreal, or Vancouver, contributing to a downward demographic trend in the province.

School districts have been facing the same budget cuts as other regions in Canada over the last several years; as a result, school districts have been amalgamated, and schools have been closed. The latest amalgamation occurred in 2012 with 14 school districts being combined into four Anglophone and three Francophone school districts for the entire province. Most school districts have experienced a reduction in student population over the last 10 years, with the resulting need for school closures.

8.2 Science Education

Work began on the development of common curricula in specific core programs for the Atlantic provinces in 1993. The Council of Atlantic Ministers of Education and Training (CAMET) primary purposes for collaborating on curriculum development were to (a) improve the quality of education for all students through shared expertise and resources, (b) ensure that the education students receive across the region is equitable, and (c) meet the needs of both students and society (CAMET, 1998).

Under the auspices of the Atlantic Provinces Education Foundation (which was superseded by CAMET), development of common core curricula for mathematics, language arts, social studies, and science follows a consistent process. Each project requires consensus by a regional committee at designated decision points with all provinces having equal weight in decision making. Each province has established procedures and mechanisms for communicating and consulting with education partners, and it is the responsibility of the provinces to ensure that stakeholders have input into regional curriculum development. In New Brunswick, input was obtained from classroom teachers, university science educators, NBDEECD officials, and external groups or organizations.

In the Anglophone sector, the science curriculum foundation document—the *Foundation for the Atlantic Canada Science Curriculum* (*FACSC*; CAMET, 1998)—was developed with the three other Atlantic provinces in 1998. *FACSC* provides an overview for all grade levels (K–12) in the public school system. It provides an explanation of scientific literacy with a focus on scientific inquiry, problem solving,

Table 8.1 Science topics according to grade level in the New Brunswick Anglophone sector

Grade	Science topics in the Anglophone curriculum			
K	Students as individuals	Healthy lifestyles	Our senses	Place and community
1	Groups	Our environment	Healthy lifestyles	Community
2	Change and the physical environment	3D objects and the properties of solids	Growth and development: Life cycles	–
3	Exploring soils	Invisible forces	Materials and structures	Plant growth and changes
4	Habitats and populations	Light	Sound	Rocks, minerals, and erosion
5	Forces and simple machines	Properties and changes in materials	Meeting basic needs and maintaining a healthy body	Measuring and describing weather
6	Diversity of life	Electricity	Flight	Space
7	Earth's crust	Heat	Interactions within ecosystems	Mixtures and solutions
8	Cells, tissues, organs, and systems	Fluids	Optics	Water systems
9	Reproduction	Atoms and elements	Characteristics of electricity	Space exploration
10	Sustainability of ecosystems	Weather dynamics	Chemical reactions	Motion
11	Individual courses in biology, chemistry, physics, and Earth and environmental sciences			
12				

Note. Adapted from NBDEECD (2002–2009)

and decision making. The document outlines (a) essential graduation outcomes that cut across all curricular areas and (b) suggestions for the teaching and learning environment. *FACSC* encourages a constructivist philosophy and an inquiry approach to the teaching of science, which is in line with the broader advisory *Common Framework of Science Learning Outcomes, K-12* (Council of Ministers of Education, Canada [CMEC], 1997) and with most other provincial and territorial curricula.

Despite the cuts that have occurred in the provincial budget, NBDEECD has made consistent efforts to maintain current curricula in both the Anglophone and Francophone sectors. In addition to *FACSC*, each grade has its own specific curriculum documents. Table 8.1 shows all science topics according to grade level in the Anglophone sector. Most of the current Anglophone elementary and middle school science curriculum was implemented between 1998 and 2002. However, some of the high school curriculum documents are newer; for example, Biology 11 and 12 in 2008, Chemistry 11 and 12 in 2009, and Introduction to Environmental Science 12 in 2013. Two new courses, Human Physiology and Advanced Environmental Science, are under development with grade-wide implementation expected in the 2017–2018 school year. Revisions to science curricula in Grades 3 through 10 began in 2017, with work on Grades K–2, 6, and 9 occurring first.

Table 8.2 Science topics according to grade level in the New Brunswick Francophone sector

Grade	Science topics in the Francophone curriculum			
K–8	***Living Universe***			
	Organization of life	Heredity	Evolution	Energy transfers
	Nonliving Universe			
	Matter and energy	The Universe	Earth	Earth
9	Reproduction	Atoms and elements	Electricity	Astronomy
10	Durability of ecosystems	Chemical processes	Movement	Meteorology
11	Individual courses in biology, chemistry, physics, and Earth and environmental sciences			
12				

Note. Adapted from NBDEECD (2009–2011)

Unlike the Anglophone sector where science curriculum is based on the shared *FACSC* platform, the curriculum in the Francophone sector is province specific, given New Brunswick's unique bilingual context. Working with other Atlantic provinces in French curriculum development is difficult because New Brunswick is the only province east of Québec with a Francophone education sector. Therefore, the current French science and technology curriculum is based on a theoretical framework developed from both US and European influences. These international influences continue to play a role as upcoming revisions to the Francophone science and technology curriculum theoretical framework are based in part on the American Association for the Advancement of Sciences' (AAAS) Project 2061 (1989), a long-term research and development initiative focused on improving science education, and include ideas from other French-speaking countries currently proposing innovations in science education, namely, Belgium's *Conseil de l'enseignement des communes et des provinces* (Municipal and Provincial Committee on Teaching, http://www.cecp.be/). It is important to mention that, although their theoretical framework may differ somewhat relative to their sources, both the Anglophone and Francophone sectors in New Brunswick share a similar vision of science and technology education, one based on scientific inquiry, problem solving, and critical decision making.

Science education in the Francophone sector includes outcomes related to technologies as indicated by the title of curriculum documents that refer to *science and technology* rather than *science*, which stands alone on Anglophone curriculum documents. In the Francophone sector, primary schools span Kindergarten through Grade 8. The science and technology curriculum has been developed in three grade clusters: K–2, Grades 3–5, and Grades 6–8. This structure has been chosen to better espouse the constructivist view of learning. Hence, a concept introduced in the initial grade of a particular cluster (e.g., Grade 3) will be further explored and consolidated in the next 2 years (e.g., Grades 4–5). Table 8.2 shows all science topics according to grade level in the Francophone sector.

Aside from a shared theoretical framework, each Francophone primary science and technology curriculum document contains a section outlining a set of six transdisciplinary learning outcomes. These outcomes look to incorporate development of the following skills: communication, use of technologies, critical thought, personal and social development, culture and heritage, and efficient work methods. Furthermore, the K–2 and 3–5 science curriculum documents focus on developing a sense of citizenship involving knowledge in science and technology.

First, students develop skills needed to contribute in a future workplace that will likely center largely on science and technology. Second, students develop the ability to think critically and act responsibly in regard to society and the environment. While Grades 6–8 also include these aims, specific skills related to the processes of science (e.g., observation, inference, analysis, and communication) are part of the curriculum. These process skills reflect the influence of the AAAS's *Benchmarks for Science Literacy: Project 2061* (1993).

Whereas the K–8 Francophone science documents are based on Project 2061 and European curricula, the Grades 9–12 curricula are based on the *Common Framework* (CMEC, 1997). The overall learning outcomes highlight scientific literacy and an appreciation for the scientific and technological process. Furthermore, overall outcomes aim to include fundamental scientific concepts as well as attitudes and values needed to build a society concerned with social justice and environmental stewardship. Francophone secondary science courses are similar to courses in the Anglophone sector and include electives in Grades 11 and 12 which range from courses in astronomy and environmental sciences to the more traditional physics, chemistry, and biology courses.

The current Francophone primary and secondary science curricula were published between 2005 and 2011. Although revisions are currently underway for the three primary science and technology curricula, no such revisions are planned for the various secondary science curricula.

8.2.1 Science Resources and e-Learning Opportunities

The Science Teacher Needs Assessment (Kierstead, Bateman, & Martin, 2008) determined that elementary and middle-level science teachers would benefit from having a resource that could supplement the provincial curriculum documents. Working in partnership with the staff of Science East (n.d.), NBDEECD developed a collection of 27 resource packages to provide science teachers with exemplars of effectively including inquiry into science instruction and assessment practices. The packages were designed to follow the 5E learning cycle (Bybee et al., 2006) and to emphasize embedded formative assessment. Most of the pedagogical resources were developed to support the Anglophone curricula. Although Science East collaborates with Francophone school districts, more resources for French-speaking students are needed.

NBDEECD operates two e-learning distance education programs for high school students in small and rural schools without appropriate teacher expertise: one for the Anglophone and one for the Francophone school system. The e-learning offerings currently consist of more than 40 courses, including all required science courses at the Grades 11 and 12 levels as well as many optional and advanced level courses. NBDEECD permits classroom teachers to register their face-to-face students in online courses, allowing them access to elements such as interactive activities and animated demonstrations that enhance instruction and learning.

8.2.2 Assessment in Science

Science teachers in New Brunswick are particularly interested in how formative assessment—or assessment *for* learning—can be used at all grade levels to document science learning through strategies such as journaling and capturing science learning with student-narrated videos. Additionally, teachers are encouraged to give students opportunities to explain and explore their own thinking as part of the assessment process—or assessment *as* learning. NBDEECD (2013) suggests that up to 90% of assessment be assessment *for* and *as* learning rather than assessment *of* learning through detailed and effective teacher feedback, peer feedback, and self-assessment.

In the English sector science is assessed provincially at Grades 4, 6, and 10 as part of the New Brunswick Assessment Program. In the French sector, science is assessed in Grade 8 only. The province participates in national and international assessments (e.g., Pan-Canadian Assessment Program and PISA) although much of NBDEECD's efforts have focused on improving literacy and numeracy success, with less emphasis on science. However, the recent NBDEECD *10-year Education Plan* (2016a, 2016b) includes science literacy as one of 10 priorities, which will hopefully result in more resources being allocated to science education in both English and French.

8.3 Science Teacher Preparation

In New Brunswick, science teacher preparation involves earning a Bachelor of Education (BEd) degree at one of four institutions. In English, the degree can be completed at the University of New Brunswick (UNB) at its Fredericton and Saint John campuses, at St. Thomas University (STU) in Fredericton, or at Crandall University (CU), a private institution in Moncton. Although some Francophone students may choose to enrol at an Anglophone university in New Brunswick or elsewhere, the vast majority enroll at the Université de Moncton (UdeM) to complete their BEd degree since that institution affords them the opportunity to study in French while remaining in New Brunswick. It is to be noted that UdeM has two satellite campuses, one in Edmundston and the other one in Shippagan (see Fig. 8.1). For the purposes of this chapter, only the UNB Fredericton and STU programs for the Anglophone sector and the UdeM program for the Francophone sector will be described.

As is the case for many Canadian universities, both UNB Fredericton and STU offer a post-degree (consecutive) BEd program. In both cases, the program can be completed in a single year following the completion of an undergraduate degree while offering preservice teachers 60 credits (or 20 course equivalents with each course being 36 hrs of class time). UNB had previously offered a 2-year, 60-credit program but revised its program in the last decade to offer the degree in 1 year, which has always been the case at STU. The UNB Faculty of Education spent a great deal of time with the stakeholders of the program, including government, teachers' union, and school districts, prior to making the decision to change to the truncated time frame. The current program was deemed more effective and efficient for students, and it suited the school districts better with regard to the time spent in schools.

UdeM offers a generalized, 5-year, BEd degree, 168-credit program for primary-level Francophone preservice teachers; secondary-level students can choose between a specialized, 5-year program (e.g., in science education) or a streamlined, 2-year, 65-credit program if they already have a bachelor's degree in a teachable discipline. This program was offered over 11 months prior to 1996 but has since been modified to a more comprehensive version delivered over 2 years. Table 8.3 compares the post-degree BEd programs in New Brunswick in both official languages.

8.3.1 Science Teacher Education at University of New Brunswick Fredericton

In the elementary stream at UNB Fredericton, there is a slight concern that preservice teachers do not have enough experience with science. Many students enter the BEd program with a humanities-based degree and need a great deal of support with the teaching of both science and mathematics. Students in the elementary BEd program are required to complete only one 3-credit (36 hrs) science methods course that focuses on inquiry learning with a constructivist approach. However, four additional courses are offered as science electives.

Preservice science teachers enter the secondary program at UNB Fredericton with between 18 and 30 credits of science courses depending on their teachables. All students in the secondary science program take four 3-credit courses that include a range of pedagogical and content knowledge such as the nature of science, student misconceptions in science, and ways of engaging students in problem solving and critical thinking.

8.3.2 Science Teacher Education at St. Thomas University

Students in the School of Education at STU enrol in either an elementary, secondary, or French-as-a-second-language stream. Preservice teachers in the elementary program take a 3-credit course in each of elementary science, mathematics, and

Table 8.3 A comparison of BEd programs in New Brunswick

Program	Anglophone sector		Francophone sector
	University of New Brunswick	St. Thomas University	Université de Moncton
BEd type	Post-degree	Post-degree	Direct Post-baccalaureate
BEd duration	11 months	11 months	5 years (direct) 2 years (post-baccalaureate)
BEd credit hours	60	60	168 (direct) 65 (post-baccalaureate)
Minimum GPA for admission	2.7	2.7	2.3 Cumulative and 2.6 in three French courses
Teachable subjects required for BEd admission	30 Credit hours in one teachable and 18 credit hours in another teachable or 24 credit hours in each of two teachables	30 Credit hours in one teachable or 24 credit hours in one subject area and 18 credit hours in another teachable	42 Credit hours in one teachable & 24 in a second teachable or 60 credit hours in one teachable & 21 in a second teachable or a multidisciplinary degree with at least one concentration in a teachable
BEd program streams	Elementary (K–5) Secondary (6–12) Adult education BEd for First Nations students	Elementary (K–5) Secondary (6–12) French as a second language	Primary (K–8) Secondary (9–12)
Science methods courses	*Elementary*: one 3-credit hour course in elementary science methods *Secondary*: four 3-credit hour courses in secondary science teaching methods	*Elementary*: one 3-credit hour course in elementary science teaching methods *Secondary*: one 3-credit hour course in each of middle-level and secondary science teaching methods	*Primary*: one 2-credit hour course in science didactics *Secondary*: two 2-credit hour science courses in secondary science didactics *Post-baccalaureate*: one 3-credit hour science didactics course in first teachable and one 3-credit hour science didactics course in second teachable
Field placement structure	One day per week during fall and winter terms as well as 2-week, 3-week, and 7-week placements during fall and winter terms, all at the same school	One 7-week placement in fall and one 8-week placement in winter, each at a different school and preferably different grade levels/ subjects	*Primary and secondary*: 3 weeks in spring of 2nd year, 4 weeks in spring of 3rd year, and 16 weeks in fall of 5th year *Post-baccalaureate*: 3 weeks in spring of 1st year and 12 weeks in fall of 2nd year, each at a different school

technology methods. The focus in the science course is on inquiry-based constructivist approaches with a special emphasis on cross-curricular extensions. Students in the elementary stream may complete a co-major in science, technology, engineering, and mathematics (STEM) education consisting of two additional 3-credit courses in secondary mathematics and science methods. Students wishing to complete the STEM co-major must also have completed a minimum of 9 credit hours in STEM discipline courses with a minimum grade of “C” (60–69.9%) during their undergraduate program.

Students who intend to teach science at the middle or high school levels take a 3-credit course in each of secondary science, mathematics, and technology methods as well as one 3-credit course in secondary sciences and mathematics pedagogy. The initial science, mathematics, and technology methods courses focus on middle level (Grades 6–8) curriculum, while the additional combined science and mathematics pedagogy course is on high school (Grades 9–12) curriculum. These methods courses focus on how to create student-centered learning opportunities with an emphasis on constructing explanatory models in forms such as simulations, analogies, physical models, graphs, equations, and diagrams so as to appeal to a diverse range of learners.

8.3.3 Science Teacher Education at Université de Moncton

Students enrolled at UdeM can choose to follow either an elementary or secondary stream; these are concurrent BEd programs offered over 5 years and combined with a Bachelor of Arts (BA; elementary, secondary) or a Bachelor of Science (BSc; secondary). The 168-credit BA/BEd elementary program, reconfigured in 2016, includes various humanities and pedagogy courses, four 3-credit science courses (two biology, one chemistry, one physics), and one 2-credit science didactics course. The 168-credit BSc/BEd secondary program, also reconfigured in 2016, has an option for preservice teachers to specialize in chemistry, biology, or physics. Students choosing the secondary stream complete a total of 33 credits in their science discipline as well as two 2-credit science didactics courses.

8.4 Teacher Certification

Graduates with a BEd from any of the province’s universities are eligible for certification. NBDEECD grants teacher certification, and the regulations under the *Education Act* are the same for applicants in both official languages. Applications for certification include a criminal record check and an official postsecondary transcript. Depending on the number of credit hours, a level 4 or 5 professional teaching certificate will be granted, which enables the holder to teach from K–12; for example, UdeM’s current 5-year teacher education program leads to a level 5 teaching certificate. Completion of a recognized MEd leads to a level 6 teaching certificate. There is a small salary difference between levels, but there is no additional level or salary increase for doctoral degrees. A teacher who has obtained a BEd outside the province must go through the same application process for certification. All successful applicants receive an interim certificate, which may become permanent after 2 years of successful teaching experience in the province.

8.5 Science Professional Development and Informal Science Education Support

NBDEECD offers some science-specific professional development (Pro-D); however, recent budget cuts have led to fewer offerings. Consequently, both UNB and STU now offer Pro-D for elementary and middle school science teachers in the Anglophone sector, while UdeM offers Pro-D for Francophone science teachers mostly at the elementary level. However, these university-supported Pro-D sessions are infrequent as limited funds are available to release teachers from their classrooms.

A number of extracurricular programs support students in the learning of science and work with schools to deliver additional programming. One tremendous support is Science East (n.d.), an interactive family science centre located in Fredericton. It uses innovative, hands-on science exhibits to demonstrate basic science concepts, prompt curiosity, and foster interest and understanding of science among people of all ages. The centre also features travelling exhibits that both Francophone and Anglophone schools and off-site summer camps utilize.

The Gaia Project (n.d.) is a nonprofit organization based in Fredericton with a mandate to educate students on issues related to energy, climate change, and sustainability. It provides interactive, project-based learning opportunities for students and the general public through French and English programs that are based on three principles: data-informed decision making, economic assessments, and environmental impacts and lifestyle assessments. Language-specific Program Delivery Officers regularly tour schools throughout the province, engaging students and teachers in project-based activities designed to foster problem-solving skills and an awareness of environmental issues. For example, the Mobile Energy Centre is a 4-metre-long trailer that contains interactive alternative energy equipment controlled through five touchscreen computer interfaces. Students and teachers can manipulate a wind turbine, track the sun with an onboard solar panel array, and pedal a bicycle with an onboard power meter to see how much power they are able to generate. Other popular programs include student-driven audits of a school's ecological footprint, which provides a hands-on look into issues like solid waste and energy consumption.

Worlds UNBound/l'Univers sans limites (n.d.) is an award-winning, bilingual, nonprofit program run by UNB engineering and science students with the goal of promoting interest in science, engineering, and technology in a hands-on, interactive, and engaging manner. Currently in its 21st year of operation, Worlds UNBound reaches close to 14,000 young New Brunswickers per year through its STEM-related camps, in-school workshops, Quest 4 Girls club, and other programs.

In 2015, the Canada-Wide Science Fair (CWSF) was held in New Brunswick for the first time. The CWSF was hosted by UNB and Science East; all public universities, school districts, the city of Fredericton, and NBDEECD partnered in supporting the event. Over 800 students from across Canada and 300 judges from throughout New Brunswick participated in the weeklong event. Over 2,000 local school children visited the CWSF and took part in Science at Work displays that showed provincial businesses using science. The event promoted awareness of science across the general public with the goal of increasing interest in science.

8.6 Science Education Research in New Brunswick

In New Brunswick, science education research occurs at all three public universities, takes place in French and English, and explores a range of diverse topics. At UNB, research is being conducted on the use of elementary science resource kits that were created by BEd students and based on curriculum outcomes for Grades 4 and 5. These kits include resource materials for inquiry-based lessons, written lesson plans, and information about inquiry learning as well as videos demonstrating the lessons. Kits have been shown to support teachers, especially those teachers who have little science background prior to entering their BEd programs (MacDonald & Sherman, 2006, 2007; Sherman & MacDonald, 2007, 2008a, 2008b, 2009). The kits also address teachers' concerns about obtaining science supplies and have been successfully implemented in numerous upper elementary classrooms.

At STU, research efforts focus on the use of models in the teaching of science and aspects of STEM learning. Models are a useful instructional support in cases where the phenomena being studied are difficult to directly observe, such as planetary motion, human respiration, continental drift, and magnetic fields (Williams & Clement, 2015). Research at STU has been focusing on a particular type of model in which K–12 students cooperatively act out, or kinesthetically simulate, particular phenomena. This research explores ways in which teachers can support student engagement in kinesthetic simulations, called *Kinulations*, to model and reason about abstract scientific concepts (Williams, Oulton, & Taylor, 2017). Other studies have examined how STEM subjects are best learned, especially by females and nontraditional populations.

At UdeM, science education research focuses on teaching and learning science in a linguistic minority setting, integrating notions of environmental education into science curricula, and the impact of experiential learning on student performance in science. Recent research on the use of the 5E learning cycle (Bybee et al., 2006) in integrating youth literature and language strategies in Francophone science classes is intended to measure the impact of such strategies on conceptual understanding in science, reading comprehension, cognitive growth, interest in science, and motivation in reading (Lirette-Pitre, Cormier, & Ferguson, 2016). Integrating notions of environmental education in science, the *Littoral et vie* environmental education action group (Coast and Life, http://www8.umoncton.ca/littoral-vie) explores socioconstructivist pedagogical strategies designed to help students and citizens better understand chemical, biological, and ecological components of their environment. Since 1996, a multidisciplinary global team of researchers has engaged in various sustainable development and science education projects, such as the Young Builders of Our Future project, where students from Canada, Romania, Tunisia, Brazil, and Columbia worked to solve local environmental problems with the help of participating chemists, urbanists, engineers, biologists, and geographers (Pruneau et al., 2015). A third area of research focuses on the development of experiential learning models and on the pedagogy of science education in natural settings (LeBlanc, Léger, Lang, & Lirette-Pitre, 2015; Léger & Pruneau, 2011, 2012, 2014–2015).

8.7 Summary

One of Canada's smallest and least-populated provinces, New Brunswick is a unique educational environment due in large part to its officially bilingual status. The New Brunswick Department of Education and Child Development operates a dual system with curriculum and instruction decisions being managed by separate Anglophone and Francophone branches. Recent amalgamations within both Anglophone and Francophone school districts as well as reductions in teacher Pro-D are reflective of both stagnation in the population and the provincial government's ever-present concern with trimming budgets.

As New Brunswickers tackle the challenges of a decreasing population in a non-industrial province, science education has nonetheless improved in the last 50 years. It should be noted that education, particularly in the French-speaking population, was not a priority as children were often kept at home to work the fields or go fishing. Furthermore, Francophone schools were mostly run by the church and referred to as confessional schools. The church influence was felt as students continuing their postsecondary studies mostly enrolled in liberal arts degree.

Fortunately, the three provincially-funded teacher education institutes (i.e., UNB, STU, and UdeM) as well as various nonprofit organizations (i.e., Science East, Gaia Project, and World's UNBound/L'univers sans limites) have developed a range of professional learning opportunities for science educators. Additionally, research projects at these three universities are producing resources to support high-quality science teaching and learning opportunities for both of New Brunswick's Anglophone and Francophone school systems.

Le Nouveau-Brunswick: l'enseignement des sciences dans la seule province bilingue au Canada

Grant Williams, Michel T. Léger, Ann Sherman, and Nicole Ferguson

Résumé Le présent chapitre sur l'enseignement des sciences examine un ensemble complexe de conditions qui marquent la singularité du Nouveau-Brunswick par rapport aux autres provinces canadiennes. Le Ministère de l'Éducation et du Développement de la petite enfance (MEDPE) comprend deux unités distinctes – une pour l'éducation francophone et une pour l'éducation anglophone – ce qui signifie qu'il y a deux ensembles complets de programmes, de bureaux ministériels, d'évaluations, etc. Il y a quatre districts scolaires anglophones et trois districts scolaires francophones au Nouveau Brunswick. Les universités provinciales offrent des programmes de préparation au B. Éd. en anglais et en français ainsi que des programmes de préparation à l'enseignement bilingue. Le Nouveau-Brunswick a accueilli l'un des projets d'éducation scientifique du CRNSG (Conseil de recherches en sciences naturelles et en génie du Canada) d'un million de dollars (2005–2010), lequel a permis de forger un grand nombre de collaborations de recherche et d'apprentissage qui existent encore de nos jours. Le présent chapitre décrit comment ces différentes complexités ont donné lieu à une variété de programmes destinés à soutenir le travail des enseignants de sciences à tous les niveaux dans l'ensemble du Nouveau-Brunswick francophone et anglophone.

8.1 Introduction

Le Nouveau-Brunswick est l'une des quatre provinces atlantiques du Canada et la troisième des plus petites provinces aussi bien en termes de géographie que de démographie, avec une population d'environ 750 000 habitants. Environ un tiers de la population est francophone et deux tiers sont anglophones. Il y a 15 collectivités Autochtones, appartenant essentiellement aux peuples migmag et malécite (Wolastogey), dont la population totale est d'environ 23 000 personnes (Statistique Canada, 2012). Il y a trois zones urbaines au Nouveau-Brunswick situées autour de

Fig. 8.1 Carte du Nouveau-Brunswick

Moncton, Saint John et Fredericton, la capitale, mais la majorité du territoire est essentiellement rurale avec de vastes espaces forestiers et agricoles (Fig. 8.1). C'est la seule province du Canada officiellement bilingue, où tous les services gouvernementaux sont offerts en anglais et en français. Le ministère de l'Éducation et du Développement de la petite enfance (MEDPE) est dirigé par un seul ministre chargé de gérer un système double, avec des sous-ministres et un personnel administratif complet pour chaque langue officielle. La plupart des décisions dans chacune des unités anglophone et francophone sont prises indépendamment les unes des autres et les curricula sont créés séparément dans chaque langue. Le principe est de ne pas traduire d'une langue dans l'autre en application de l'engagement constitutionnel envers la dualité et la protection de la langue. En d'autres termes, les documents des programmes d'études sont créés selon un processus distinct pour chaque langue. Un autre exemple de la particularité de l'éducation au Nouveau-Brunswick concerne la catégorisation des écoles. Dans les districts anglophones, on trouve des écoles élémentaires (M-5), intermédiaires (6–8) et secondaires (9–12), tandis que dans les districts francophones, les écoles sont soit primaires (M-8) soit secondaires (9–12).

Actuellement, il y a environ 69 000 élèves de la maternelle à la 12^{e} année dans les écoles anglophones et 29 000 dans les écoles francophones (MEDPE, 2016c). Les collectivités Autochtones ne sont guère représentées au Ministère du fait que l'éducation des élèves Autochtones qui vivent dans les réserves est financée et administrée par le gouvernement fédéral. Neuf collectivités Autochtones ont leurs propres écoles élémentaires administrées par leur bande et parfois des écoles intermédiaires; il n'y a pas d'école secondaire Autochtone au Nouveau-Brunswick, et tous les élèves Autochtones de niveau secondaire fréquentent les écoles publiques.

Les données démographiques du Nouveau-Brunswick évoluent. En 2012, le nombre des décès dans la province l'emportait sur le nombre des naissances (Statistique Canada, 2012). Malgré cette réalité démographique, beaucoup d'écoles des trois principaux centres urbains ont connu un afflux d'élèves depuis 2006 dû à une migration notable de la population des villes et des villages du Nord de la province. Ces trois centres urbains sont également la destination préférée des immigrants qui choisissent de s'établir au Nouveau-Brunswick. En même temps, la province connait à un important exode de travailleurs spécialisés vers l'ouest du Canada. En effet, un grand nombre d'immigrants finissent par quitter la province pour se rendre dans des centres urbains plus importants comme Toronto, Montréal ou Vancouver, ce qui accentue la tendance démographique à la baisse dans la province.

Ces dernières années, les districts scolaires ont subi les mêmes compressions budgétaires que dans les autres régions du Canada et c'est pourquoi des districts scolaires ont été fusionnés et des écoles ont fermé. La fusion la plus récente a eu lieu en 2012, lorsque 14 districts scolaires ont été fusionnés de façon à créer quatre districts scolaires anglophones et trois districts scolaires francophones pour l'ensemble de la province. La plupart des districts scolaires ont subi une réduction de la population étudiante au cours des dix dernières années, ce qui a obligé certaines écoles à fermer.

8.2 Enseignement des sciences

Les premiers efforts d'élaboration d'un curriculum commun pour certains programmes de base dans les Provinces atlantiques datent de 1993. Les principaux objectifs du Conseil atlantique des ministres de l'Éducation et de la Formation (CAMEF) concernant l'élaboration du curriculum étaient (a) d'améliorer la qualité de l'éducation de tous les élèves en partageant les connaissances et les ressources, (b) d'assurer que l'éducation que reçoivent les élèves de toute la région soit équitable et (c) de répondre aux besoins aussi bien des élèves que de la société (CAMEF, 1998).

Sous les auspices de la Fondation d'éducation des provinces atlantiques (qui a été remplacée par CAMEF), l'élaboration de curricula de base communs pour les mathématiques, les langues, les sciences humaines et les sciences se poursuit de façon régulière. Chaque projet requiert le consensus d'un comité régional à certains points de décision désignés, toutes les provinces ayant un poids égal dans la prise de décision. Chaque province a adopté des procédures et des mécanismes pour communiquer avec ses partenaires en éducation et les consulter, et il revient à chaque province de veiller à ce que les parties intéressées participent à l'élaboration du curriculum régional. Au Nouveau-Brunswick, on a fait appel à la participation de titulaires de classe, de professeurs de sciences à l'université, de fonctionnaires du Ministère et de groupes ou d'organismes extérieurs.

Dans le secteur anglophone, le document de base du curriculum de sciences – intitulé *Foundation for the Atlantic Canada Science Curriculum* (Fondements du curriculum des sciences au Canada atlantique, *FACSC*; CAMEF, 1998) – a été élaboré avec les autres provinces atlantiques en 1998. Ce document propose une vue d'ensemble pour toutes les années (M-12) du système d'écoles publiques. Il donne une définition de la culture scientifique, en insistant sur l'enquête scientifique, la résolution des problèmes et la prise de décisions. Le document présente (a) les résultats essentiels couvrant tous les aspects du programme requis pour la remise du diplôme et (b) des suggestions pour le milieu d'enseignement et d'apprentissage. Le *FACSC* invite à enseigner la science d'un point de vue constructiviste, en utilisant une approche fondée sur l'enquête, en accord avec le projet canadien plus vaste du *Cadre commun des programmes d'études* (Conseil des ministres de l'éducation, Canada [CMEC], 1997) et avec la plupart des autres curricula provinciaux et territoriaux.

Malgré les compressions du budget provincial, le Ministère a déployé des efforts constants pour maintenir les programmes d'études actuels dans les deux secteurs anglophone et francophone. Outre le *FACSC*, chaque année d'études a ses documents particuliers. On trouvera au Tableau 8.1 une énumération de tous les thèmes scientifiques selon l'année d'études dans le secteur anglophone. La plupart des programmes de sciences des volets élémentaire et intermédiaire anglophones ont été adoptés entre 1998 et 2002. Certains des documents pour le volet secondaire sont plus récents; par exemple, Biologie (*Biology*) 11 et 12 en 2008, Chimie (*Chemistry*) 11 et 12 en 2009 et Introduction aux sciences de l'environnement (*Introduction to Environmental Science*) 12 en 2013. Deux nouveaux cours, Physiologie humaine (*Human Physiology*) et Sciences de l'environnement avancées (*Advanced Environmental Science*), sont en préparation avec implantation à tous les niveaux prévue au cours de l'année scolaire 2017–2018. Une révision des programmes d'études de sciences de la 3e à la 10e année a débuté en 2017, en commençant par le groupe de la maternelle à la 2e année, la 6e année et la 9e année.

Contrairement au secteur anglophone, où le programme de sciences est fondé sur le partage de la plateforme du *FACSC*, le programme du secteur francophone est particulier à la province, compte tenu du contexte bilingue unique du Nouveau-Brunswick. Le partage de l'élaboration du curriculum en français avec les autres provinces atlantiques est difficile du fait que le Nouveau-Brunswick est la seule province à l'est du Québec avec un secteur d'éducation francophone. C'est pourquoi le curriculum français actuel pour les sciences et la technologie est fondé sur un cadre théorique élaboré à partir des influences américaines et européennes. Ces influences internationales continuent à jouer un rôle, et les révisions prévues du cadre théorique du curriculum français de sciences et de technologie sont fondées en partie sur le « Projet 2061 » (1989) de *l'American Association for the Advancement of Science* (Association américaine pour l'avancement des sciences, AAAS) – une initiative de recherche et développement à long terme axée sur l'amélioration de l'enseignement des sciences – et ont emprunté des idées à d'autres pays francophones qui proposent actuellement des innovations dans l'enseignement des

Tableau 8.1 Thèmes étudiés selon le niveau scolaire au secteur anglophone du Nouveau-Brunswick

Niveau	Thèmes scientifiques dans le curriculum anglophone			
K	L'étudiant comme individu	Les modes de vie saines	Nos sens	Place et la communauté
1	Les groupes	L'environnement	Les modes de vie saine	La communauté
2	Le changement et l'environnement physique	Les objets 3D et les propriétés des solides	La croissance et le développement: les cycles de la vie	–
3	Explorer les sols	Les forces invisibles	Les matériaux et leurs structures	La croissance des plantes et leurs structures
4	Les habitats et les populations	La lumière	Le son	Les roches, les minéraux et l'érosion
5	Les forces et les machines simples	Les propriétés et les changements des matériaux	Les besoins de base pour maintenir un corps en santé	Mesurer et décrire la météo
6	La diversité	L'électricité	Le vol	L'espace
7	La croute terrestre	La chaleur	Les interactions entre écosystèmes	Les mélanges et les solutions
8	Les cellules, tissus, organes et systèmes	Les fluides	L'optique	Les systèmes d'eau
9	La reproduction	Les atomes et les éléments	Les caractéristiques de l'électricité	L'exploration de l'espace
10	Développement durable et écosystèmes	Les dynamiques de la météo	Les réactions chimiques	Le mouvement
11	Des cours spécifiques en biologie, en chimie, en physique et en sciences de la Terre et de l'environnement			
12				

Note. Adapté du ministère de l'Éducation et du Développement de la petite enfance (2002–2009)

sciences, notamment le *Conseil de l'enseignement des communes et des provinces* (http://www.cecp.be/) de Belgique. Il est important de mentionner que, bien que leur cadre théorique puisse quelque peu différer quant aux sources, les deux secteurs anglophone et francophone du Nouveau-Brunswick partagent une vision similaire de l'enseignement des sciences et de la technologie fondée sur l'enquête scientifique, la résolution des problèmes et la prise de décisions.

L'enseignement des sciences dans le secteur francophone vise des résultats liés aux technologies tel qu'indiqué par le titre du programme d'études, à savoir « Sciences et Technologies », plutôt que « Sciences » seulement dans le programme d'études anglophone. Dans le secteur francophone, les écoles primaires vont de la maternelle à la 8e année. Le programme d'études des Sciences et technologies a été élaboré en trois groupes: de la maternelle à la 2e année, de la 3e à la 5e année et de la 6e à la 8e année. Cette structure a été choisie pour mieux correspondre à la perspective constructiviste de l'apprentissage. De cette façon, un concept introduit lors de la première année d'un groupe particulier (p. ex., 3e année) sera approfondi et

Tableau 8.2 Thèmes étudiés selon le niveau scolaire au secteur francophone du Nouveau-Brunswick

Niveau	Thèmes scientifiques dans le curriculum francophone			
K–8	***Univers vivant***			
	L'organisation de la vie	L'hérédité	L'évolution	Les transferts d'énergie
	Univers non vivant			
	La matière et l'énergie	L'univers	La Terre	La Terre
9	La reproduction	Les atomes et les éléments	L'électricité	L'astronomie
10	Développement durable et écosystèmes	Les processus chimiques	Le mouvement	La météorologie
11	Des cours spécifiques en biologie, en chimie, en physique et en sciences de la Terre et de l'environnement			
12				

Note. Adapté du ministère de l'Éducation et du Développement de la petite enfance (2009–2011)

consolidé au cours des deux années suivantes (p. ex., 4e et 5e années). Le Tableau 8.2 indique tous les thèmes scientifiques enseignés suivant l'année d'études dans le secteur francophone.

Outre le cadre théorique partagé, chaque programme d'études des Sciences et Technologies du volet primaire francophone contient une section sur les grandes lignes d'un ensemble de six résultats d'apprentissage transdisciplinaires. Ces résultats visent à intégrer le développement des aptitudes suivantes: communication, utilisation des technologies, pensée critique, développement personnel et social, culture et patrimoine, et méthodes de travail efficaces. Plus encore, les programmes d'études des Sciences et Technologies M–2 et 3–5 visent à développer un sens de la citoyenneté grâce à la connaissance des sciences et des technologies.

Pour commencer, les élèves sont encouragés à acquérir les aptitudes nécessaires pour apporter plus tard leur contribution dans un milieu de travail qui sera sans doute axé en grande partie sur les sciences et les technologies. Ensuite, ils développent l'aptitude à réfléchir de façon critique et à se conduire de façon responsable à l'égard de la société et de l'environnement. Bien que le programme 6–8 comprenne également ces objectifs, des compétences plus spécifiques aux processus scientifiques (p. ex., observation, inférence, analyse et communication) y sont ajoutées. L'enseignement de ces compétences reflète l'influence du document du Projet 2061 de l'AAAS, *Benchmarks for Science Literacy* (Standards de performance en littératie des sciences, 1993).

Bien que le programme francophone d'études des sciences M-8 soit fondé sur le Projet 2061 et les curricula européens, le programme d'études 9–12 est surtout basé sur le *Cadre commun* (CMEC, 1997). Les résultats d'apprentissage généraux insistent sur la culture scientifique élémentaire et l'appréciation des processus scientifiques et technologiques. De plus, ils cherchent à inclure des concepts scientifiques de base ainsi que les attitudes et les valeurs nécessaires pour développer une société préoccupée par la justice sociale et la gérance environnementale. Les cours de sciences du volet secondaire francophone sont similaires aux cours du secteur anglophone et proposent des cours facultatifs en 11e et 12e année qui comprennent l'astronomie, les sciences de l'environnement, ainsi que les cours de sciences plus traditionnels comme la physique, la chimie, et la biologie.

Les programmes actuels d'études des sciences des volets primaire et secondaire francophones ont été publiés entre 2005 et 2011. Bien que des révisions soient actuellement en cours pour les trois programmes d'études des sciences et des technologies des écoles primaires, aucune révision n'est prévue pour les différents programmes d'études des sciences des écoles secondaires.

8.2.1 Ressources scientifiques et possibilités d'apprentissage en ligne

Le *Science Teacher Needs Assessment* (évaluation des besoins des enseignants de sciences) de Kierstead, Bateman et Martin (2008) a déterminé que les enseignants de sciences aux niveaux primaire et intermédiaire auraient avantage à disposer d'une ressource qui pourrait compléter les documents du curriculum provincial. En partenariat avec le personnel de Science Est (n.d.), le Ministère a élaboré une collection de 27 trousses de ressources pour munir les enseignants d'exemples montrant comment incorporer efficacement l'approche par enquête à l'enseignement des sciences et aux pratiques d'évaluation. Ces trousses ont été conçues pour suivre le cycle d'apprentissage 5E (Bybee et al., 2006) et mettent l'accent sur l'évaluation formative intégrée. La majorité des ressources pédagogiques ont été prévues pour appuyer les programmes d'études anglophones. Bien que Science Est collabore avec les districts scolaires francophones, il faut davantage de ressources pour les élèves francophones.

Le MEDPE veille au fonctionnement de deux programmes d'études à distance en ligne à l'intention des élèves du secondaire dans les petites écoles et les écoles rurales qui manquent d'enseignants avec les connaissances appropriées, l'un pour le système scolaire anglophone et l'autre pour le système francophone. Les études en ligne comprennent plus de 40 cours, y compris tous les cours de sciences obligatoires en 11^{e} et en 12^{e} années ainsi qu'un grand nombre de cours facultatifs et de niveau avancé. Le MEDPE permet également aux titulaires des classes ordinaires d'inscrire leurs élèves à des cours en ligne, ce qui leur donne accès à des éléments comme des activités interactives et des démonstrations animées qui enrichissent l'instruction et l'apprentissage.

8.2.2 L'évaluation en sciences

Les enseignants de sciences du Nouveau-Brunswick sont particulièrement intéressés par la façon dont l'évaluation formative – ou évaluation *au service de* l'apprentissage – peut être utilisée à tous les niveaux scolaires pour étayer l'apprentissage des sciences par des stratégies comme le journal de bord et la prise vidéo avec narration par l'apprenant. De plus, les enseignants sont encouragés à donner aux élèves des occasions d'exposer et d'approfondir leurs propres réflexions dans le cadre du processus d'évaluation – ou évaluation *en tant qu'*apprentissage. Le MEDPE (2013) suggère que, plutôt que des évaluations *de* l'apprentissage, 90% des évaluations soient des évaluations *au service de* l'apprentissage et *en tant qu'*apprentissage, où l'enseignant offre une rétroaction régulière et détaillée, où l'élève reçoit la rétroaction de ses pairs et où il a l'occasion de s'autoévaluer.

Dans le secteur anglophone, les sciences sont évaluées au niveau provincial en 4e, 6e et 10e année dans le cadre du programme d'évaluation du Nouveau-Brunswick. Dans le secteur francophone, les sciences sont évaluées uniquement en 8e année. La province participe aux évaluations nationales et internationales (p. ex., Programme pancanadien d'évaluation et Programme international pour le suivi des acquis des élèves [PISA]), mais une grande partie des efforts du MEDPE portent sur l'amélioration de la littératie et de la numératie avec moins d'insistance sur les sciences. Cependant, le récent *Plan d'éducation de 10 ans* (2016a, 2016b) du MEDPE compte la culture scientifique parmi ses priorités, ce qui, on l'espère, aura pour effet d'augmenter les ressources allouées à l'enseignement des sciences tant dans le secteur anglophone que dans le secteur francophone.

8.3 Préparation à l'enseignement des sciences

Au Nouveau-Brunswick, les enseignants se préparent à enseigner en obtenant un baccalauréat en éducation (B. Éd.) dans l'un de quatre établissements. En anglais, on peut obtenir le diplôme à la University of New Brunswick (UNB, à Fredericton ou à Saint John), à St. Thomas University (STU, à Fredericton) et à Crandall University (un établissement privé à Moncton). En français, bien que quelques étudiants choisissent de s'inscrire à une université anglophone, au Nouveau-Brunswick ou ailleurs, la grande majorité préfère s'inscrire à l'Université de Moncton (UdeM) pour préparer le baccalauréat en éducation puisqu'ils peuvent ainsi recevoir leur éducation en français tout en demeurant au Nouveau-Brunswick. Il faut préciser que l'UdeM a deux campus satellites, un situé à Edmundston et l'autre, à Shippagan (voir Fig. 8.1). Aux fins de ce chapitre, nous décrivons les programmes anglophones de l'UNB à Fredericton et de la STU, et le programme francophone de l'UdeM.

Comme dans plusieurs autres universités canadiennes, l'UNB à Fredericton et la STU offrent un programme post baccalauréat de B. Éd. Dans les deux cas, le programme peut être exécuté en un an seulement, suite à l'obtention d'un diplôme de premier cycle, tout en offrant aux futurs enseignants 60 crédits (ou 20 cours équivalents où chaque cours comporte 36 heures de temps en classe). L'UNB offrait autrefois un programme de 60crédits en deux ans, mais elle l'a modifié durant la dernière décennie pour l'offrir en un an, ce qui a toujours été le cas à la STU. La Faculté d'éducation de l'UNB a passé beaucoup de temps avec les parties prenantes du programme, notamment le gouvernement, le syndicat des enseignants et les districts scolaires, avant d'opter pour une durée plus courte. Le programme actuel a été jugé plus efficace et efficient pour les étudiants et préférable par les districts scolaires sur le plan du temps passé dans les écoles.

L'UdeM offre un programme généralisé de B. Éd. de cinq ans et 168 crédits pour les futurs enseignants du volet primaire; les futurs enseignants du volet secondaire peuvent choisir entre un programme spécialisé de cinq ans (en enseignement des sciences, par exemple) ou un programme accéléré de deux ans et 65 crédits s'ils ont déjà un baccalauréat dans une discipline qu'ils peuvent enseigner. Ce programme de 11 mois offert avant 1996 a été remplacé par une version plus complète étalée sur deux ans. Le Tableau 8.3 compare les programmes B. Éd. au Nouveau-Brunswick dans les deux langues officielles.

8.3.1 Le programme d'enseignement des sciences à la University of New Brunswick, Fredericton

Au volet primaire à l'UNB de Fredericton, on craint un peu que les futurs enseignants n'aient pas suffisamment d'expérience en sciences. Beaucoup d'étudiants qui s'inscrivent au B. Éd. ont obtenu un diplôme en arts ou en sciences humaines et ont besoin d'appui pour se préparer à l'enseignement des sciences et des mathématiques. Les élèves du volet primaire du B. Éd. n'ont besoin qu'un qu'à un seul cours de trois crédits (36 heures) sur les méthodes scientifiques, qui utilise l'apprentissage fondé sur l'enquête avec une approche constructiviste. Il est toutefois possible de suivre quatre cours supplémentaires parmi les cours facultatifs de sciences.

Pour être admis au volet secondaire de l'UNB Fredericton, les futurs enseignants de sciences doivent posséder entre 18 et 30 crédits en sciences suivant que les sciences sont leur principal secteur d'enseignement. Tous les étudiants du volet d'enseignement secondaire doivent suivre quatre cours qui comprennent un éventail de connaissances scientifiques et pédagogiques tel que la nature des sciences, les idées erronées des élèves et les façons d'amener les élèves à résoudre les problèmes et à stimuler leur réflexion critique.

8.3.2 Le programme d'enseignement des sciences à St. Thomas University

Les étudiants de la faculté d'éducation de STU s'inscrivent soit au volet primaire, soit au volet secondaire, soit au programme de français langue seconde. Les futurs enseignants du volet primaire suivent un cours de trois crédits chacun en sciences au primaire, en mathématiques et en méthodes technologiques. Dans le cours de sciences, l'accent est mis sur une approche constructiviste fondée sur l'enquête et plus particulièrement sur la transdisciplinarité. Les étudiants du volet primaire qui

Tableau 8.3 Une comparaison des programmes de B. Éd. au Nouveau-Brunswick

Programme	Secteur anglophone		Secteur francophone
	University of New Brunswick	St. Thomas University	Université de Moncton
B. Éd. – type	Post-diplôme	Post-diplôme	Direct
			Post-diplôme
B. Éd. – durée	11 mois	11 mois	5 ans (direct)
			2 ans (post-diplôme)
B.Éd. – crédits	60	60	168 (direct)
			65 (post-diplôme)
Moyenne minimale d'admission	2.7	2.7	2.3 cumulative et 2.6 dans trois cours de français
Matières enseignées requises pour l'admission	30 crédits dans une matière enseignée et 18 crédits dans une autre OU 24 crédits dans chacune de deux matières enseignées	30 crédits dans une matière enseignée OU dans une matière enseignée et 18 crédits dans une autre	42 crédits dans une matière enseignée et 24 crédits dans une autreOU 60 crédits dans une matière enseignée et 21 crédits dans une autre OU un diplôme multidisciplinaire avec au moins une concentration dans une matière enseignée
B. Éd. -programme livré	*Primaire* (M–5) *Secondaire* (6–12) Éducation aux adultes B. Éd. pour élèves des Premières Nations	*Primaire* (M–5) *Secondaire* (6–12) Français comme langue seconde	*Primaire* (M–8) *Secondaire* (9–12)
Cours requis en didactiques des sciences	*Primaire*: un cours de 3 crédits en enseignement des sciences au primaire	*Primaire*: un cours de 3 crédits en enseignement des sciences au primaire	*Primaire*: un cours de 2 crédits en didactique des sciences au primaire
	Secondaire: quatre cours de 3 crédits en enseignement des sciences au secondaire	*Secondaire:* un cours de 3 crédits en enseignement des sciences au secondaire	*Secondaire*: deux cours de 2 crédits en didactique des sciences au secondaire
			Post-diplôme: un cours de 3 crédits en didactiques dans une matière scientifique enseignée et un cours de 3 crédits en didactique dans une deuxième matière enseignée

(continued)

Tableau 8.3 (continued)

Programme	Secteur anglophone		Secteur francophone
	University of New Brunswick	St. Thomas University	Université de Moncton
Structure des stages	Une journée par semaine à l'automne et à l'hiver, en plus de stages de 2 semaines, 3 semaines et 7 semaines à l'automne et à l'hiver, tous dans la même école.	Un stage de 7 semaines à l'automne et un stage de 8 semaines à l'hiver, dans deux écoles différentes et, de préférence, dans des matières/niveaux différents	*Primaire et secondaire*: un stage de 3 semaines au printemps de la 2e année, un stage de 4 semaines au printemps de la 3e année, un stage de 4 mois à l'automne de la 5^{e} année *Post-diplôme*: un stage de 3 semaines au printemps de la 1re année et un stage de 12 semaines à l'automne de la 2e année, dans deux écoles différentes

souhaitent faire une majeure double en sciences, technologies, ingénierie et mathématiques (STIM) peuvent s'inscrire à deux cours supplémentaires de trois crédits du volet secondaire en méthodes d'enseignement des mathématiques et des sciences. Les étudiants qui souhaitent poursuivre la majeure double en enseignement des STIM doivent aussi avoir cumulé au moins neuf heures créditées en STIM avec au minimum la note « C » (60% à 69,9%) dans leur programme de 1er cycle.

Les étudiants qui souhaitent enseigner les sciences aux niveaux intermédiaire et secondaire doivent suivre un cours de trois crédits dans chacune des méthodes d'enseignement des sciences, des mathématiques et de la technologie, ainsi qu'un cours supplémentaire de trois crédits en pédagogie des sciences et des mathématiques au secondaire. Les cours initiaux sur les méthodes d'enseignement des sciences, des mathématiques, et de la technologie sont axés sur le programme d'études du niveau intermédiaire (6–8) alors que le cours supplémentaire de pédagogie combinée des sciences et des mathématiques est axé sur le programme du niveau secondaire (9–12). Ces cours visent la création d'occasions d'apprentissage axées sur l'apprenant en mettant l'accent sur la construction de modèles explicatifs par le biais de simulations, d'analogies, de modèles physiques, de graphiques, d'équations et de diagrammes pour susciter l'intérêt d'une gamme variée d'apprenants.

8.3.3 Le programme d'enseignement des sciences à l'Université de Moncton

Les étudiants de B. Éd. à l'UdeM peuvent choisir de s'inscrire soit au volet primaire soit au volet secondaire. Il s'agit de programmes concomitants de B.Éd. répartis sur cinq ans et combinés avec un baccalauréat ès arts (B. A. primaire, secondaire) ou un baccalauréat ès sciences (B. Sc. secondaire). Le programme primaire B. A./B. Éd. de 168 crédits, reconfiguré en 2016, comprend différents cours de sciences humaines et de pédagogie, quatre cours de sciences de trois crédits (deux de biologie, un de chimie, un de physique) et un cours de deux crédits en didactique des sciences. Le programme B. Sc./B. Éd. de 168 crédits offert aux futurs enseignants du secondaire, également reconfiguré en 2016, offre la possibilité aux futurs enseignants de se spécialiser en chimie, en biologie ou en physique. Les étudiants qui choisissent le volet secondaire doivent obtenir un total de 33 crédits dans leur discipline scientifique ainsi que deux cours de deux crédits en didactique des sciences.

8.4 Certificat d'enseignement

Les détenteurs d'un B. Éd. de l'une des universités de la province sont admissibles à une certification. Le MEDPE octroie les certificats, et les règlements aux termes de la Loi sur l'Éducation sont les mêmes, que les candidats parlent l'une ou l'autre des deux langues officielles. Les demandes de certification doivent être accompagnées d'une vérification du casier judiciaire et d'un relevé officiel des résultats postsecondaires. Suivant le nombre d'heures-crédits, un certificat d'enseignement professionnel de niveau 4 ou 5 est accordé, ce qui permet au détenteur d'enseigner de la maternelle à la 12e année; par exemple, le programme actuel de formation des enseignants d'une durée de cinq ans permet d'obtenir un certificat d'enseignement de niveau 5. La réussite à une M. Éd. reconnue permet d'obtenir un certificat d'enseignement de niveau 6. Il y a une légère différence de salaire entre les niveaux, mais il n'y a pas de niveau ni de salaire supplémentaire pour les détenteurs d'un doctorat. Un enseignant qui a obtenu un B. Éd. en dehors de la province doit suivre le même processus de demande de certificat. Tous les candidats acceptés reçoivent un certificat intérimaire qui peut devenir permanent après deux ans d'enseignement réussi dans la province.

8.5 Développement professionnel en sciences et soutien informel à l'enseignement des sciences

Le MEDPE offre certaines activités de développement professionnel axées sur l'enseignement des sciences, mais les récentes compressions budgétaires en ont réduit le nombre. Par conséquent, dans le secteur anglophone, l'UNB et la STU offrent actuellement des occasions de développement professionnel aux enseignants de sciences des volets primaire et intermédiaire alors que, du côté francophone, l'UdeM offre un développement professionnel en sciences aux enseignants francophones, essentiellement au niveau primaire. Toutefois, ces sessions de développement professionnel financées par l'université sont rares car très peu de fonds sont disponibles pour libérer les enseignants de leurs tâches.

Un certain nombre de programmes parascolaires favorisent l'initiation aux sciences et collaborent avec les écoles pour offrir des programmes supplémentaires. Un soutien considérable est apporté par Science Est, un centre interactif de sciences pour les familles situé à Fredericton. Ce centre organise des expositions innovantes et interactives pour présenter les concepts scientifiques de base, stimuler la curiosité et favoriser l'intérêt et la compréhension des sciences chez les gens de tous âges. Il organise également des expositions itinérantes pour les écoles francophones et anglophones ainsi que pour des camps d'été.

Le projet Gaïa (n.d.) est un organisme sans but lucratif dont le siège est à Fredericton et qui a pour mandat de sensibiliser les élèves aux problématiques liées à l'énergie, au changement climatique et au développement durable. Il offre des possibilités d'apprentissage interactif par projets aux élèves et au grand public par le biais de programmes en français et en anglais. Tous les programmes sont fondés sur les trois principes suivants: la prise de décision basée sur des données, les évaluations économiques et l'évaluation du mode de vie et des effets sur l'environnement. Des agents d'exécution des programmes propres à chaque langue font régulièrement le tour des écoles de la province et font participer les élèves et les enseignants à des activités axées sur des projets et destinées à favoriser le développement des aptitudes à résoudre les problèmes et encourager la sensibilisation aux questions environnementales. Par exemple, son Centre d'énergie mobile est une remorque de quatre mètres qui contient un équipement interactif d'énergie de remplacement que l'on peut contrôler à partir de cinq écrans d'ordinateurs tactiles. Ainsi les élèves et les enseignants peuvent manipuler une éolienne, suivre un soleil avec un système de panneaux solaires ou monter à bicyclette équipée d'un wattmètre pour voir la quantité d'énergie qu'ils peuvent générer en pédalant. Il y a d'autres programmes populaires comme la vérification par les élèves de l'empreinte écologique d'une école, ce qui permet d'observer concrètement les questions liées aux déchets solides et la consommation d'énergie.

L'Univers sans limites/Worlds UNBound (n.d.) est un programme bilingue primé sans but lucratif dirigé par des étudiants de l'UNB en génie et en sciences. Son but est de stimuler l'intérêt – de façon concrète, interactive et engageante – des jeunes de la province pour les sciences, l'ingénierie et les technologies. Le programme en est à sa 21^{e} année de fonctionnement et rejoint annuellement près de 14 000 jeunes Néo-brunswickois avec des camps STIM, des ateliers en milieu scolaire, le club *Quest 4 Girls* et d'autres programmes.

En 2015, le Nouveau-Brunswick a accueilli pour la première fois l'Expo-sciences pancanadienne (ESPC). L'UNB et Science Est étaient les hôtes officiels de l'ESPC, mais toutes les universités publiques, les districts scolaires, la Ville de Fredericton et le MEDPE ont uni leurs efforts pour appuyer l'évènement. Plus de 800 étudiants de partout au Canada et 300 juges de toutes les régions du Nouveau-Brunswick ont participé à l'événement d'une durée d'une semaine. Plus de 2 000 écoliers locaux ont visité l'exposition et participé à « La science à l'œuvre » (*Science at Work*), qui mettait en vedette les entreprises provinciales qui utilisent la science au quotidien. L'événement a favorisé la sensibilisation aux sciences du grand public et avait pour but d'augmenter l'intérêt pour la science.

8.6 Recherche sur l'enseignement des sciences au Nouveau-Brunswick

Au Nouveau-Brunswick, des recherches sur l'enseignement des sciences se poursuivent dans les trois universités publiques, en anglais et en français, et cela dans plusieurs domaines. À l'UNB, des recherches portent sur l'utilisation, au niveau primaire, de trousses de sciences qui ont été créées par des étudiants de B. Éd. et sont basées sur les résultats du programme d'études de la 4e et de la 5e années. Ces trousses comprennent du matériel de base pour les leçons basées sur l'enquête, des plans de leçons et des informations sur l'apprentissage fondé sur l'enquête, ainsi que des vidéos de démonstration. Il a été démontré que les trousses apportent un soutien aux enseignants, particulièrement à ceux qui avaient peu de connaissances en sciences avant de commencer leur programme de B. Éd. (MacDonald et Sherman, 2006, 2007; Sherman et MacDonald, 2007, 2008a, 2008b, 2009). Les trousses répondent aussi aux préoccupations que crée chez les enseignants le manque de fournitures en sciences, et elles ont été utilisées avec succès dans nombre de classes du 2e cycle du primaire.

À la STU, les efforts de recherche portent sur l'utilisation de modèles pour l'enseignement des sciences et certains aspects de l'apprentissage des STIM. Les modèles sont un soutien utile à l'enseignement lorsque les phénomènes étudiés sont difficiles à observer directement comme le mouvement planétaire, la respiration humaine, la dérive des continents et les champs magnétiques (Williams et Clement, 2015). Les recherches se concentrent sur un type particulier de modèle selon lequel les élèves de la maternelle à la 12e année interprètent ou simulent ensemble certains phénomènes particuliers. Elles explorent les façons dont les enseignants peuvent encourager l'engagement des élèves dans des simulations kinesthésiques appelées *Kinulations* aux fins de modélisation et de raisonnement sur des concepts scientifiques abstraits (Williams, Oulton et Taylor, 2017). D'autres recherches ont examiné les méthodes qui ont le plus de succès pour l'apprentissage des disciplines STIM, particulièrement par les filles et les populations non traditionnelles.

À l'UdeM, les recherches sur l'enseignement des sciences portent sur l'enseignement et l'apprentissage des sciences dans un milieu linguistique minoritaire, sur l'intégration des principes de sensibilisation à l'environnement dans les programmes de sciences et sur l'étude des effets de l'apprentissage par l'expérience sur le rendement des élèves en sciences. Des recherches récentes sur l'utilisation du Cycle d'apprentissage 5E (Bybee et al., 2006) pour l'intégration de la littérature pour les jeunes et des stratégies linguistiques dans les classes de sciences francophones ont pour but de mesurer l'effet de ces stratégies sur la compréhension conceptuelle en sciences, la compréhension de la lecture, la croissance cognitive, l'intérêt pour les sciences et la motivation pour la lecture (Lirette-Pitre, Cormier et Ferguson, 2016). Sur le plan de l'intégration des principes de sensibilisation à l'environnement dans les programmes de sciences, le groupe d'action en éducation relative à l'environnement *Littoral et vie* (http://www8.umoncton.ca/littoral-vie) explore des stratégies pédagogiques socioconstructivistes conçues pour aider les élèves et les citoyens à mieux comprendre les composants chimiques, biologiques et écologiques de leur environnement. Depuis 1996, une équipe multidisciplinaire de chercheurs venus du monde entier travaille à divers projets sur le développement durable et l'enseignement des sciences comme *Les jeunes bâtisseurs de l'avenir,* un projet dans le cadre duquel des étudiants du Canada, de Roumanie, de Tunisie, du Brésil et de Colombie tentent de résoudre des problèmes environnementaux locaux avec l'aide de chimistes, d'urbanistes, d'ingénieurs, de biologistes et de géographes (Pruneau et al., 2015). Un troisième domaine de recherche porte sur le développement de modèles d'apprentissage par l'expérience et sur la pédagogie de l'enseignement des sciences dans les milieux naturels (LeBlanc, Léger, Lang et Lirette-Pitre, 2015; Léger et Pruneau, 2011, 2012, 2014–2015).

8.7 Résumé

L'une des provinces les plus petites et les moins peuplées du Canada, le Nouveau-Brunswick possède un milieu éducatif unique en grande partie à cause de son statut bilingue officiel. Le ministère de l'Éducation et du Développement de la petite enfance du Nouveau-Brunswick veille au fonctionnement d'un système double sur le plan linguistique dans lequel les prises de décisions à l'égard des programmes d'études et de l'enseignement sont gérées par deux secteurs séparés, le secteur anglophone et le secteur francophone. Les fusions récentes au sein des deux secteurs scolaires (anglophone et francophone) ainsi que la réduction des occasions de développement professionnel pour les enseignants reflètent à la fois la stagnation de la population et la préoccupation constante du gouvernement provincial en matière de compressions budgétaires.

Malgré les défis posés par une population décroissante vivant dans une province non industrialisée, l'enseignement des sciences s'est amélioré au cours des cinquante dernières années. Il est à noter que l'éducation n'était pas une priorité pour les enfants qui, surtout dans les familles francophones, étaient souvent gardés à la maison afin de travailler aux champs ou d'aller à la pêche. De plus, les écoles francophones relevaient plutôt de l'église et étaient appelées écoles confessionnelles. L'influence de l'église se faisait sentir dans les choix des étudiants, qui s'inscrivaient en majorité à des programmes universitaires en arts et en sciences sociales.

Heureusement, les trois établissements de formation à l'enseignement financés par la province (UNB, STU et l'UdeM) ainsi que divers organismes sans but lucratif (Science Est, Projet Gaïa et l'Univers sans limites/Worlds UNBound) ont créé un éventail d'occasions de développement professionnel pour les enseignants qui se spécialisent en sciences. De plus, les projets de recherche à l'œuvre dans ces trois universités produisent des ressources qui favorisent un enseignement et des occasions d'apprentissage des sciences de grande qualité pour les systèmes scolaires anglophone et francophone du Nouveau-Brunswick.

Dedication/Dédicace

This chapter is dedicated to the memory of Dr. Ann Sherman. Dr. Sherman had been Director of the School of Education at St. Francis Xavier University in Nova Scotia, Vice Dean of Education at the University of Calgary in Alberta, and, most recently, Dean of Education at the University of New Brunswick. Ann loved her profession and received many awards and accolades; she was most proud to receive a Lifetime Membership in the Association of Canadian Deans of Education for her contributions to the association. Her co-authors are privileged to have worked with Ann on one of her final writing projects.

Ce chapitre est dédié à la mémoire de Dre Ann Sherman. Dre Sherman a été directrice de l'École d'éducation de St. Francis Xavier University en Nouvelle-Écosse, vice-doyenne de l'éducation à la University of Calgary en Alberta et, plus récemment, doyenne de l'éducation à la University of New Brunswick. Ann a aimé sa profession et a reçu de nombreux prix et distinctions; elle était particulièrement fière de recevoir une adhésion à vie à l'Association canadienne des doyens d'éducation en reconnaissance de ses contributions à l'association. Ses co-auteurs ont le privilège d'avoir travaillé avec Ann sur l'un de ses derniers projets d'écriture.

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Ann Sherman, BScEd (St. Francis Xavier University), MEd and MEd (University of New Brunswick, PhD (University of Nottingham), was the dean of the Faculty of Education at the University of New Brunswick in Fredericton prior to her death in 2017. She began her teaching career as a high school science and mathematics teacher, moved to elementary schools, and then became a school administrator before embarking upon her university career. She conducted research in the areas of early learning, formative assessment, inquiry-based science, and the connections between all three. She partnered in the development of support resources for elementary science teachers as part of a larger CRYSTAL grant on science education. She was involved in numerous professional learning opportunities for inservice teachers across the maritime provinces.

Nicole Ferguson, BA (Université d'Ottawa), BEd (Université de Moncton), MEd (Université Nouveau-Brunswick), PhD (Université de Montréal), est retraitée et travaille entre autres comme chargée de cours et consultante. Elle a une riche expérience universitaire acquise à la Bishops University et à l'Université de Moncton. Par ailleurs, sa vaste expérience scolaire, autant en tant qu'enseignante de sciences au secondaire que dans son rôle d'agente pédagogique lui permet d'avoir un regard à la fois de chercheure, de praticienne et de rédactrice de programmes d'études en sciences. Ces perspectives multiples se transposent efficacement dans ses travaux de recherche. Ce regard polyvalent permet une compréhension unique des finalités en enseignement des sciences. Les recherches de Nicole Ferguson se concentrent sur la pensée critique et sur les dispositions affectives pour l'apprentissage des sciences. Ses récents projets de recherche se penchent sur l'intégration de la langue et des sciences en milieu scolaire.

Chapter 9
Science Education in Nova Scotia: Building on the Past, Facing the Future

G. Michael Bowen, A. Leo MacDonald, and Marilyn Webster

Abstract Nova Scotia has a small, and declining, student base as its general population both decreases and ages. Schools are being closed or amalgamated, which causes disruption within the school system, between the system and parents, and within teacher education programs. Secondary school programs are particularly affected because there may be too few students to offer a wide variety of science courses. Current provincial curriculum directions arise from public consultations undertaken by the province in 2015. The government has committed to continuing with those directives. Historically science programs in NS have been based on an innovative curriculum developed by the Atlantic Science Curriculum Project in the 1980s. However, the current science curriculum has mostly been derived from the 1997 Pan-Canadian Common Framework and has been minimally updated. Recently, the province has begun modifying the elementary science curriculum and has provided various information and communication technology resources (e.g., probeware, robots, programming tools) to schools. The expectation is that teachers will take a more integrated approach to teaching science across multiple subject areas. Nova Scotia science education faces challenges related to setting entry requirements for BEd programs, providing meaningful professional development opportunities, and including Indigenous perspectives.

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C. D. Tippett, T. M. Milford (eds.), *Science Education in Canada*,
https://doi.org/10.1007/978-3-030-06191-3_9

9.1 Introduction

Located on the eastern Atlantic coast of Canada, Nova Scotia is one of the smallest provinces in the country, with an area of approximately 53,000 km^2, a population of just under 1 million people, and the third highest rural population at 43% (Statistics Canada, 2011). Although Nova Scotia's overall population is increasing, that increase is due to growth in its capital city of Halifax; 42% of the province's population resides in Halifax Regional Municipality, the only large city in Nova Scotia (Fig. 9.1). From 2010 to 2014, 10 of 18 counties' population were stable or showed slow decline (0–4.9%), and six counties showed rapid decline (5–9.9%); only Halifax and one of its neighbouring counties showed growth (Nova Scotia Finance & Treasury Board, 2015). The median age of Nova Scotia's population has been steadily trending upward from 25.4 years in 1971 to 43.7 years in 2011 (Statistics Canada, 2011). From 2006 to 2011, the 65+ age group increased by 11%, the 15–64 age group increased by 0.2%, and the 0–14 age group declined by 5.6%. The rural to urban shift, combined with an aging population, has resulted in school closures across much of the province.

Fig. 9.1 Map of Nova Scotia

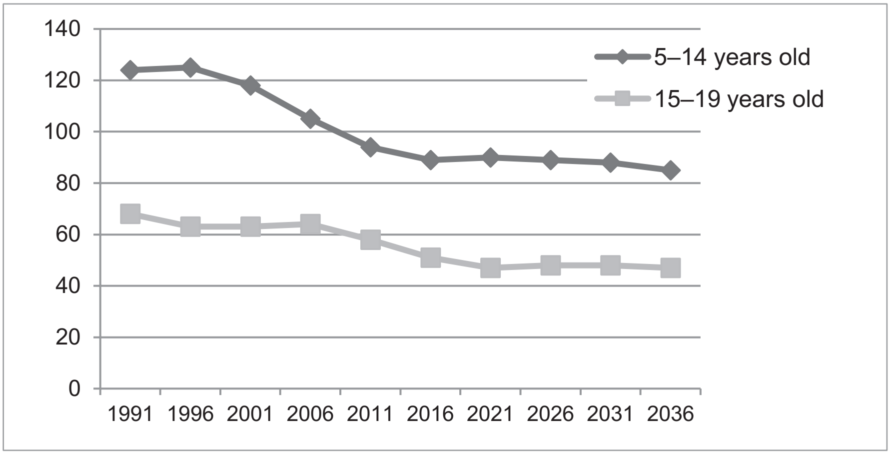

Fig. 9.2 Student enrolment in Nova Scotia, in thousands (Statistics Canada, 2015)

In fact, the student population has been declining for well over 20 years (Fig. 9.2), although it is now gradually reaching a plateau (Statistics Canada, 2015). This student decline has not been accompanied by an associated decline in the number of educators; between 2001 and 2011, student populations declined by 24.5%, whereas the number of educators declined much less at 3.8%—from 9,594 to 9,231—between 2002 and 2013 (Statistics Canada, 2016). This imbalance in student-educator populations has implications for new teachers for whom it is more difficult to find employment. An obvious solution would appear to be reducing the number of student teachers admitted to faculties of education; however, unpublished studies suggest that students who are not admitted at provincial universities attend universities in the US state of Maine and then return to be licensed in the province (R. Berard, personal communication, June 1, 2016), thus not reducing the number of certified teachers.

Schools in Nova Scotia start at Primary (P) rather than Kindergarten (K), registering students who turn 5 years old by December 31 of the school year. Schools are organized in several different grade configurations. Recently, Nova Scotia has started pre-primary programs in schools (for students who are 4 years old by December 31) on a limited basis across the province, a program that is now being expanded. In 2016, the Nova Scotia Department of Education and Early Childhood Development (NSDE, 2017a) reported that there were:

- 210 elementary schools (P–2, P–4, P–5, P–6, 3–5, 3–6, 4–6)
- 52 elementary/junior schools (P–7, P–8, P–9, 5–7, 5–8, 6–8, 6–9)
- 33 elementary/junior/senior high schools (P–12, 5–12, 6–12)
- 25 junior high schools (7–8, 7–9, 8–9)
- 40 junior/senior high schools (7–12, 9–12)
- 18 senior high schools (10–12)

Those schools with Grade 7 and up are more likely than elementary schools to have science specialist teachers. In many areas of the province, schools seem to be transitioning to a P–8/9–12 or P–12 structure in response to the changing demographics of their school-age population. If there are sufficient students, then P–8 and 9–12 schools are being built; in smaller catchment areas, P–12 schools are being built, such as in Bridgetown (a former town of 900, now part of a municipal region) where a new P–12 school is slated for opening in the fall of 2017.

Until recently there were seven English language school boards and one province-wide French language (Acadian) school board with a combination elected/appointed governance structure. In 2018 the Nova Scotia government eliminated elected school boards, redesignated the Regional Centres for Education, and had them all managed by a single appointed advisor council. Areas included in each Regional Centre conform to county boundaries, with individual Centres being comprised of one to three counties (see http://ns-schools.ednet.ns.ca/). There are also 14 band-operated schools—federally-funded schools operated by First Nations education authorities for K–12 students who live on reserves; the Mi'kmaq Services division of NSDE acts as a liaison between the department, these schools, and the Council on Mi'kmaq Education (NSDE, 2017b). There are also approximately 24 private schools in the province.

9.2 History of Nova Scotia's Science Curriculum

From the mid-1980s to the late 1990s, the Nova Scotia junior high school science curriculum was guided by the Atlantic Science Curriculum Project (ASCP) and the *SciencePlus* series of textbooks (ASCP, 1986, 1987, 1988). ASCP was an initiative headed by two professors of science education: Charles McFadden and John Haysom, University of New Brunswick and Saint Mary's University, respectively. The ASCP curriculum was developed with teams of teachers and science education consultants and academics, field tested in schools, and revised as necessary to reach the desired learning outcomes. Detailed teacher manuals were produced, and extensive professional development (Pro-D) workshops were offered to teachers about how to teach science using a hands-on inquiry investigation approach. This curriculum was very forward-looking for its time, reflecting many of the approaches for science classrooms that are currently advocated such as hands-on investigation activities, inquiry investigations, depictions of gender and ethnic diversity of individuals doing science, and authentic science. The curriculum was subsequently adopted in other jurisdictions (including various boards in Ontario and the US state of California). In the late 1990s, the Education Ministers of Atlantic Canada adopted the *Common Framework of Science Learning Outcomes, K–12* (Council of Ministers of Education, Canada [CMEC], 1997) as the basis of science education. Implementation of the *Common Framework* in Nova Scotia began in 2000, with specific workshops and resources being developed for teachers.

Table 9.1 Topics in primary through Grade 10 science in Nova Scotia

Grade	Earth/space science	Life science	Physical science
P	Explore sand and water	Explore living things	Chemistry Explore objects
1	Daily and seasonal changes	Needs and characteristics of living things	Materials and their properties Constructing objects
2	Air and water in the environment	Animal growth and changes	Chemistry—liquids and solids Motion
3	Exploring soils	Plant growth and changes	Materials and structures Invisible forces
4	Rocks, minerals, and erosion	Habitats	Light Sound
5	Weather	Healthy body	Forces and simple machines Chemical and physical properties of matter
6	Space	Diversity of life	Electricity Flight
7	Earth's crust	Interactions within ecosystems	Mixtures and solutions Heat
8	Water systems	Cells	Fluids Optics
9	Space	Reproduction	Atoms and elements Electricity
10	Weather	Sustainability of ecosystems	Chemical reactions Motion

The P–3 science curricula were revised in 2015 and the Grades 4–6 curricula in 2016. NSDE officials have said that the Grades 7–8 curricula will be revised next, in accordance with Nova Scotia's *Action Plan for Education* (NSDE, 2015). Topics currently included in the P–10 science curricula are shown in Table 9.1. Details of the specific science knowledge, skills, and attitudes required for each grade level can be found in the document *Foundation for the Atlantic Canada Science Curriculum* (Atlantic Provinces Education Foundation, 1998). Whereas the Grades 11–12 science curricula have not been updated since their implementation in 2000, the Grade 10 curriculum was updated in 2012.

Revision was called for in part because, according to teachers, there was *too much curriculum*; the revised curriculum has been streamlined in terms of content and the number of listed outcomes. For many teachers, this change was welcomed as it tended to simplify the science curriculum, making it easier to connect lessons with outcomes. However, the time allocated for teaching science was also adjusted. At the P–3 level, rather than having a designated block of time for science, as is the case for language arts (615–790 min/week), mathematics (375–450 min/week), music (60 min/week), and physical education (100–150 min/week), science was included in a block of courses (along with social studies, health, information and communication technology, and visual arts) that has no specifically allocated teaching time. The expectation and hope was that teachers would integrate science (and the other subjects) as part of the English language arts and mathematics curricula that dominate the weekly timetable (Ministry official, personal communication, June 15, 2016). However, the message heard by teachers seems to have been that they were only to teach science when it supported the mathematics and literacy curricula. The outcomes of this approach to science education are likely at best to be mixed; it is quite possible that overall science instruction in those grades will decline as a result. On the other hand, if the integrated approach to curriculum takes hold, then the science that is taught might be better embedded in a broader range of knowledge outcomes for the students, such as being able to relate a science concept to an applied example from a historical social studies event.

Similarly, the Grades 4–6 curricula were streamlined and times reallocated, with 450–500 minutes/week designated for mathematics and English language arts and 40 minutes/week each for other subjects such as science, social studies, and computer coding. Again, there is a danger that many teachers will include little or no science in their classrooms as they emphasize helping students achieve learning outcomes in literacy and mathematics over achieving outcomes in science. Several elementary teachers have told the authors that they believe the removal of science as a distinct area with allocated time from the weekly timetable to be an unfortunate change. However, NSDE clearly expects cross-curricular learning activities to be developed.

NSDE's expectations for cross-curricular implementation highlight the importance of helping preservice and inservice teachers understand how science can be effectively integrated with other subjects, particularly language arts and mathematics. To support preservice teachers in cross-curricular approaches, faculties and schools of education at some Nova Scotia institutions are developing methods courses that use an integrated approach to subjects. For instance, during their second science methods course, elementary education students at Mount Saint Vincent University develop integrated, cross-curricular lesson plans that include the use of a technology tool. The integration of science with other subjects is more likely to occur in Grades 5 and 6, perhaps because the science curriculum for these grades has a strong focus on data literacy, including collection and analysis of data and drawing conclusions, which is consistent with aspects of the mathematics curriculum.

The Grades 9–12 science curriculum documents, with the exception of Grade 10, were last revised between 2000 and 2003 and were based on the *Common Framework* (CMEC, 1997). There are currently no publicized plans to update the remaining documents, but given the recent revision of the P–6 documents, the impending revision of the Grades 7 and 8 documents, and the age of the Grades 9, 11, and 12 documents, it is likely that these last three documents will be revised to address aspects of the *Action Plan for Education* (NSDE, 2015), such as including computer coding across the curriculum.

High school courses generally have 120 contact hours over either a semester or school year. Apart from typical science courses in general science, chemistry, physics, and biology, Nova Scotia offers Agriculture/AgriFood 11, Oceans 11, Geology 12, and Food Science 12. There are also options for locally-developed science courses to accommodate local needs. Students require two science courses for graduation: one of biology, chemistry, Science 10, or physics, and any other approved science course.

In addition to the provincially-designed curriculum, each school board has at least one International Baccalaureate (IB) program (http://www.ibo.org/) with its associated science courses; there are 13 IB programs across the province. As well, several high schools offer the Advanced Placement (AP) program (https://apcanada.collegeboard.org/) with its associated science courses. Both the IB and AP programs have standardized curricula and final examinations, and both offer additional opportunities for students interested in science. The presence of IB/AP programs guarantees that school boards provide adequate materials for teaching science in the schools that offer those programs. Anecdotally, these programs are popular, with more students wanting to register than can be accommodated.

9.3 Assessment

Nova Scotia regularly participates in international and national assessments of student science achievement, specifically, the Programme for International Student Assessment (PISA) and the Pan-Canadian Assessment Program (PCAP), both of which assess science knowledge as well as other subjects. However, while the academic performance of Nova Scotia students has remained fairly consistent in these assessments, the average performance in mathematics, science, and reading is "significantly below the performance of students living elsewhere in Canada" (Minister's Panel on Education, 2014, p. 9).

Until 2002, Nova Scotia had provincially mandated the final examinations in Grade 12 Chemistry and Physics that counted as part of the final grade. In 2013, Grade 12 provincial examinations in Mathematics and English were halted although there have been arguments against their elimination (Bennett, 2017). However, as of 2015, the province instead requires Grade 10 examinations in Mathematics and English that count for 20% of the final grade.

9.4 Bachelor of Education Programs

Nova Scotia has five postsecondary institutions that have Bachelor of Education (BEd) programs: Acadia University (Acadia), Cape Breton University (CBU), Mount Saint Vincent University (MSVU), St. Francis Xavier University (StFx), and Université Sainte-Anne. A sixth institution, Saint Mary's University (SMU), has a BEd program in their calendar but is currently not allocated any BEd students by the provincial government, which means if they did accept students they would not receive any funding. Twenty-five years ago, undergraduate elementary/secondary education programs at both SMU and Dalhousie University had their student allocations reduced to zero, resulting in Dalhousie closing its program and SMU essentially putting its program in stasis by maintaining it *on the books* with an assigned dean but no students. Closing the Dalhousie program means that Nova Scotia is the only province without a faculty of education in one of its keystone institutions, which—one might argue—has implications for faculty recruitment, retention, and research.

At that same time, the MSVU BEd program had its student allocation increased and subsequently developed its secondary education program. Some Dalhousie and SMU faculty members moved to MSVU, while others retired. Dalhousie's graduate programs in education were closed as was SMU's master's program; enrolled students were allowed to finish their degree program. MSVU started its own graduate program—initially a master's program that has since expanded to become a joint doctoral program (PhD) in education with Acadia and StFx—mostly along the lines of the programs that had been offered at Dalhousie. The shared PhD program did not begin until 2011, and it remains the only one in the province. SMU currently offers some upgrading and graduate courses in education, including upgrading for science teachers who do not have appropriate certification for teaching elementary science to meet provincial requirements.

With the exception of Université Sainte-Anne, all BEd programs in the province are post-baccalaureate, or consecutive, programs and typically consist of four semesters (totalling 45 credit hours, with a 3-credit hour course usually one semester in length) and a minimum of 15 weeks of practicum experience (worth 15 credit hours but taking substantially more time per credit hour). Some programs include longer placements; MSVU and StFx, for instance, have 22 weeks of practicum over 2 years. Three universities (i.e., Acadia, StFx, and MSVU) have tenured/tenure-track professors who are science methods instructors, and each institution can accept up to 125 BEd students per year into its program (across both secondary and elementary education) with typically 15 to 20 students having a high school science as a major or minor teachable (certified teaching area) at each university. CBU can accept a total of 40 students per year into their BEd program. Along with their regular 2-year program, Acadia offers an accelerated option with students being able to complete essentially the same requirements within a 16-month period (starting in September 1 year and finishing at the end of the following December). Université Sainte-Anne offers a program where the BEd can be integrated with a Bachelor of Arts or a Bachelor of Science, which meets the provincial minimum of 90 credit hours of approved undergraduate studies and 60 credit hours of approved professional studies (including practicum).

9.4.1 Admission Requirements

The province sets minimum standards for university admission, but institutions typically set their own higher requirements. Individual BEd programs at different institutions may have minimum mark, course level, and laboratory course requirements for admission, but there is no consistency across programs. There are no provincial stipulations regarding the level (first to fourth year of university) of the required subject-specific courses or minimum grade requirements for admission to the BEd. Thus, students might be accepted with fewer than the required (for licensure) number of undergraduate courses in the teachable areas; however, these students must complete those courses before graduation through summer or online courses.

Admission requirements to Nova Scotia's BEd programs include prerequisites that pertain specifically to science education. Those applicants who wish to teach at an elementary level require 6 credit hours of science coursework at the undergraduate level, which may be a course from a science faculty/department or a foundations of science type of course offered through an education department/faculty specifically for prospective elementary teachers. Although the province does not require it, some institutions have a laboratory prerequisite. In the past, it was generally expected that people entering a BEd program would have these requirements before they began the program, thus providing some science background for their methods instruction on how to teach science. However, some institutions admit students to BEd programs with only 3 credit hours of undergraduate science coursework, with the stipulation that the remaining 3 credit hours be completed before graduation. Therefore, it is possible that a student could complete all required science methods courses without the science content needed to inform their developing understanding of science pedagogy.

Secondary science teacher candidates have more stringent requirements to meet than elementary teacher candidates. Secondary teacher candidates must have at least two teachable subject areas. At some institutions (e.g., MSVU), one teachable would be science and the other a non-science subject, such as mathematics, social studies, or art. At other institutions (e.g., StFx), it is possible to graduate with science as both a major and a minor teaching area. Secondary teacher candidates require 30 university credit hours of coursework (i.e., five full-year courses or 10 half-year courses or a combination thereof) in their major teachable subject area and 18 credit hours of coursework (i.e., three full-year courses or six half-year courses or combination thereof) in their minor teachable subject area. According to provincial rules, one full-year course (or equivalent) for each teachable may come from a cognate or related area; for instance, someone might receive equivalent-to-science credit for completing a biostatistics course. The designation of major and minor teachable areas has implications for the content knowledge of science teachers, which is discussed later in this chapter.

9.4.2 Education Programs

Both elementary and secondary programs may have general methods courses with a few subject-specific courses, or they may have a series of subject-specific methods courses. The provincial expectation is that students in elementary education take a minimum of one 3-credit hour science-specific methods course. At CBU, Acadia, and StFx, elementary teacher candidates are required to take one 3-credit hour science methods course and might have the opportunity to take another as an elective. At MSVU, elementary teacher candidates take two science methods courses—one with a science focus and the other with a science, technology, engineering, and mathematics (STEM) focus—where they learn to develop cross-curricular lessons in line with NSDE revisions of the P–6 curriculum.

Students in secondary science education are required to complete a minimum of two 3-credit hour science methods courses for a major teachable and one 3-credit hour course for a minor teachable although variations occur. MSVU requires a third science methods course for those students who have science as a major teachable; at some institutions, students have the option of taking up to two additional science methods-oriented electives. Some institutions (e.g., StFx) offer other science pedagogy courses on a rotating basis (e.g., environmental or middle school science) and encourage their secondary science teacher candidates to take more than 6 credit hours in their major teaching area and 3 credit hours in their minor teaching area. There are currently no teacher education institutions in Nova Scotia that offer separate science methods courses focused on distinct disciplines such as biology, chemistry, physics, or earth science. The dominant perspective is that science is a generic area and that one or two science methods courses will be sufficient to meet the needs of teachers who will teach in these separate areas of science. The net effect is that many new secondary science teachers have a limited and somewhat generic experience in science pedagogy and curriculum.

9.4.3 Teacher Certification and Progress Through the Ranks

"To be granted a teacher's certificate in Nova Scotia, an applicant must have completed an 'Approved Program of Professional Studies' as part of the broader certification requirements" (Nova Scotia Office of Teacher Certification [NSOTC], 2017a). Graduates of these programs would be expected to have completed courses that explore The Context of Public Education, Human Development and the Learning Process, The Act of Teaching, and The Professional Context (NSOTC, 2017b). There are, however, no provincial stipulations with respect to the number of required courses in specific subject areas such as science. Although in general The Act of Teaching courses may include science-teaching-methods-specific courses, the number of these courses varies by institution. Other required courses in the BEd program—for elementary and secondary teachers—conform to the description of an approved program of professional studies that can be implemented as individual institutions might wish "in a variety of ways including, but not limited to, formal courses, professional workshops and a supervised practicum of at least 15 weeks" (NSOTC, 2017b, p. 1). It should be noted that the province is currently discussing a revision of the BEd programs with the Faculties of Education, but as of yet no firm direction for change has been decided upon.

The licence that every Nova Scotia secondary teacher receives includes a major and minor endorsation. Teachers can have more teachable endorsations added to their licence if they have the requisite number of approved courses in the subject area along with at least one methods course in that subject area. In the case where a teacher candidate wishes to be licensed with science as both a major and a minor teachable area because they have sufficient undergraduate credit hours in two different science disciplines, the province allows teacher candidates to *double dip* in the sense that they can use their two required courses in science curriculum and pedagogy for both science subject licence certifications.

Following certification, a teacher is placed on a salary grid in a category related to education and at a level related to length of teaching experience. Years of teaching experience result in upward movement within the category until a maximum salary is reached. For instance, a beginning teacher with a 4-year university degree and a 2-year BEd would start at teacher certification (TC) 5 with a salary of approximately $53,276 (Nova Scotia Teachers Union [NSTU], 2019), while a teacher with the same education and 11 years' experience would earn approximately $76,038. Teachers can progress from TC 5 to another category (e.g., TC 6, 7, and 8) by completing either a certificate course or an administrative program or by completing a graduate degree (for details, see § 24–28 and 30D–G of the Government of Nova Scotia (2015) Order in Council). A graduate degree in education is by far the most common choice, and a large number of teachers in Nova Scotia have two or three graduate degrees. Universities offer Masters of Education, Masters of Arts, and Research Masters of Arts in addition to the joint PhD program. It should be noted that (a) none of these graduate programs is science education-specific; (b) there are some graduate courses in science education, but they reportedly are rarely, if ever, taught; and (c) the number of thesis students studying science education issues appears low; therefore, there is some question as to exactly how much graduate-level science education actually occurs in the province.

9.5 Challenges and Opportunities

Every educational system has things it does well, while having with room for improvement in others, and Nova Scotia is no exception. Challenges discussed in this section include current entry requirements for BEd programs, the effect of minimal contractual obligations for Pro-D on attendance at opportunities offered by the province, and the limited updates to science curriculum in the past two decades. Opportunities for enhancing science education in the province include summer science camps, science fairs, robotics competitions, and the new provincial coding initiative.

9.5.1 Secondary Science Teacher Quality

There are several factors that impact the quality of secondary science teachers in the province, including small cohorts of science teacher candidates and a lack of stringent admission requirements. The small number of preservice secondary science teachers in each BEd program means that methods courses for specific science disciplines are not widely offered. The comparatively small size of BEd programs in Nova Scotia means that it is often not feasible to offer major and minor teachables in two different science disciplines. As a result, preservice secondary science teachers typically have a major teachable in science and a minor teachable in another subject area (or the reverse), which means that the content background of certified science teachers may be limited in comparison with teachers in other provincial/territorial jurisdictions. The small program size also means that science methods courses tend to be generic rather than discipline specific, resulting in fewer opportunities to develop pedagogical content knowledge. The province's lack of rigorous admission requirements further negatively impacts the academic depth and breadth of science teacher content knowledge. When standards for entry into BEd programs are reduced and/or the number of applications decline, as is currently the case, there are likely to be fewer elective courses offered, including elective science methods courses. These aspects will undoubtedly have a negative impact upon secondary science teacher quality.

9.5.2 Professional Development

Professional development (Pro-D) opportunities are provided by NSDE, individual school boards, and NSTU. Although there are no Pro-D requirements associated with teacher certification in terms of salary level, category upgrades, or pay increases, according to government regulations (Government of Nova Scotia, 2015), teachers are required to submit annually a Pro-D profile that documents 100 completed hours of Pro-D every 5 years. There is no contractual obligation to attend Pro-D events held by NSDE or school boards during the summer or on weekends. There are provincial and local grants as well as funding from school boards to support teachers who want to attend various out-of-province science education conferences. For instance, every year a number of teachers from Nova Scotia attend the annual national conference of the National Science Teachers Association (http://www.NSTA.org) in the United States.

When a NSDE initiative or update requires teacher inservice sessions, arrangements are made at the board or school level, and teachers are typically pulled from regular classroom duties and replaced with a substitute teacher (Ministry official, personal communication, June 15, 2017). For example, NSDE recently provided a 1-day workshop on the streamlined Grades 4–6 curricula. NSDE has also offered weeklong, science-focused summer institutes at different locations around the province. However, these institutes were often poorly attended despite providing opportunities to also acquire new classroom resources such as microscopes, thermometers, balances, and laboratory coats. This low attendance likely reflects the lack of contractual obligation to participate in Pro-D outside the school year, and currently these institutes are no longer being held.

During a regular school year, each school board schedules 5 or 6 Pro-D days—called PD days—with timing and topics determined by the individual boards. PD days are those days over and above the required number of school days where teachers are directly involved in teaching students. The number of contact, or teaching, days is set out in the Education Act, while the number of PD days is not (P. Hayden, personal communication, June 15, 2017). These PD days are typically noninstructional days and usually involve the entire teaching staff, with the school being closed to students. There is variation among school boards around how PD time is managed, whether it will be scheduled as full days, half days, or through flex time arrangements, and reportedly does not often deal with subject-specific topics.

NSTU has 22 Professional Associations, including the Association of Science Teachers (AST). On one noninstructional day every fall, NSTU sponsors Professional Association Conferences and, although attendance is optional, there is an expectation that teachers will engage in some form of Pro-D on that day. The annual conference organized by the AST consists of workshops on a variety of science education topics such as conducting laboratory activities, inquiry investigations, and data analysis. These workshops are facilitated by teachers, college and university educators, and not-for-profit groups such as Project WILD (http://cwf-fcf.org/en/explore-our-work/education/for-educators/project-wild.html). The diverse range of topics is generally applicable to the classroom, and this Pro-D event typically attracts hundreds of teachers of science from Primary through Grade 12.

9.5.3 Initiatives Related to Science Education

There are currently a number of initiatives and activities in the province that relate to science education. Apart from the typical summer science/engineering camps offered at universities by various science/engineering departments, there are science fairs that are coordinated by the nonprofit Nova Scotia Youth Experiences in Science! (NS YES!) organization, robotics competitions, and the provincial coding initiative that involves the not-for-profit organization Brilliant Labs (https://www.brilliantlabs.ca/).

9.5.3.1 Summer Camps

Most science-related summer camps focus on a selection of *entertaining* activities from science, engineering, and robotics. Some of the opportunities available to Nova Scotia children include:

- Science camps (http://maritimes.madscience.org/summercamps.aspx)
- STEM-focused camps (http://www.supernova.dal.ca/about/)
- Camps for girls (http://www.wiseatlantic.ca/)
- More formal marine research activities (http://www.smu.ca/academics/science-marine-mammal-summer-camp.html)
- STEM and architecture activities with LEGO® (http://www.bricks4kidz.com/canada-novascotia-halifax/)

9.5.3.2 Science Fairs

Properly done, a science fair project gives students a chance to pick a topic and design an experiment, followed by visual, oral, and written reporting; thus, science fair investigations often reflect *authentic science* better than classroom instruction (C. Coveyduc, personal communication, June 23, 2016). Regional science fairs are usually held in each of the Regional Centres for Education and among First Nations schools. Funding to support science fairs usually occurs at the Regional Centre for Education level with no direct funding from NSDE.

NS YES! was conceived in 1998 as a representative vehicle at the national, provincial, and board level; it opened doors to funding support from private groups and the provincial government. As a result of the efforts of NS YES!, the maximum number of participants that could be sent to the national science fair was quickly reached, a success level that continues to date (C. Coveyduc, personal communication, June 23, 2016). Nova Scotia typically sends 40 regional science fair winners to the national Canada-Wide Science Fair (CWSF). NS YES! hosts a yearly showcase of winning projects that includes dinner with scientists, a public presentation of the projects, educational workshops, and tours of actual science research facilities, which many students in this very rural province have never before seen. The annual Provincial Showcase has become an amazing display of the creative talent, ability, and determination of Nova Scotia's young people (C. Coveyduc, personal communication, June 23, 2016). Current funding difficulties make it difficult to predict if the showcase will continue.

9.5.3.3 Robotics Competitions

Students in Nova Scotia have the opportunity to participate in a provincially-funded robotics competition hosted and run by Acadia University's Joudrey School of Computer Science. Started in 2005 with 12 teams from eight high schools, the competition recently had 17 high school Robofest® teams and 29 middle school *FIRST* LEGO League (FLL) teams from across the province selected from the 63 registered teams that went through a qualifying round. These two competitions offer opportunities for students to design and implement hardware and software. The Robofest competition (http://robots.acadiau.ca/robofest.html) provides students with a programming challenge that they solve by structuring algorithms. The FLL competition requires teams to build robots out of LEGO and to research a yearly theme; a recent theme was Trash Trek. Although robotics competitions are consistent with the newly developed information and communication technologies and coding curricula described earlier, there is currently little explicit integration with the science or mathematics curricula.

9.5.3.4 Provincial Coding Initiative

NSDE recently introduced a curriculum focus on computer coding that is now required across all grades from Primary through Grade 12. Coding is meant to be integrated with other subjects; for example, some resources that were recently provided to elementary schools (P–6) for science and mathematics (notably Chromebooks, iPads, Sphero SPRK, Makey Makey kits, and PASCO probes and software) also require coding. Apart from these resources, school boards are introducing coding tools such as Kodable, Tynker, LightBot, and Scratch. These technology tools are intended to provide teachers a focal point for creating lessons that integrate subject areas (e.g., an activity combining mathematics, science, and English language arts using one of the technology tools). A federally funded initiative has resulted in class sets of the BBC Micro:bit being distributed to dozens of schools in Nova Scotia to support teaching senior elementary and middle school student coding.

To further support these coding initiatives, NSDE has contracted a private organization, Brilliant Labs, to create a makerspace for each school board that will contain 3D printers, robotics equipment, and video production equipment. Along with these technology centres, schools will be provided with makercarts. Some boards have been buying additional supplies for their schools so more students can have access to these types of technologies. Individual teachers have access to a fund to buy additional technological equipment to support their teaching. This funding support and availability of technological supplies has led to changes in how science is taught in Nova Scotia schools. An example of an early supporter of the move to integrate technology into science classrooms who changed his teaching of physics to incorporate Arduino and programming can be seen at https://www.youtube.com/watch?v=-b2Hgf5KrMc. In addition, NSDE has been encouraging teachers to have students participate in Hour of Code events to learn the basics of computer coding.

9.5.3.5 Indigenous Perspectives on Science

There are many reasons for having Indigenous perspectives included in the school curriculum from both a social justice perspective so as to more accurately reflect history and to provide a grounding in the curriculum for Indigenous students (see Chap. 6, Ontario, this volume, for a more extended discussion of this topic). Despite Indigenous issues becoming more prevalent in the cultural zeitgeist in the last several years, Nova Scotia science education documents do not presently reflect this change and do not deal with indigeneity. However, this does not mean that the NSDE does not expect Indigenous perspectives to be incorporated into curriculum activities. In a June 15, 2016, workshop attended by various stakeholder groups, which was the same workshop provided P–6 teachers that year about the new technology and changed curricula, the main example of how to enact the integrated curricular approach drew on Indigenous perspectives in relation to the science of sound (in an integrated social studies, Indigenous music and poetry, and the science of sound activity). NSDE officials made it clear in their discussion that Indigenous perspectives were to be incorporated into the integrated curriculum lessons. However, the middle and high school science documents currently reflect minimal Indigenous perspectives—with the last update done more than 20 years ago, this is unsurprising. It remains unclear how the NSDE specifically expects Indigenous perspectives to be incorporated into middle and high school science activities at this juncture.

9.6 Concluding Remarks

Nova Scotia's current science curriculum was derived from a 20-year-old document, the *Common Framework* (CMEC, 1997); even the recently revised Primary through Grade 6 curricula still reflect the pedagogies expressed in it. However, the recent attempt to revise Nova Scotia's science curriculum, including the coding initiative, may have been halted in its tracks. With some resistance from teachers arising from a recent contract dispute (NSDE staff, personal communications, December 20, 2016), the provincial government appears to have paused curriculum development and revision. This hiatus is not necessarily a bad thing as the revision process was reportedly being conducted both quite quickly and without review external to the NSDE. The revision of the P–3 and Grades 4–6 science documents is rumoured to have been completed in less than a week by a team of three persons, none of whom had science expertise. This lack of external involvement in the process of curriculum design or evaluation is unusual, particularly when compared with science curriculum development in other provinces.

Recently, the province's five faculties of education have had undersubscribed BEd programs, some quite considerably, although there are reports that numbers have been higher in the last two years at some institutions. In addition, there are areas of the teacher preparation system that are problematic. These conditions seem to warrant a comprehensive re-examination of teacher education in general. Such a re-examination would, of course, include aspects of science teacher education raised in this chapter. It should not be surprising that this chapter concludes by calling for a thorough and critical examination of the science topics, and the sequencing of those topics, that are taught in Nova Scotia.

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Chapter 10
Science Education in Prince Edward Island: The Perspective from Canada's Smallest Province

Ronald J. MacDonald, Clayton W. M. Coe, and David Ramsay

Abstract This chapter outlines science education in the province of Prince Edward Island (PEI) and includes a brief history of the education system; curriculum development; current science education; descriptions of student assessment, science teacher preparation, and teacher certification; professional development for science education; and discussion on issues and unique characteristics of science education in the province. An aging population and decreasing numbers of school-age students have led to consolidation of school districts into two English language and one French language units and one Indigenous elementary school. PEI has been a member of an innovative consortium of Atlantic Provinces to develop science curriculum and resources. Teacher education and professional development programs address the generalist and specialist needs of teachers in the English and French language schools. Science achievements of PEI students have approximated the Canadian averages for national and international surveys. There are several concerns about school policy and science education that are characteristic of this small province.

10.1 Introduction

Prince Edward Island, often referred to as PEI, is known as the *Birthplace of Confederation* because the capital city, Charlottetown (Fig. 10.1), is where meetings were held in 1864 to discuss the founding of the country of Canada. Early Mi'kmaq settlement dates back thousands of years before the historic Charlottetown Conference. There are two Mi'kmaq Bands in PEI: the Lennox Island First Nations

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C. D. Tippett, T. M. Milford (eds.), *Science Education in Canada*,
https://doi.org/10.1007/978-3-030-06191-3_10

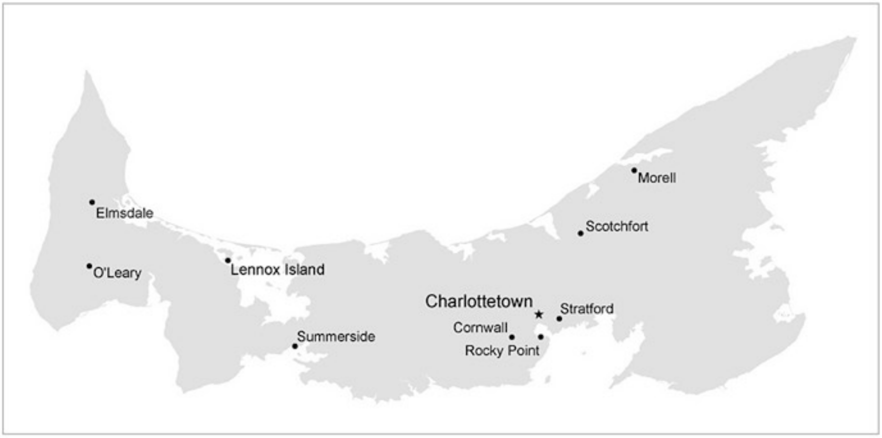


Fig. 10.1 Map of Prince Edward Island

band located in the western part of the Island, and the Abegweit First Nations band with members in Scotchfort, Rocky Point, and Morell. However, PEI has the smallest proportion of Indigenous people of all provinces and territories, at only 2% of the total population (Statistics Canada, 2016). Early European settlers arrived mainly from France, Scotland, England, and Ireland (Government of PEI, 2017).

PEI has the unique distinction of being the smallest province in Canada, with a land area of 5,685 square kilometres and a population density of 25.1 persons per square kilometre (Statistics Canada, 2017). It also has the smallest population of all Canadian provinces with just under 143,000 people in 2016, up 1.9% from 2011 (Statistics Canada, 2017). Like other provinces, PEI's population is aging. Since 1971, the median age has risen by 18.9 years, from 24.8 to 43.7 (PEI Statistics Bureau, 2015), which corresponds to a decrease in the number of school-age children and downsizing pressure on the public education system.

10.2 Historical Context of the Education System in PEI

PEI has a long and proud history of public education. On March 18, 1852, the *Free Education Act* was passed, making the province the first jurisdiction in North America to provide universal publicly funded education. The *Public Schools Act* of 1877 gave the provincial government the responsibility to administer school legislation, determine curriculum, regulate school standards and administration, and license teachers (PEI Education Governance Commission, 2011).

Until the early 1960s, there were few major changes in the structure of the education system. Over the last 50 years, however, PEI's school system has experienced considerable structural change and consolidation. In 1967, there were 412 schools in the province, including 268 one-room schools (PEI Education Governance Commission, 2011). The 1971 *School Act* created five regional administrative units:

four English and one French. At the same time, the PEI Department of Education, Early Learning, and Culture (DEELC) assumed total responsibility for the funding of these units (PEI Education Governance Commission, 2011).

Major changes in the education system took place in 1993. A French First Language school opened in Charlottetown with more being considered for other areas. Consequently, the *La Commission scolaire de langue française* (CSLF) was created to administer all French First Language schools. At the same time, DEELC combined the four Anglophone regional administrative units into two: the Western School Board and the Eastern School District. This structure existed until 2012 when the two Anglophone units were amalgamated into a single English Language School Board (ELSB).

The ELSB has responsibility for 56 schools: 36 in rural areas and 20 in the urban centres of Charlottetown, Summerside, Stratford, and Cornwall (Fig. 10.1). The CSLF has responsibility for six French First Language schools: two urban and four rural. There are also three private schools in the province. Typical school grade configurations are primary/elementary (K–6), junior high (7–9), and high school (10–12). As of September 2016, the total student population was just over 20,000 (Table 10.1).

While Indigenous students attend all public schools in PEI, there are eight public schools that predominantly serve Indigenous students (N. Forbes, personal communication, March 3, 2016). There is one federally-funded First Nations elementary school in the province, John J. Sark Memorial School, that is located on Lennox Island; it has a total student enrolment between 40 and 50 (Lennox Island First Nation, 2013). Furthermore, in conjunction with the Mi'kmaq Confederacy of PEI, K–9 Mi'kmaq language courses jointly developed by the Confederacy and DEELC are offered at three schools: John J. Sark Memorial School (K–6), Mount Stewart Consolidated School (K–6, Grades 7–8), and Hernewood Intermediate School (Grades 7–9). Currently, there is only one Aboriginal Studies high school course that is offered at two schools: Colonel Gray Senior High School in Charlottetown and Westisle Composite High School in Elmsdale.

In 2015, the provincial government decided to move in a new direction for education and learning; it established an advisory process at the provincial level with the PEI Learning Partners Advisory Council (LPAC). The council includes representatives from the PEI Home and School Federation, the University of Prince Edward Island, Holland College, and the PEI Teachers' Federation. LPAC supports a broad view of learning that spans from the early years to the workforce and allows for better integration of government social and employment services to support learners (Government of PEI, 2015).

Table 10.1 Student enrolment as of September 2016

Grade range	Public schools	CSLF (French)	Private schools	Total
K–6	10,021	540	161	10,722
7–9	4,591	183	73	4,769
10–12	4,532	140	43	4,944
Total	**19,144**	**863**	**277**	**20,284**

Note. CSLF = La Commission scolaire de langue française. Adapted from DEELC (2016a)

To facilitate the new advisory process, the government created District Advisory Councils (DAC), which is structured to correspond to the notion of *families of schools*. These families include a regional high school and the primary/elementary and intermediate schools that are the feeder schools. Government documents describing the new advisory structure indicate that each DAC will provide for active engagement and collaboration among parents, students, and the local school community (DEELC, 2017b). Topics to be addressed by the DACs include outcomes and expectations for student achievement and the inclusion of 21st century skills in the curriculum. A Principals' Council has also been established to enable conversations among principals and government officials regarding learning perspectives, learner needs, school leadership, and high-quality educational opportunities, among other topics.

Due to the creation of these new administrative and advisory bodies, the functions of the ELSB have been integrated, resulting in the formation of a Public Schools Branch within the DEELC. Previously, the DEELC developed the curriculum, and the school board was responsible for its implementation. Now, the Minister of Education, Early Learning, and Culture is responsible and accountable for the results and outcomes of the education system. All new or revised curricula, including science, will be developed and implemented by the DEELC.

10.3 Science Education in PEI

Science education in PEI is one of the major components in the provincial list of authorized programs and courses (DEELC, 2017a). All students are required to take science from Kindergarten to Grade 10 in both the French and the English programs.

10.3.1 Science Curriculum Development

The departments of education in the four Atlantic Provinces have a long history of working together for the benefit of the public education system in the region. Under the mandate of the Maritime Provinces Education Foundation (1982–1994) and the Atlantic Provinces Education Foundation (1994–2004), regional projects focused on the joint development of curriculum, procurement of school buses, and learning resources. Soon after the decision to work collaboratively, a regional science committee was established to write the *Foundation for the Atlantic Canada Science Curriculum* (*FACSC*; Atlantic Provinces Education Foundation [APEF], 1998). This foundational document used the *Common Framework of Science Learning Outcomes, K to 12* (Council of Ministers of Education, Canada [CMEC], 1997) as a starting point in the development of the regional science curriculum guides. Regional curriculum development committees were established for K–9, with each province taking the lead for a particular grade range; PEI was the lead province for Grades 7–9. Provincial committees composed of departmental representatives and teachers reviewed the curriculum documents at these levels and provided feedback to the lead provinces.

The regional science committees developed grade-specific curriculum guides with front matter summarizing relevant information from the *FACSC* (APEF, 1998). This information included, for example, the processes of scientific literacy and the curriculum outcomes framework. Each topic area, including specific curriculum outcomes from the *Common Framework* (CMEC, 1997), was described in a four-column, two-page format (Fig. 10.2). Some curriculum outcomes were reworded or combined in order to reflect the context of the unit or, if it made sense to do so, the pedagogy. For example, in the Grade 6 Diversity of Life unit, two outcomes from the *FACSC:*

> 204-1 propose questions to investigate and practical problems to solve
> 205-8 identify and use a variety of sources and technologies to gather pertinent information
> (Atlantic Canada Science Curriculum, 1998, p. 20)

were combined into one specific curriculum outcome stating:

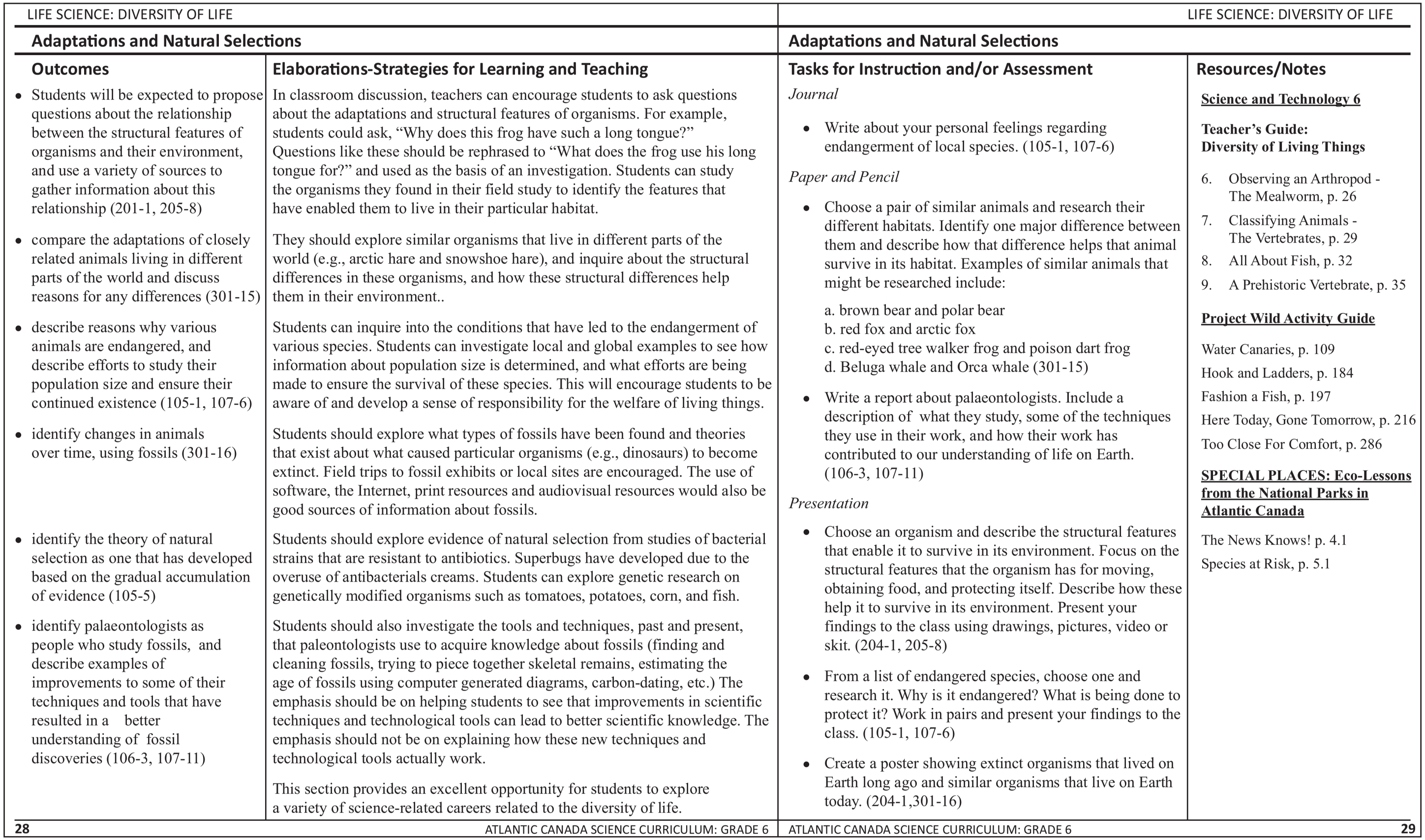
> propose questions about the relationship between the structural features of organisms and their environment, and use a variety of sources to gather information about this relationship (204-1, 205-8). (Atlantic Canada Science Curriculum, 1998, p. 28)

In 1999, the first of the regionally developed K–9 science curriculum guides were implemented in PEI schools. Provincial review and regional science committees continued to draft curriculum guides in biology, chemistry, and physics as well as other areas (e.g., agriscience and environmental science). While there have been some recent changes in PEI's science curriculum, the *Common Framework* (CMEC, 1997) and the *FACSC* (1998) continue to be influential in curriculum development in the province.

10.3.2 Science K–10

Science is introduced in Kindergarten, where students are involved in activities that allow them to explore the world using their senses (Table 10.2). The current Grade 1 curriculum guide, updated in 2012, contains the same topics as the initial version that was based on the *Common Framework* (CMEC, 1997). However, there were some modifications to the format, fewer specific curriculum outcomes were delineated using achievement indicators, and cross-curricular connection suggestions were provided (Fig. 10.3). The current Grades 2–6 science curriculum guides were created using the *Common Framework* and are still currently in use. The Grades 7 and 8 science curriculum guides were updated and implemented in 2014. The original *Common Framework* topics remained the same. The structure of the guides, however, mirrors that of the Grade 1 science curriculum guide. They contain specific curriculum outcomes that are further delineated by achievement indicators.

The science curriculum developed by the French Programs Division (2016b) also used the *Common Framework* (CMEC, 1997) and the *FACSC* (APEF, 1998) as



LIFE SCIENCE: DIVERSITY OF LIFE | LIFE SCIENCE: DIVERSITY OF LIFE

Adaptations and Natural Selections | **Adaptations and Natural Selections**

Outcomes	Elaborations-Strategies for Learning and Teaching	Tasks for Instruction and/or Assessment	Resources/Notes
• Students will be expected to propose questions about the relationship between the structural features of organisms and their environment, and use a variety of sources to gather information about this relationship (201-1, 205-8)	In classroom discussion, teachers can encourage students to ask questions about the adaptations and structural features of organisms. For example, students could ask, “Why does this frog have such a long tongue?” Questions like these should be rephrased to “What does the frog use his long tongue for?” and used as the basis of an investigation. Students can study the organisms they found in their field study to identify the features that have enabled them to live in their particular habitat.	*Journal* • Write about your personal feelings regarding endangerment of local species. (105-1, 107-6) *Paper and Pencil* • Choose a pair of similar animals and research their different habitats. Identify one major difference between them and describe how that difference helps that animal survive in its habitat. Examples of similar animals that might be researched include: a. brown bear and polar bear b. red fox and arctic fox c. red-eyed tree walker frog and poison dart frog d. Beluga whale and Orca whale (301-15)	**Science and Technology 6** **Teacher’s Guide: Diversity of Living Things** 6. Observing an Arthropod - The Mealworm, p. 26 7. Classifying Animals - The Vertebrates, p. 29 8. All About Fish, p. 32 9. A Prehistoric Vertebrate, p. 35 **Project Wild Activity Guide** Water Canaries, p. 109 Hook and Ladders, p. 184 Fashion a Fish, p. 197 Here Today, Gone Tomorrow, p. 216 Too Close For Comfort, p. 286 **SPECIAL PLACES: Eco-Lessons from the National Parks in Atlantic Canada** The News Knows! p. 4.1 Species at Risk, p. 5.1
• compare the adaptations of closely related animals living in different parts of the world and discuss reasons for any differences (301-15)	They should explore similar organisms that live in different parts of the world (e.g., arctic hare and snowshoe hare), and inquire about the structural differences in these organisms, and how these structural differences help them in their environment..		
• describe reasons why various animals are endangered, and describe efforts to study their population size and ensure their continued existence (105-1, 107-6)	Students can inquire into the conditions that have led to the endangerment of various species. Students can investigate local and global examples to see how information about population size is determined, and what efforts are being made to ensure the survival of these species. This will encourage students to be aware of and develop a sense of responsibility for the welfare of living things.	• Write a report about palaeontologists. Include a description of what they study, some of the techniques they use in their work, and how their work has contributed to our understanding of life on Earth. (106-3, 107-11)	
• identify changes in animals over time, using fossils (301-16)	Students should explore what types of fossils have been found and theories that exist about what caused particular organisms (e.g., dinosaurs) to become extinct. Field trips to fossil exhibits or local sites are encouraged. The use of software, the Internet, print resources and audiovisual resources would also be good sources of information about fossils.	*Presentation*	
• identify the theory of natural selection as one that has developed based on the gradual accumulation of evidence (105-5)	Students should explore evidence of natural selection from studies of bacterial strains that are resistant to antibiotics. Superbugs have developed due to the overuse of antibacterials creams. Students can explore genetic research on genetically modified organisms such as tomatoes, potatoes, corn, and fish.	• Choose an organism and describe the structural features that enable it to survive in its environment. Focus on the structural features that the organism has for moving, obtaining food, and protecting itself. Describe how these help it to survive in its environment. Present your findings to the class using drawings, pictures, video or skit. (204-1, 205-8)	
• identify palaeontologists as people who study fossils, and describe examples of improvements to some of their techniques and tools that have resulted in a better understanding of fossil discoveries (106-3, 107-11)	Students should also investigate the tools and techniques, past and present, that paleontologists use to acquire knowledge about fossils (finding and cleaning fossils, trying to piece together skeletal remains, estimating the age of fossils using computer generated diagrams, carbon-dating, etc.) The emphasis should be on helping students to see that improvements in scientific techniques and technological tools can lead to better scientific knowledge. The emphasis should not be on explaining how these new techniques and technological tools actually work. This section provides an excellent opportunity for students to explore a variety of science-related careers related to the diversity of life.	• From a list of endangered species, choose one and research it. Why is it endangered? What is being done to protect it? Work in pairs and present your findings to the class. (105-1, 107-6) • Create a poster showing extinct organisms that lived on Earth long ago and similar organisms that live on Earth today. (204-1,301-16)	

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Fig. 10.2 Example of the two-page, four-column spread format (Atlantic Canada Science Curriculum, 1998, pp. 28–29)

Table 10.2 PEI English science topics for Grades K–10

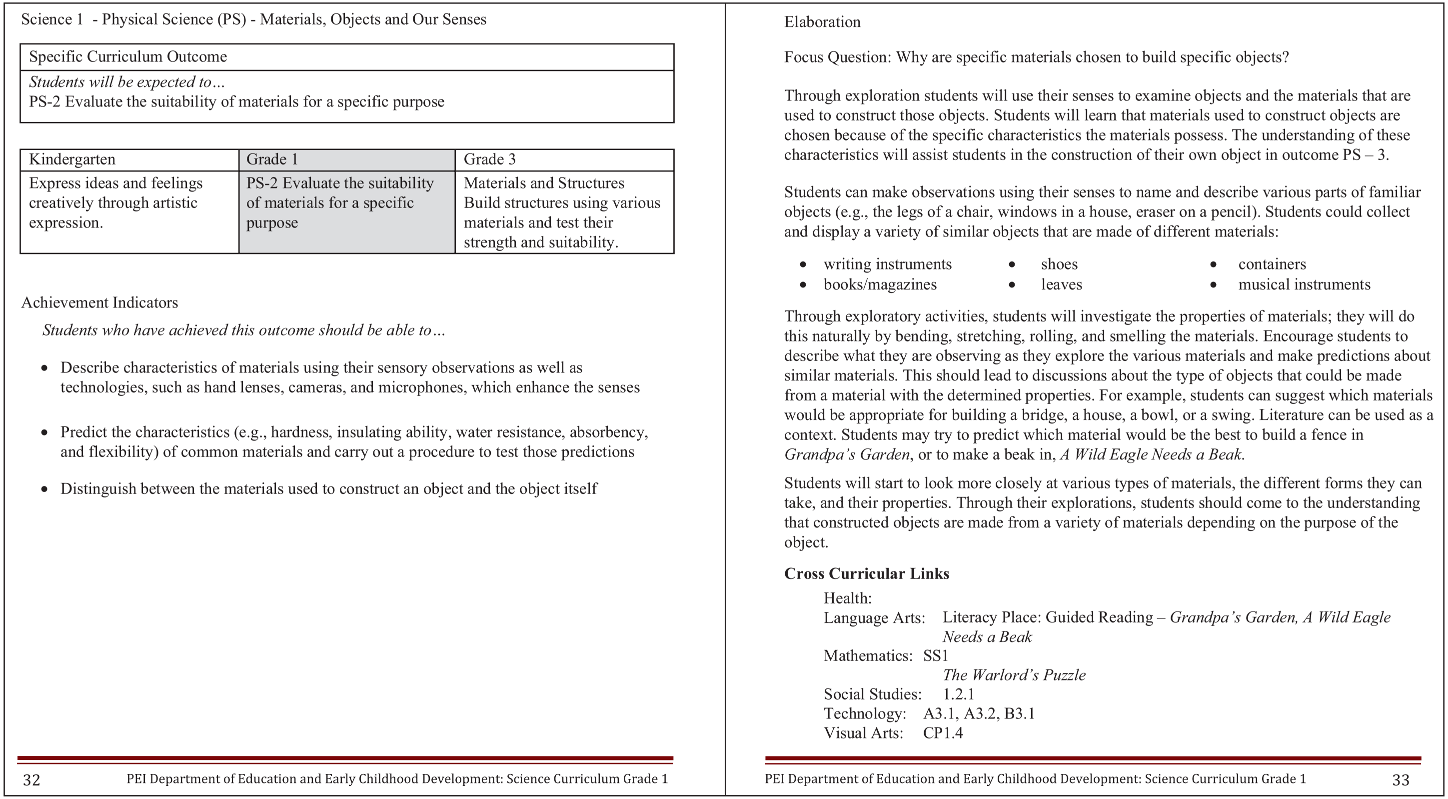
Grade	Life science	Physical science	Earth and space science
K	Exploring the world using our senses	–	–
1	Needs and characteristics of living things	Exploring objects and materials with our senses	Daily and seasonal changes
2	Animal growth and changes	Properties of liquids and solids Relative position and motion	Air and water in the environment
3	Plant growth and changes	Invisible forces Materials and structures	Exploring soils
4	Habitats and communities	Sound Light	Rocks, minerals, and erosion
5	Meeting basic needs and maintaining a healthy body	Properties and changes of materials Forces and simple machines	Weather
6	Diversity of life	Electricity Flight	Space
7	Interactions within ecosystems	Mixtures and solutions Heat	Earth's crust
8	Cells, tissues, organs, and systems	Optics Fluids	Water systems on Earth
9	Reproduction	Atoms and elements Electricity	Space exploration
10	Sustainability of ecosystems	Chemical reactions Motion	Weather

Note. Adapted from DEELC (2012, pp. 14–15)

guiding documents. The principle difference in the French science curriculum is that some of the topics and associated specific curriculum outcomes were placed at different grade levels (Table 10.3). This placement addressed the fact that available French resources had these topics at different grade levels. For example, in the English language science curriculum, the Diversity of Life unit is addressed in Grade 6, whereas in the French language science curriculum that unit is in Grade 5.

10.3.3 Science Grades 10–12

In the English school system, students must complete, with a minimum mark of 50%, 20 credits (or 110-hr courses) in Grades 10, 11, and 12 in order to earn a provincial graduation diploma. Of those 20 credits, 12 are compulsory and 2 must be in science (DEELC, 2015). Most schools require students to take one of the two compulsory courses in Grade 10; the other course is usually taken in Grade 11. Many



Science 1 - Physical Science (PS) - Materials, Objects and Our Senses

Specific Curriculum Outcome
Students will be expected to… PS-2 Evaluate the suitability of materials for a specific purpose

Kindergarten	Grade 1	Grade 3
Express ideas and feelings creatively through artistic expression.	PS-2 Evaluate the suitability of materials for a specific purpose	Materials and Structures Build structures using various materials and test their strength and suitability.

Achievement Indicators

Students who have achieved this outcome should be able to…

- Describe characteristics of materials using their sensory observations as well as technologies, such as hand lenses, cameras, and microphones, which enhance the senses
- Predict the characteristics (e.g., hardness, insulating ability, water resistance, absorbency, and flexibility) of common materials and carry out a procedure to test those predictions
- Distinguish between the materials used to construct an object and the object itself

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Elaboration

Focus Question: Why are specific materials chosen to build specific objects?

Through exploration students will use their senses to examine objects and the materials that are used to construct those objects. Students will learn that materials used to construct objects are chosen because of the specific characteristics the materials possess. The understanding of these characteristics will assist students in the construction of their own object in outcome PS – 3.

Students can make observations using their senses to name and describe various parts of familiar objects (e.g., the legs of a chair, windows in a house, eraser on a pencil). Students could collect and display a variety of similar objects that are made of different materials:

- writing instruments
- books/magazines
- shoes
- leaves
- containers
- musical instruments

Through exploratory activities, students will investigate the properties of materials; they will do this naturally by bending, stretching, rolling, and smelling the materials. Encourage students to describe what they are observing as they explore the various materials and make predictions about similar materials. This should lead to discussions about the type of objects that could be made from a material with the determined properties. For example, students can suggest which materials would be appropriate for building a bridge, a house, a bowl, or a swing. Literature can be used as a context. Students may try to predict which material would be the best to build a fence in *Grandpa's Garden*, or to make a beak in, *A Wild Eagle Needs a Beak.*

Students will start to look more closely at various types of materials, the different forms they can take, and their properties. Through their explorations, students should come to the understanding that constructed objects are made from a variety of materials depending on the purpose of the object.

Cross Curricular Links

Health:
Language Arts: Literacy Place: Guided Reading – *Grandpa's Garden, A Wild Eagle Needs a Beak*
Mathematics: SS1
The Warlord's Puzzle
Social Studies: 1.2.1
Technology: A3.1, A3.2, B3.1
Visual Arts: CP1.4

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Fig. 10.3 Example of the revised two-page format (DEELC, 2012, pp. 32–33)

Table 10.3 PEI French Immersion and French First Language system science topics for Grades K–9

Grade	Topic [English translation]			
1	L'exploration du monde en utilisant ses sens [Exploring the world with our senses] La découverte des couleurs [The discovery of colour] Les besoins et les caractéristiques des êtres vivants [Needs and characteristics of living things]			
2	L'exploration de son milieu – le temps et sa mesure [Our surroundings – Time and its measurement] Les forces invisibles – L'électricité [Invisible forces – Electricity] L'air et l'eau dans l'environnement [Air and water in the environment] Les changements quotidiens et saisonniers [Daily and seasonal changes]			
3	Les habitats et les communautés [Habitats and communities] La position relative et le mouvement [Relative position and movement] Les effets de la lumière [The effects of light]			
4	L'exploration du sol [Soil] L'eau dans l'environnement [Water in the environment] Les objets, les substances et les structures [Objects, materials, and structures] La croissance et les changements [Growth and change]			
5	La diversité de la vie [Diversity of life] Le vol [Flight] Le temps qu'il fait [Weather] Le son [Sound] L'espace [Space]			
6	Les besoins fondamentaux du corps [The basic needs of the body] Les forces et les machines simples [Forces and simple machines] Les propriétés et les changements de substances [Properties and changes of substances] Les roches, les minéraux et l'érosion [Rocks, minerals, and erosion]			
	Univers matériel [Physical universe]	Univers vivant [Living universe]	Terre et espace [Earth and space]	Univers technologique [Technological universe]
7	Les propriétés de la matière [Properties of matter] Les transformations de la matière [Transformations of matter]	La diversité de la vie [Diversity of life] Le maintien de la vie [Maintenance of life] La perpétuation des espèces [Perpetuation of species]	Les caractéristiques de la Terre [Earth's characteristics] Les phénomènes géologiques et géophysiques [Geological and geophysical phenomena] Les phénomènes astronomiques [Astronomical phenomena]	Le langage des lignes [Language of lines] L'ingénierie mécanique [Mechanical engineering] Les matériaux [Materials] La fabrication [Manufacturing]

(continued)

Table 10.3 (continued)

Grade	Topic [English translation]			
8	Les transformations de la matière [Transformations of matter] L'organisation de la matière [Organization of matter]	La diversité de la vie [Diversity of life] Le maintien de la vie [Maintenance of life] La perpétuation des espèces [Perpetuation of species]	Les caractéristiques de la Terre [Earth's characteristics] Les phénomènes géologiques et géophysiques [Geological and geophysical phenomena] Les phénomènes astronomiques [Astronomical phenomena]	L'ingénierie mécanique [Mechanical engineering] Les matériaux [Materials] La fabrication [Manufacturing]
9	Les propriétés de la matière [Properties of matter] Les transformations de la matière [Transformations of matter] L'organisation de la matière [Organization of matter] Les fluides [Fluids] Les ondes [Waves]	Les parties et systèmes de l'anatomie des animaux [Parts and systems of animal anatomy] La perpétuation des espèces [Perpetuation of species]	Les caractéristiques de la Terre [Earth's characteristics] Les phénomènes astronomiques [Astronomical phenomena]	Le langage des lignes [Language of lines] L'ingénierie mécanique [Mechanical engineering] Les matériaux [Materials] La biotechnologie [Biotechnology]

Note. E. Arseneault, personal communication, March 15, 2016; D. Tutty, personal communication, March 16, 2016; DEELC (2016b)

students choose to take additional science courses in Grades 11 and 12, and these science courses are counted as optional credits. In addition to provincially-developed science courses, DEELC provides support for and recognizes the Grades 11/12 International Baccalaureate program (http://www.ibo.org/) at two high schools. Several schools provide opportunities for their students to take Advanced Placement courses developed by the College Board in the United States (https://apcanada.collegeboard.org/). In the French school system, students must complete 25 credits (or 92.5-hr courses) in Grades 10, 11, and 12 with a minimum of 2 science credits (DEELC, 2015). Most of the specific curriculum outcomes are the same in both the English and the French language science curricula. However, more courses are available in the English system (Table 10.4) as there are many more schools and students.

Table 10.4 PEI science courses in Grades 10–12

Grade	English courses offered	French courses offered [translation]
10	Applied science Science Science (general) Science (pre-international baccalaureate)	Sciences [science]
11	Agriscience Animal science Biology Chem-study (advanced course) Chemistry Human biology Physics	Biologie [biology] Chimie [Chemistry] Physique [Physics] Sciences appliquées [Applied science]
12	Agriscience Animal science Biology Chem-study (advanced course) Chemistry Environmental Science Oceanography Physics	Biologie [Biology] Chimie [Chemistry] Physique [Physics

Note. Adapted from DEELC (2016b, c)

10.4 Student Assessment

PEI administers provincially-constructed assessments in literacy and mathematics; science is not part of the provincial assessment program. However, PEI participates in the national Pan-Canadian Assessment Program (PCAP) and the Programme for International Student Assessment (PISA). According to the most recent PCAP assessment report (CMEC, 2014; O'Grady & Houme, 2014), 93% of PEI students achieved baseline proficiency or higher in science, compared to 92% of students across Canada. The PCAP scale ranges from 1 to 1,000 with the Canadian mean set at 500; in 2013, the mean score for PEI was 491. There was no significant difference between the results for PEI girls and boys, which reflects Canada-wide results. PEI students did not perform as well as Canadian students in the nature of science or life science subdomains but had similar scores in the physical sciences and earth sciences subdomains. Students in PEI achieved similar scores in the three competencies of science inquiry, problem solving, and scientific reasoning compared to students in Canada overall (CMEC, 2014; O'Grady & Houme, 2014). Although in the 2012 PISA Canadian students performed well, PEI was an exception, with students performing below the OECD average (Brochu, Deussing, Houme, & Chuy, 2013). In the 2015 PISA, where science was the major domain assessed, PEI students scored above the OECD average and outperformed several other provinces (O'Grady, Deussing, Scerbina, Fung, & Muhe, 2016).

10.5 Science Teacher Preparation

PEI has one university—the University of Prince Edward Island (UPEI)—that has two teacher education degree programs overseen by the Faculty of Education: the Bachelor of Education (BEd) (English) and the BEd (français langue seconde). The two programs run in parallel and are very similar with regard to entrance requirements, required courses, and practicum placements. The English BEd degree is a 12-month post-degree program of 20 3-credit hour courses, each of which consists of 36 contact hours. The "program is designed to provide the variety of courses and extended field experiences through which students can develop the knowledge and skills needed to teach in the modern classroom." (UPEI, 2016, para. 1) Students can focus their studies in primary/elementary years (K–6) or intermediate/senior years (Grades 7–12) and may specialize in international, Indigenous, or adult and workplace education.

10.5.1 Entrance Requirements

Prospective teachers must complete a 3- or 4-year undergraduate degree from an approved university with an overall average at least 70% (between C+ and B-) for the 20 highest grades of the last 22 3-credit hour courses. Students must have at least 6 credit hours in English or equivalent (at least 3 of which are recommended to be in composition) and at least 6 credit hours in mathematics or statistics (of which 3 could be the special Mathematics for Teachers course). Students must also have completed academic courses, as follows:

- Primary/elementary (K–6): 6 credit hours in social studies, 6 credit hours in science (3 of which must be a laboratory-based science), and a 3-credit hour course in developmental psychology (or equivalent)
- Intermediate/senior (Grades 7–12): at least 42 credit hours in one teachable area and at least 18 credit hours in a second teachable area. Teachable areas are those subjects that are taught in PEI schools and include mathematics, social studies, science, and language arts

10.5.2 Program Requirements

For both primary/elementary and intermediate/senior cohorts, the program begins in May and ends the following April. Field experiences include 21 weeks of practicum placements that mainly occur in two large blocks in the fall and winter. Primary/elementary preservice teachers take one 3-credit hour science methods course and one 3-credit hour science, technology, engineering, and mathematics—STEM—course focused on inquiry-based learning. Intermediate/secondary preservice science teachers take two science methods courses and a STEM course focused on inquiry-based learning. There are no required science content courses within either the primary/elementary or the intermediate/secondary cohort.

10.5.3 Teacher Certification

To be certified as a teacher in PEI, applicants must hold a BEd degree from UPEI or an equivalent degree from an accredited university. Such certification is required and leads to a Teacher's License at Qualification Level 5 with a designation of either primary/elementary or intermediate/senior (DEELC, 2017d). A teacher's licence can be upgraded to Level 5-A, 6, or 7—along with an increase in pay—through the completion of 400-level or graduate-level university courses in either K–12 education or teachable subjects. Teachers most often complete a Master's of Education (MEd) degree to achieve this upgrade. An acceptable MEd degree consists of ten 3-credit hour courses, or six 3-credit hour courses, and a thesis. It is possible, although rare, for teachers to upgrade their licence by completing a master's of science degree.

10.6 Professional Development

Professional development (Pro-D) includes professional learning days and inservice opportunities that arise during the school year. A typical school year includes 10 or 11 professional learning days; high school teachers have 10 days, while K–9 teachers have 11 days. DEELC uses input from advisory committees consisting of the English and French School Boards, the PEI Teachers' Federation (PEITF), and the PEI Home and School Federation to create the schedule. Professional learning days are overseen by either DEELC or PEITF; for example, in 2016–2017 the DEELC was designated 3 professional learning days, while the PEITF was designated 5 days. DEELC uses professional learning days to focus on educational goals that address literacy, numeracy, public confidence, and student well-being. DEELC also coordinates inservice Pro-D for teachers regarding courses that are the current focus of curriculum development. None of the 2016–2017 DEELC days were designated days for science specific professional development (DEELC, 2017c).

Two of the PEITF days are typically set aside for all PEI educators to attend the Annual PEITF Convention held in the fall. The convention has a variety of speakers and sessions, some of which are science-centered. One PEITF day is for all educators to attend PEITF annual general meetings that center on federation issues. The remaining two PEITF professional learning days are school-based, which means that a variety of sessions are held in various schools across PEI. Although some of these sessions may be science-centered, there is no guarantee that science educators will have access to science-focused Pro-D.

All educators are required to create or join a teacher-led collaborative team approved by DEELC. These teams are similar to a community of practice or a professional learning community of like-minded teachers working together to achieve common goals that are focused on student achievement, instructional and/or assessment practices, and/or the achievement of school effectiveness goals. These goals may or may not involve science.

Inservice Pro-D opportunities for science educators in both the English and French programs also exist; however, these opportunities are currently not part of a larger coordinated effort with a science focus. DEELC coordinates inservice Pro-D for courses that are the current focus of curriculum development. For example, science curriculum is reviewed, on average, every 10 years; when a curriculum is renewed, teachers receive inservice instruction on strategies to implement the new curriculum, including appropriate laboratory activities. This inservice is the most systematic coordinated effort of Pro-D for science teachers. Educators identified for DEELC curriculum inservice are required to participate and do not have the option to be part of a teacher-led collaborative team.

There are two standing committees within the PEITF (2012) that are involved with Pro-D. The first committee—Curriculum, Professional Development, Teacher Education—monitors the implementation of curriculum changes in the province, identifies the Pro-D needs of the membership, develops programs to meet those needs, and monitors teacher education programs. The second committee—Annual Convention Planning—is responsible for all aspects of the PEITF annual convention. There are also Special Associations within the PEITF whose general objectives are to improve practice in a specific field by increasing members' knowledge and understanding, to act as a clearinghouse for ideas and a source of trends and new developments, and to furnish recommendations and advice on matters affecting the special subject field (PEITF, 2012). Currently there is not a special association for science teachers, although such associations do exist for mathematics, home economics, and social studies.

10.7 Issues and Characteristics of PEI Science Education

There are a number of issues and characteristics that may impact the quality of science education in PEI. These issues include changes in governance of the education system, small size of the province, elementary teachers' lack of science literacy, and limited Pro-D focused on science.

10.7.1 Changes in Governance of the Education System

Education governance in PEI is in the midst of a major reorganizational initiative. In 2015, the provincial government announced that the governance model would become a system of advisory councils. A new Education Act (Government of PEI, 2016) to enable the change was adopted in May 2016, and the integration process was completed in September 2016. Many ELSB functions were integrated into the DEELC including, but not limited to, curriculum delivery support, administration support for principals, and student services. A Public Schools Branch was created to replace the ELSB functions of supporting human resources, busing, and student support services. There were no changes to the French School Board.

The establishment of the Principals' Council, the DACs, and the LPAC, combined with the integration of the ELSB functions within the DEELC, was intended to enable an intersectoral approach; such an approach is expected to identify and advance province-wide learning goals and to provide for alignment of resources and priorities in order to better serve and support learners from early years to the workforce. This major shift in education governance will surely have an effect on teaching and learning in K–12, including science education.

10.7.2 Small Size of the Province

PEI is a small jurisdiction, which presents unique opportunities. For example, as evident in the recent DEELC overhaul, the province is nimble and can implement major changes within a short period of time. Because travel is not a major limitation, the annual PEITF convention brings together teachers from across the entire province. There are close relationships among the DEELC, UPEI, Holland Community College, teachers, and organizations such as the advisory councils. These relationships can simplify the planning of Pro-D opportunities and allow coordinated input into the curriculum while helping to create an alignment of industry and educational needs, available resources, and local expertise.

10.7.3 Elementary Teachers' Lack of Science Literacy

Primary/elementary teacher generalists are currently required to complete one science methods course and one STEM course, which is not enough time for them to become comfortable and capable to teach science in K–6. To address this issue, the UPEI Faculty of Science, in conjunction with the Faculty of Education, is developing a science literacy prerequisite undergraduate course specifically designed for those students who plan to become teachers. This course will be one of the preferred prerequisite science courses for entry into the BEd program.

10.7.4 Limited Professional Development in Science

The DEELC is responsible for much of the professional learning of K–12 teachers. Professional learning opportunities for science teachers are provided by the same specialists who are responsible for providing Pro-D for mathematics teachers. However, mathematics is often given priority because of the provincial mathematics assessments in Grades 3, 9, and 11. With a limited number of professional learning days in the school calendar, most of which are tied to province-wide literacy and numeracy goals, there are few opportunities for science-focused professional learning. For example, in the 2016–2017 PEI School Calendar, the DEELC professional learning days were allocated for areas that directly support province-wide learning goals in improving literacy and results on the provincial mathematics assessment. One way to address the limited science Pro-D opportunities would be to form an official science association under the PEITF; such an association could spearhead a movement of science teachers providing Pro-D for one another.

10.8 Conclusion

PEI is going through a significant re-imagining of how education is experienced by all Islanders from early childhood to the workforce. As a result, novel collaborations have been created among formal and informal education and community organizations. This re-imagining is focused on improving levels of literacy and numeracy. However, there are stakeholders who believe that inquiry-based science projects could be the vehicle through which literacy and numeracy skills are attained. This interest in inquiry-based instruction is, in the authors' view, a positive move. If this move is combined with other actions—such as ensuring deeper science content knowledge and enhanced science literacy for preservice teachers and providing more science specific Pro-D—then PEI will be well positioned to improve science literacy for all students.

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Chapter 11
Science Education in Newfoundland and Labrador: Mapping the Landscape

Karen C. Goodnough and Gerald J. Galway

Abstract This chapter outlines the status of science education in the province of Newfoundland and Labrador. Starting with pre-Confederation, to Newfoundland joining the Confederation of Canada, and then to recent educational reform, Goodnough and Galway situate science education within the broader context of educational change. A description is provided of the education of Indigenous peoples in the province, the current state of the K–12 science curriculum, and the role of Memorial University of Newfoundland and other stakeholders in initial teacher education. The role of several stakeholders involved in the professional learning and professional development of science teachers in the province is also described. Finally, opportunities and challenges for the continuing development of education in NL as it relates to provincial geography, declining student enrolments, Indigenizing the curriculum and respecting Indigenous ways of knowing, and ongoing reform in the K–12 science curriculum are highlighted.

11.1 Introduction

Science education plays a critical role in fostering scientific literacy. While consensus on the meaning of scientific literacy has been difficult to achieve, conceptions typically have focused on various aspects of science knowledge, science inquiry, and attitudes towards science (Bybee, 1997; Duggan & Gott, 2002; Hodson, 2002). These aspects of scientific literacy influence what is included and emphasized in science curricula (Council of Ministers of Education [CMEC], 1997; Fensham, 2000; National Research Council, 2012; Osborne, 2007). The *Common Framework of Science Learning Outcomes, K-12* (CMEC, 1997) has guided the K–12 science

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C. D. Tippett, T. M. Milford (eds.), *Science Education in Canada*,
https://doi.org/10.1007/978-3-030-06191-3_11

curriculum for almost 20 years in Newfoundland and Labrador—the official name for the province since a constitutional amendment in 1997. This has implications not only for the design of the K–12 curriculum (e.g., assessment, content, learning resources) but also for how teachers are prepared to teach science and their professional learning and classroom practices. From an international perspective, much has been written about K–12 science curricula, science teacher professional learning and development, and the preparation of science teachers; however, little literature exists about the status of these three areas in the context of Newfoundland and Labrador.

This chapter addresses the gap by providing a historical context for the school system in Newfoundland and Labrador and by describing more recent provincial restructuring initiatives. The current K–12 curriculum is described with a focus on courses offered, prevalent themes in the curriculum, and the assessment of student learning in K–12 science. In the remaining sections, initial teacher preparation in the province, opportunities for teachers to avail themselves of professional development in science, and issues and future considerations for science education in the province are addressed.

11.2 Educational Context in Newfoundland and Labrador

Since Newfoundland and Labrador entered Confederation with Canada in 1949, formal education has undergone some profound changes. Relative to other Canadian provinces, the education system in mid-20th century Newfoundland was poorly developed and inaccessible to many citizens (Galway & Dibbon, 2012).

11.2.1 Pre-Confederation

Plagued by longstanding British-imposed restrictions, government instability, and religious segregation, a stable and equitable system of schooling in Newfoundland was slow to develop. Early British merchants, who used the island as a seasonal fishing base, exerted their considerable political influence to resist the establishment of Newfoundland as a permanent settlement. In fact, Newfoundland was not granted colonial status by Britain until 1825. Rowe (1964) articulated the problem of educational underdevelopment as being rooted in colonialism, economic exploitation, and religious intolerance. These factors, combined with geographic isolation, poverty, and early 20th century economic turbulence—brought on by severe World War I debt, overspending on the Newfoundland Railway, and the failure of export markets for fish—were overwhelming obstacles to the development of a modern education system.

Other than a few isolated schools established and funded by the main Christian churches, prior to the mid-1800s, there was no discernible structure to education in Newfoundland. Schools existed in larger communities such as Bonavista, Harbour Grace, and St. John's (Fig. 11.1). There were attempts to establish schools in various

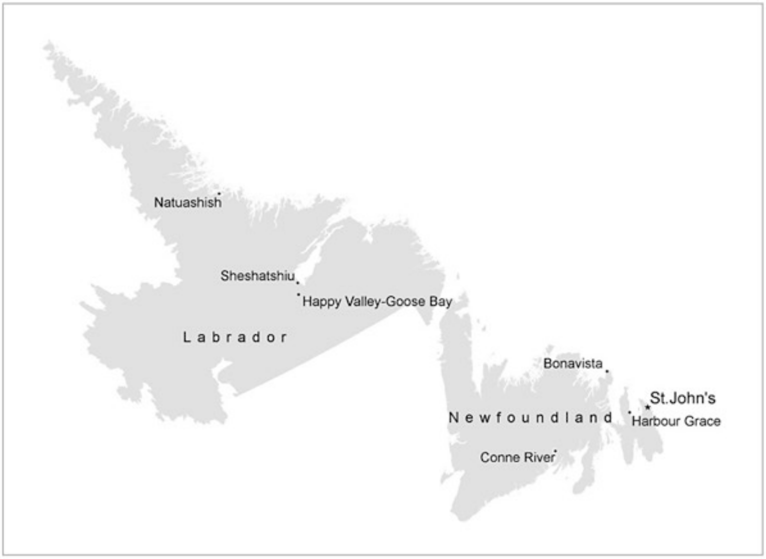

Fig. 11.1 Map of Newfoundland and Labrador

coastal settlements, but these arrangements could scarcely be called an education system. Difficulty attracting teachers—some of whom had little more than a high school education—meant that there was no real continuity or connection among schools (McCann, 1988). The province's two main immigrant groups—Irish Roman Catholics and English Protestants—composed virtually the entire population and maintained an intense distrust of each other. According to Rowe's (1964) account, the relationship between the English and the Irish settlers was acrimonious. The Irish were denied religious and political rights and considered their situation to be an extension of the "tyranny" they experienced at the hands of the English in their native Ireland; the English settlers maintained their fear of "Popery" and regarded their Irish brethren as "unstable, quarrelsome and thriftless" (Rowe, 1964, p. 17).

The *Education Act of 1843* divided public funding for education between the Roman Catholic and Protestant churches, effectively inscribing in the Newfoundland way of life a denominational system of schooling that lasted for more than a century and a half (McCann, 1988). Denominational authority over education was further solidified in 1949 when the Terms of Union with Canada entrenched the rights of the denominational authorities in the administration of education, including the funding of schools (Galway & Dibbon, 2012). The churches resisted all attempts at full structural consolidation until citizens voted in 1997 to abolish denominational schools in favour of a public school system (Warren, 2012).

A functioning Department of Education was not established until 1920, at which time the student population of about 55,000 was spread over 1,107 mostly one-room schools. The student-teacher ratio was 37:1, and 25% of the teaching force had no postsecondary training (Government of Newfoundland and Labrador [GNL], 1967–1968). The *Education Act of 1920* more than doubled the education grant and authorized the establishment of a normal school for potential teachers (Rowe, 1964). While these early efforts signalled promise, the funding level for education was paltry in comparison to the need. Early reports revealed that very few children continued past elementary school and less than 10% reached Grade 9 (Andrews & Warren, 1985).

By the 1940s, there had been some notable increases in the education grant, which created better learning conditions; family allowances (i.e., government payments to support dependent children) became an incentive for children to attend school, and they came in significantly greater numbers and for longer periods (Rowe, 1964). When Newfoundland entered Canada as a province, about three in four school-age children were attending school (GNL, 1967–1968). Still, the education system was woefully underfunded. As the 1950s approached, Newfoundland's annual per-student spending on education was less than $50, about one third of the Canadian average of $143 per student (Statistics Canada, 1999).

11.2.2 Post-Confederation

After Confederation, the newly formed provincial government had a difficult time making up for lost ground. One of its first legislative acts was to give Memorial College full university status. The government strongly supported and endorsed the need for teachers to earn degrees as a condition of certification. Accordingly, the Faculty of Education was established as one of the founding faculties of the new Memorial University of Newfoundland and awarded its first degree in education, the Bachelor of Arts (Education) in 1950 and its first Bachelor of Education degree in 1963 (Galway & Seifert, 2015). However, the Department of Education continued to be plagued with a legacy system that, from a structural perspective, was duplicative, underfunded, and grossly inefficient (Graesser, 1990).

In 1964, there were 1,266 schools governed by 270 overlapping denominational school districts, most of which were responsible for fewer than 500 students. Denominations included Catholic, Anglican, United Church of Canada, Salvation Army, and Pentecostal, among others. The 1967–1968 Royal Commission report revealed that many schools still had outdoor washroom facilities or no washrooms at all; few had gymnasiums, libraries, or science laboratories; most teachers had not completed university degrees; and very few rural students made it to high school (GNL, 1967–1968).

11.2.3 Recent Educational Reforms

In the wake of the post-war baby boom of the 1950s and 1960s, the government initiated an aggressive program of school construction and modernization, including the professionalization of the teaching force (Crocker & Riggs, 1979).

To augment longstanding provincial high school certification examinations and to monitor student achievement, the province embarked on a program of standardized testing in 1974 that used the norm-referenced Canadian Tests of Basic Skills at Grades 4, 6, and 8 (Newfoundland and Labrador Department of Education [NLDE], 1997). Early results were disappointing, with performance in language, reading, and mathematics hovering just under the 30th percentile. By 1977, there were marginal gains on some indicators, but results remained stubbornly below the 50th percentile. A 1989 Task Force Report on Mathematics and Science Education (Crocker, 1989, p. 2) complained of a "crisis of low expectations" and called for sweeping curricular changes—especially in mathematics and science—combined with recommendations meant to increase participation in advanced mathematics. Other recommendations focused on increasing instructional time, improving classroom and laboratory facilities, enhancing teacher qualifications and instructional practices, and overhauling assessment programs. The province responded by adopting many of the Task Force recommendations, taking a radically different, secularized curricular approach (McCann, 2012).

During the last 25 years, each elected government—sometimes with the involvement of the courts—has restructured its governance model for education with the stated goal of improving operational efficiency (Galway, 2014). The most publicly visible reform has been a reduction in the number of schools and school districts, largely through consolidation (Dibbon, Sheppard, & Brown, 2012). Following a public referendum in 1997, 27 denominational school districts were combined into nine public English school districts and a single province-wide Francophone district. Seven years later, the nine English districts were amalgamated into four large regional districts. In 2013, the government eliminated regional school governance entirely by consolidating the four English districts into a single provincial English school district. Between 1997 and 2013, a total of 170 schools were closed or amalgamated (NLDE, 2014).

The present education system is comprised of two school districts: the Newfoundland and Labrador English School District (NLESD) and the Conseil scolaire francophone (CSF), which are 100% publicly funded. NLESD serves approximately 65,000 English-speaking students in 262 schools and employs approximately 8,000 teaching staff, student assistants, support staff, and management (NLDE, 2018c; NLESD, 2017a, 2017b). CSF serves approximately 350 French-speaking students in five schools: two in Labrador, two on the west coast of Newfoundland, and one in St. John's that serves about two-thirds of the French-speaking population (NLDE, 2018c). In addition, there are a small number of parochial and independent schools operating in Newfoundland and Labrador with a total student population of approximately 900 students. Private schools in Newfoundland and Labrador are entirely privately funded, but the program of instruction is as prescribed or approved by the Minister of Education, and teachers must hold a valid certificate or licence issued by the province (Schools Act, 2018).

11.2.4 Education of Indigenous Peoples

Five Indigenous groups are recognized in Newfoundland and Labrador: the Innu, the Nunatsiavut Inuit, the Southern Inuit of NunatuKavut, the Miawpukek Mi'kmaq, and the Qalipu Mi'kmaq on the island of Newfoundland (Hanrahan, 2013). Two Innu groups form the Innu Nation (population 2,200), which was established in 1990 and formally recognized under the *Indian Act* of Canada in 2006. The Sheshatshiu Innu live primarily in the community of Sheshatshiu, while the Mushuau Innu live in Natuashish; both communities are located in coastal Labrador (Higgins, 2008). There is one K–12 school in each Innu community, operated under the administration of the Innu Nation.

Following three decades of negotiations with the federal government, in 2005 the Nunatsiavut Inuit (population 2,330) settled their land claim and established the Nunatsiavut Government, the first Inuit government in Canada (Nunatsiavut Government, 2017). Although it is their right to establish independent schools, the Nunatsiavut Government has not exercised that right so Inuit students attend public schools in the five Nunatsiavut communities. The Nunatsiavut Government is a significant partner in K–12 education, especially in respect to language and cultural education. For example, in 2014, Memorial University and the Nunatsiavut Government signed a memorandum of understanding to offer a community-based Inuit Bachelor of Education degree program in Goose Bay, Labrador. Part of that program is a parallel, 4-year Inuktitut language component.

According to Kennedy (2012), the Southern Inuit of NunatuKavut (originally called the Labrador Métis Nation, estimated population 6,000) are the descendants of the children of Inuit women and European men who worked in the fishery in southern and central Labrador as early as the 1700s. The NunatuKavut group is a non-status Indigenous group and is also the name of the territory the group is seeking in a land claim application with the federal government. Presently, people who identify as Southern Inuit attend schools operated by NLESD.

The Miawpukek Mi'kmaq First Nation is located on the central-south coast of the island of Newfoundland at Conne River and is the only recognized reserve on the island portion of the province. After many years of use as a temporary camping site for the then-nomadic Mi'kmaq people, Conne River became a permanent settlement in 1822. The Miawpukek Mi'kmaq First Nation (population: 862 on-reserve and 2,066 off-reserve) was formally established in 1984; and St. Anneway School, an independent First Nations school, opened a short time later. The school has been recognized for its high academic standards and strong cultural and music programs (Jonas, 2001).

Finally, the Qalipu Mi'kmaq First Nation has not been officially recognized and does not yet control any reserve lands. This group is the largest Indigenous group in the province with an estimated population of 24,000.

11.3 The K–12 Science Curriculum

The *Common Framework* (CMEC, 1997) was the basis for developing the *Foundation for the Atlantic Canada Science Curriculum* (*FACSC*, Council of Atlantic Ministers of Education and Training [CAMET], 1998), a document that is "intended to be a framework for science programs in the Atlantic provinces" (p. 1). Developed collaboratively by the Atlantic Provinces Education Foundation (which was superseded by CAMET) in consultation with regional stakeholders, the *FACSC* "outlines the nature of science education, science curriculum outcomes, the instructional philosophy for science, and principles of assessment" (1998, p. 1).

In the *FACSC*, science literacy includes four general outcomes that reflect the *Common Framework* (CMEC, 1997) and that underpin the Newfoundland and Labrador curriculum: science, technology, society, and the environment (STSE); skills; knowledge; and attitudes. In addition to these broad outcomes, students are considered to be scientifically literate when they are able to engage in the processes of inquiry, problem solving, and decision making as related to the outcomes. Teachers are encouraged to be facilitators of learning by creating learning environments in science that provide opportunities for all students to learn and engage in doing science. Guided by constructivist principles of learning (Brooks, 2015; Piaget, 1973), teachers are expected to "accommodate the diverse range of learners [considering] individual learning needs, preferences, and the abilities, experiences, interests, and values that learners bring to the classroom" (NLDE, 2004, p. 5). Each grade level or course curriculum guide follows a similar structure: course overview, general and specific learning outcomes, suggestions for teaching and learning strategies, assessment approaches, and resources (Fig. 11.2). A timeline for completion of units is provided at the beginning of each unit guide.

As of 2016, Newfoundland and Labrador is revising the science curriculum; implementation of new curricula has begun and is expected to continue until 2020. The revised science curricula (NLDE, 2019) have (a) a more explicit focus on creating inclusive classrooms, (b) a greater emphasis on differentiating instruction and the use of appropriate learning contexts, and (c) a multimedia repository of content to support new curriculum implementation and to act as a resource for professional learning after implementation.

While the *Common Framework* and its vision for scientific literacy are guiding this renewal process and the generation of new curriculum documents, the overall emphasis in the curriculum on learning science through inquiry has become a much stronger focus. Students will have opportunities to develop an understanding of the big ideas in science by developing and engaging in both simple and complex inquiry skills. For example, a revised Grade 1 curriculum is currently being used province-wide by teachers for the first time (NLDE, 2019). The revised Grade 1 guide has three sections: an overview of the curriculum (philosophy and orientations), information on the design of the guide, and the specific learning outcomes for each unit (planning/coordination adjuncts, recommended calendar/timelines, emphases, teaching and assessment strategies, connections to instruction materials, etc.).

Atomic Theory

Outcomes	Elaborations – Strategies for Learning and Teaching
Students will be expected to • Explain the importance of using the terms law and theory in science (109-14) • distinguish between a theory and a law	This is an opportune time to introduce and discuss theories and laws in science. Students will have heard about the Particle Theory of Matter (Grade 7), the Law of Reflection (Grade 8), etc., and may either ask what the difference is between a law and a theory or will use the terms interchangeably. Unfortunately, even among scientists, there is little consensus between a theory and a law. For example, some physicists speak of the 'law of gravitation' while others speak of the 'theory of gravitation'. The latter group would say that gravity is, as yet, poorly understood. This very disagreement points to a useful means of distinguishing between theories and laws. We may think of the terms "theory" and "law" as expressing a degree of confidence in the available experimental and observational evidence. Most laws are support by different and robust experimental evidence. In contrast, a theory is less well supported – further experimental or observational evidence may be required for its broad acceptance by the relevant scientific community. (For example, a theory may suggest something that has not been, or cannot yet be, produced in experiment). Theories change or are modified as new or conflicting evidence from experimental data or observations are presented, whereas laws rarely change due to their high degree of confidence. Even more tentative than a theory is a conjecture. A conjecture may have no experimental of observational support whatsoever. However, in scientific inquiry it is an important convention that conjectures must be testable – we call these 'hypotheses'. Teachers could use a mystery box or black box activity to demonstrate the different level of confidence between laws and theories. To give students a real taste of what it is to be a scientist, the teacher could keep the actual contents of the box a secret even after they have examined it and make their 'theory' of its contents based on their observations.

Atomic Theory

Suggested Assessment Strategies	Resources
Journal • Explain the difference between a theory and a law to your Younger sibling. (109-14) *Presentation* • Create a display of theories and laws of Science. (109-14)	www.gov.nl.ca/educ/science_ref/main.htm ST pp. 24-35

Fig. 11.2 Snapshot of a unit in the Newfoundland and Labrador science curriculum guide (adapted from NLDE, n.d., pp. 64–65)

A variety of resources has been developed to augment the curriculum: multimedia learning objects, science cards outlining scientific processes, anchor videos connected to the content of each unit, a classroom science library of resources containing 40 fiction and nonfiction texts, whiteboard activities, posters outlining the processes of inquiry and technological design, and a password-protected teacher resource website. Similar renewal initiatives are proceeding for all grade levels and courses in K–12 science (NLDE, 2019). Table 11.1 summarizes the K–10 guides that list a variety of units from life, earth and space, and physical sciences, while Grades 11 and 12 list units from specific disciplines (life science, chemistry, physics, Earth systems, or environmental science).

Programming for the five French First Language schools is similar to the Anglophone programs; time allotments for subjects, subjects studied, and resources are similar in both districts except that instruction occurs in French (NLDE, 2017).

Table 11.1 Newfoundland and Labrador science units by grade level

Grade/course	Science unit
K	Exploring my world
1	Daily and seasonal changes; materials and our senses; properties of objects and materials; characteristics and needs of living things
2	Air and water in the environment; solids and liquids; relative position and motion; animal growth and changes
3	Exploring soils; materials and structures; invisible forces; plant growth and changes
4	Rocks, minerals, and erosion; sound; light; habitats and communities
5	Weather; forces and simple machines; properties and changes in materials; body systems
6	Space; flight; electricity; diversity of life
7	Interactions within ecosystems; heat and temperature; mixtures and solutions; Earths' crust
8	Water systems on Earth's surface; fluids; optics; cells, tissues, organs, and systems
9	Space; atoms, elements, and compounds; electricity; reproduction
Science 1206	Weather dynamics; chemical reactions; motion; Sustainability of ecosystems
Biology 2201	Matter and energy for life; biodiversity; maintaining dynamic equilibrium I; interactions among living things
Biology 3201	Maintaining dynamic equilibrium II; reproduction and development; genetic continuity; evolution, change, and diversity
Chemistry 2202	Stoichiometry; from structures to properties; organic chemistry
Chemistry 3202	From kinetics to equilibrium; acids and bases; thermochemistry; electrochemistry
Earth Systems 3209	Introduction to earth science, historical geography; earth materials; the forces within Earth; Earth resources: real-life applications
Environmental Science 3205	Introduction to environmental science; recreation in the environment; land use and the environment; water use and the environment; the atmosphere and the environment
Physics 2204	Kinematics; dynamics; work and energy; waves
Physics 3204	Force, motion, and energy; fields; matter energy interface

Note. Adapted from NLDE (2019)

11.3.1 Provincial Assessment of K–12 Science

Developments in science curricula demonstrate a deliberate and well-grounded effort to improve science teaching and learning on several fronts (e.g., from inquiry-based instruction to inclusive learning); but work on the system-level assessment of learning in science has been far less robust. The province has devoted considerable attention to outcomes-based or criterion-referenced assessment in mathematics and language arts; however, there is presently no provincial evaluation of science outcomes at the primary-elementary level. Science achievement was assessed every 3 years at the Grade 9 level until 2009 when it was discontinued. In 2018, following the recommendations of a provincial task force on education, the NLDE also discontinued its assessment program in mathematics and language arts and announced a plan to develop a new provincial assessment framework, which may or may not include science (NLDE, 2018b). Table 11.2 provides an overview of provincial assessment activity in K–9 from 2006 to 2018.

Newfoundland and Labrador maintains a provincial high school certification system. The Department of Education and Early Childhood Development, which is the body authorized to issue graduation diplomas, monitors and records grades in all provincially-approved Grade 12 courses. Provincial graduation requirements stipulate that students must complete at least four credits (two courses) in science; because most postsecondary entrance requirements are more stringent, most students tend to complete more than the minimum number of required science courses. Enrolment trends in Grade 12 science courses have been fairly stable over the 2006–2018 period.

High school provincial examinations are required as part of most science course evaluations and account for 50% of the final grade for the course. Science courses with provincial Grade 12 examinations are biology (English and French), chemistry

Table 11.2 Provincial assessment schedule for Newfoundland and Labrador, 2006–2018

Year	Mathematics	Language arts	Science
2006	Grades 3, 6, 9	Grades 3, 6, 9	Grade 9
2007	Grades 3, 6, 9	Grades 3, 6, 9	–
2008	Grades 3, 6, 9	Grades 3, 6, 9	–
2009	Grades 3, 6, 9	Grades 3, 6, 9	Grade 9
2010	Grades 3, 6, 9	Grades 3, 6, 9	–
2011	Grades 3, 6, 9	Grades 3, 6, 9	–
2012	Grades 3, 6, 9	Grades 3, 6, 9	–
2013	–	Grades 3, 6, 9	–
2014	Grades 3, 6, 9	–	–
2015	–	Grades 3, 6, 9	–
2016	Grades 3, 6, 9	–	–
2017	–	Grades 3, 6, 9	–
2018	–	–	–

Note. Source: Education Statistics Databases, NLDE, 2006–2007 to 2017–2018

(English and French), physics (English), and earth science (English). Pass rates in 2016–2017 were in the range of 75–90% for earth science and biology and 94–95% for physics and chemistry (NLDE, 2018a).

11.4 Initial Teacher Education

The first institution established for the purpose of teacher education in Newfoundland was a Normal School, which opened in 1921. A full-time teaching staff of six professors supported the initial cohort of 55 students. In the early years of the Depression, both Memorial University College and the Normal School closed for a short period. Upon reopening in 1934, the Normal School became a teacher training department within Memorial University College, offering one of the largest programs in the college (Galway & Seifert, 2015). Given the geographic and economic challenges existing in Newfoundland at the time, the development of a competent teaching force in the province proved to be a longer-term proposition. Premier Joseph R. Smallwood's (1967) assessment of the quality of education provides a snapshot of teacher qualifications in mid-20th century Newfoundland:

> there was no essential difference between the type of education enjoyed by children at all levels and that which had been available seventy years before.... Out of the 2,375 teachers in 1949, fifty-seven had degrees and these, of course, were for the most part in St. John's and the larger centres. Out of 1187 schools 778 were 'sole-charge,' that is, one-room schools, and of these 778 teachers over 700 had not spent even one year at University. (p. 114)

The establishment in 1949 of Memorial University of Newfoundland, and particularly the Faculty of Education, was a key turning point in education. Since that time, the Faculty of Education has awarded around 23,500 bachelor degrees and 4,500 graduate degrees. Memorial University's first PhD in education was awarded in 2008. The Faculty continues to provide initial and postgraduate degree and diploma programs for teachers, counsellors and educational psychologists, educational administrators, and adult educators. Admission to undergraduate and graduate programs is competitive, and, notwithstanding recent provincial and pan-Canadian labour market challenges for new teachers, the number of applications continues to be relatively strong. As the only university in the province, Memorial University has a special responsibility to the people of Newfoundland and Labrador for the education of teachers and education professionals.

The Faculty of Education is the sole institution responsible for the preparation of K–12 teachers, in conjunction with many partners and collaborators such as the NLDE, the Newfoundland and Labrador school districts, and the Newfoundland and Labrador Teachers' Association. Teacher certification is a provincial responsibility, and teachers may be certified at one of four levels: Level I is an academic degree and an education degree, Level II is the equivalent of two undergraduate degrees and 150 credit hours, Level III is Level II requirements plus an additional

30 credit hours of university study, and Level IV is Level III requirements plus a postgraduate degree.

11.4.1 Primary/Elementary Teacher Education

The Faculty of Education offers two options for preparing primary/elementary teachers (K–6): a 5-year Bachelor of Education as a first degree, or a Bachelor of Education as a second (post) degree. The first-degree option requires the completion of 150 credit hours (50 university courses of 36 hrs each) with 75 credit hours of education courses. Of the remaining 75 credit hours, 60 must be completed prior to admission to the Faculty with 15 completed in a focus area such as English, French, history, linguistics, music, religious studies, science, or theatre arts. In terms of science education prerequisites, applicants are expected to have completed 9 credit hours (three university courses) from three of the following areas: biochemistry, biology, chemistry, earth sciences, environmental science, or physics. Applicants may also choose from science courses that are specifically designed for students entering the primary/elementary teacher preparation program.

The pedagogy adopted throughout the program is premised on constructivist, experiential learning. In terms of preparation for teaching science, one 36-hour course in science curriculum is required. This course includes a school-university partnership in which preservice teachers visit local schools to implement inquiry-based science lessons with K–6 students. The first-degree program includes two school placements that run once a week for 5 weeks. A full-semester internship is completed in the final year of the program. During these experiences, students focus on teaching in all curriculum areas, including science.

The post-degree option for the preparation of primary/elementary teachers is a 72-credit hour program that can be completed in four consecutive semesters. Entrance requirements for this program are similar to those of the first-degree option except that applicants must hold a university degree. Classroom experiences for the post-degree program are comparable to the first-degree program.

11.4.2 Intermediate/Secondary Science Teacher Education

The Faculty of Education offers a Bachelor of Education (Intermediate/Secondary) program, which is a 51-credit hour second-degree program designed to prepare teachers to teach intermediate science (Grades 7–9) and a range of Grades 10–12 science courses. Students admitted to the Intermediate/Secondary program must hold a bachelor’s degree from a university recognized by Memorial University and specialize in two teachable areas or academic disciplines corresponding to curricular areas determined by the NLDE Grades 7–12 Program of Studies. For their first teachable area, prospective science teachers must have completed at least 36 credit hours in one of the following academic disciplines: biochemistry, biology, chemistry, earth sciences/geology, environmental science, physics, or general science. A student who is accepted with general science as an academic discipline may complete courses in biochemistry, biology, chemistry, earth sciences/geology, environmental science, or physics but must complete a minimum of 12 credit hours in each of the disciplines selected. For the second teachable area, students must have completed an additional 24 credit hours in another academic discipline, either in one of the sciences listed above or in another subject area. Additionally, students must have attained an average of at least 65% in the courses comprising their two teachable areas.

The Intermediate/Secondary program runs over three consecutive terms. Students complete two field experiences: an introductory 10-day internship block undertaken early in the first term and a 12-week extended internship comprising the entire second term. A Teacher Development Seminar, completed in three segments over the entire program, is connected to these field experiences; and students remain in contact with the same instructor/mentor for this experience—in class and via an e-learning platform. Students also complete 3 credit hours selected from a range of offerings, an e-portfolio, and a culminating activity presented at a conference at the conclusion of the program.

11.4.3 Indigenous Teacher Education

Following Memorial University's (2009) Presidential Task Force on Aboriginal Initiatives Report, several education-related initiatives were identified. One of these was to establish a community-based teacher education program for Labrador's Indigenous peoples. The principles underlying the planning and implementation of this program were developed collaboratively between the Faculty of Education and the Nunatsiavut Government; these principles reflect a vision for Indigenous teacher education that respects both Indigenous and Western ways of knowing.

The Inuit Bachelor of Education (IBED) degree program aligns with the first-degree Primary/Elementary program with additional and/or parallel curriculum content designed to increase the relevance of the program for Inuit students. The program of instruction includes a modular Inuktitut language component developed and delivered by the Nunatsiavut Government in parallel with the IBED program. Upon graduation, participants are expected to return to Nunatsiavut communities and begin careers as K–6 teachers in community schools. Program headquarters and classroom facilities are located at Memorial University's campus in Happy Valley–Goose Bay in Labrador. With the cooperation of the Labrador Institute (see http://www.mun.ca/labradorinstitute/), a 30-credit hour preparatory program was offered in 2014–2015. Approximately 20 students who identified as members of the Nunatsiavut First Nation were accepted into the IBED program in September 2015.

11.4.4 Professional Learning and Professional Development in Science Education

In Newfoundland and Labrador, supporting the professional learning of teachers of science is a shared responsibility involving many partners and collaborators. Regrettably, there are no current data on the extent to which teachers actually avail themselves of these opportunities.

11.5 Department of Education and Early Childhood Development

The NLDE is responsible for early childhood development, the K–12 school system, and public libraries with the stated objective of "building an educational community in Newfoundland and Labrador that fosters safe, caring and inclusive learning environments for all children and youth in early childhood settings, regulated child care and family resource centres, and pre-school to grade 12" (NLDE, 2016, para. 1). Supports for professional learning are focused mainly on new program implementation. The Department provides face-to-face and blended support to teachers and school district personnel in science and other subject areas through the K–12 Professional Learning Newfoundland and Labrador initiative—a collaboration between NLDE and the English school district that will be discussed in a subsequent section.

11.5.1 Centre for Distance Learning and Innovation

Established in 2001, the Centre for Distance Learning and Innovation (CDLI) is a division of NLESD with its primary function to offer high school courses to students in rural, remote, and isolated communities in the province. However, CDLI is also responsible for supporting the delivery of K–12 technology projects and providing resources and technical support for teacher professional learning. In the latter category, teachers may utilize web-based resources and multimedia learning objects (MLOs) that explain particular concepts (e.g., Newton's Laws, bonding in benzene, or the process of meiosis). Teachers and students may access review materials for public examinations in biology, chemistry, earth science, and physics as well as materials developed by e-teachers. These resources come in the form of text, graphics, and some MLOs; they are specifically mapped to prescribed curriculum objects and are widely available to teachers and students.

11.5.2 Newfoundland and Labrador School Districts

The NLESD works closely with the NLDE in coordinating the delivery of training and professional development for all professional staff. Program specialists in each of the four regions (i.e., Eastern, Central, Western, and Labrador) provide support to teachers in a variety of ways. Each region has a Grades 7–12 program specialist in science. These individuals have responsibility for other subjects such as mathematics, technology, and/or physical education. Each region has K–6 program specialists who support teachers and curriculum delivery for all subject areas. As well, the district employs a professional learning program specialist who has provincial responsibilities. While many professional learning activities are focused on numeracy and literacy, according to the district's Strategic Plan 2014–2017, there is no explicit focus on science (NLESD, 2014). Professional learning opportunities for teachers in the CSF district are similar to what has been described for the English school district. A program specialist supports French language science programming. Parochial and independent schools follow the prescribed provincial curriculum and have access to resources through CDLI for professional learning in science.

11.6 Faculty of Education

Completion of a postgraduate degree can serve as a means for many science teachers to continue professional learning. Graduate students may complete either (a) a comprehensive course route (30 credit hours of courses); (b) an internship, paper folio, or project route that requires 24 credit hours of course work; or (c) a thesis route that includes 18 credit hours of course work. While the Master of Education graduate program is large (almost 1,000 admissions per year), only six to eight science education students are accepted each year.

Other formalized programs or options for practicing science teachers to pursue professional qualifications in science are not offered through the Faculty of Education. However, the Faculty works collaboratively with many stakeholders in supporting teachers' professional learning. Faculty members work in a range of collaborations and research projects with teachers in the area of science. One ongoing project—the Memorial University/Hibernia STEM (Science, Technology, Engineering, and Mathematics) Project: Teacher Inquiry Program—is currently in its third year of implementation and offers K–9 teachers the opportunity to work in collaborative school-based action research teams to examine or change some aspects of their classroom practice in STEM disciplines (Teachers in Action, n.d.). Supporting 80–90 teachers per year from all areas of Newfoundland and Labrador, the program promotes teacher-centered, active, relevant professional learning that focuses on student learning. The goals of the program are to:

- Enhance the STEM content knowledge and pedagogical content knowledge of K–9 teachers in the province
- Increase the interest and knowledge of K–9 students in STEM education
- Build the capacity of STEM education in the province
- Create a model of teacher professional learning that reflects current research about how people learn with particular emphasis on STEM education
- Support teachers in fostering active, inquiry-based student learning in STEM subject areas

For more detailed information about this program, see www.mun.ca/tia.

11.7 Newfoundland and Labrador Teachers' Association

The Newfoundland and Labrador Teachers' Association (NLTA), founded in 1890, is the professional organization that represents over 6,000 teachers. It supports its members through a range of services (e.g., collective agreements, pensions, employee assistance) and programs, including "a commitment to the promotion of the professional excellence and personal well-being of teachers" (NLTA, 2016a, para. 1).

Teachers of science may avail themselves of a number of professional learning opportunities and financial supports, such as specific support to new teachers through orientations and a conference for teachers in their first year of teaching; several forms of funding are available to present at or participate in conferences and other professional learning experiences (see NLTA, 2016b); and teachers may apply for educational leave to complete university studies. The Association has a Special Interest Council (SIC) in Math and Science (NLTA, 2016c), one of 11 SICs that support the professional growth of teachers.

11.8 Other Agencies

Many other organizations in Newfoundland and Labrador provide opportunities for teachers and their students to engage in learning science outside the regular classroom. While it is beyond the scope of this chapter to describe all of these in detail, a few that have an explicit focus on teacher learning in science are highlighted (Table 11.3).

Table 11.3 Newfoundland and Labrador organizations supporting teacher and student learning in science

Organization	Description	Outreach activities/programs (examples)
Johnson Geo Centre https://www.geocentre.ca/	The Johnson Geo Centre is a geological interpretation centre designed "to educate and inform the public on the importance of Newfoundland and Labrador's geology, and to foster curiosity in science and the world around them"	Onsite school programs: GEO explorations (2–6, 7–9, 10–12) Tectonic travellers (Grade 7)
Let's Talk Science http://www.letstalkscience.ca/	Let's Talk Science "offers a full suite of science, technology, engineering and math (STEM) programs for Kindergarten to Grade 12 educators, including hands-on STEM classroom outreach, online chat forums, program planning resources, action projects and professional learning opportunities"	National programs: Tomatosphere (K–12) Outreach programs (onsite school visits by trained volunteers)
Memorial University Botanical Garden www.mun.ca/botgraden	Memorial University of Newfoundland Botanical Garden "is a resource centre for basic and applied botanical research and education with a particular interest in the flora of Newfoundland and Labrador. It seeks to foster an appreciation of natural history in the development and future of the university and the province"	Preschool and school programs (K–12) Web of life (K–6) Teacher and educator workshops: Growing air plants
Oceans Learning Partnership http://olp.oceansnl.net/ns	The Oceans Learning Partnership focuses on engaging youth with ocean science through the integration of technology with real-world field experience	Coastal explorers, oceans live!
Salmonier Nature Park http://www.env.gov.nl.ca/env-/snp/programs/education/index.html	The Salmonier Nature Park is an environmental centre that provide[s] … "experiences that connect people with the natural communities of Newfoundland and Labrador. These experiences must encourage a better understanding of and contribute to a sustainable future for people, wildlife and the environment on which they depend". It also focuses on wildlife rehabilitation, research, and environmental monitoring	Outreach through school visits (K–12) Species at risk (Grades 4–6) Onsite visits and programs: Biodiversity (various levels)
Suncor Energy Fluvarium http://fluvarium.ca/	The Suncor Energy Fluvarium is a "public environmental education centre focusing on freshwater and riparian ecology. It is a venue for individuals, families and school groups to be entertained while exploring the natural environment, discovering and learning about our water resources, taking this learning home and contributing to the sustainability of our environment"	Onsite program: Teacher zone (K–3, 4–6, 7–12) Freshwater Babies (K–3) Teacher previsit kits

11.9 Challenges and Opportunities

The continued development of education in Newfoundland and Labrador generally, and in science education specifically, faces some important challenges as the province approaches 2020 and beyond. However, many of these challenges present opportunities to re-examine the policies, goals, and practices associated with K–12 science curriculum reform, teacher professional learning, and initial teacher preparation.

11.9.1 Geographic Challenges

The current population of Newfoundland and Labrador is approximately 530,000; however, its geography covers more than 400,000 square kilometres (GNL, n.d.). The province's land mass is three times the size of the other three Atlantic Provinces combined, but its population is almost four times smaller. Moreover, a large number (about 40%) of people reside in smaller, rural communities, creating service delivery challenges for all social programs, especially health and education (Statistics Canada, 2011). From an educational delivery standpoint, CDLI is one of the province's success stories. Through its programming, CDLI offers students in rural and remote areas accessibility to a wide range of quality high school science programming that would, in many cases, be otherwise unavailable. Still, under such a geographically disparate school system, the cost of program delivery at all levels creates difficult fiscal challenges and the incentive to continually examine opportunities for consolidation.

11.9.2 Enrolment Decline

A second, related challenge is school enrolment decline. Demographic factors such as changing fertility rates, outmigration, urbanization, and an aging population have had a profound impact on the size and distribution of the school-aged population (Galway, 2015). During the post-World War II period, before the province could adequately adapt to a massive increase in the number of school-aged children, educational demographers were already predicting a reversal in enrolment trends. As the 1980s progressed, the gravity of the problem had become clear. School enrolment, which had peaked at 162,818 students in 1971, was on a downward slide. By the time the numbers began to level off in 2010, overall enrolment had declined by 58%; enrolment now stands at 65,401 students. Although the majority of the structural realignment has already taken place, school closures in rural areas are still an all-too-regular occurrence and have become a continuing tension among parents, the government, and other educational agencies. There have also been intraprovincial enrolment shifts whereby larger centres, such as the greater St. John's area, have been gaining students at the expense of rural communities. These shifts have implications for the quality and methods of science instruction and resources in (mainly rural) schools whose student numbers are in decline.

11.9.3 Teacher Education

Teacher education in Newfoundland and Labrador faces some important challenges, many of which are common to faculties of education in other Canadian jurisdictions. There are high public expectations for science teacher quality, signalling a need to continually monitor and interrogate both admission and graduation standards. There has been a decrease in teacher supply in the province. There are fewer new teachers entering the profession now than in the recent past, and the proportion of new entrants relative to teaching positions is decreasing (Galway, 2015).

There are increasing demands for efficiency in program delivery and productivity, including larger class sizes in some education programs and pressure to increase faculty research output. There is also debate over the balance between online and classroom delivery. Online program delivery creates highly accessible course experiences; however, an important part of teaching—especially science teaching—is the practical component, which is embedded in classroom practice and hands-on experiences. Teacher educators want to model effective and inclusive science pedagogy for teacher candidates and practicing teachers, which in most circumstances should take place in a face-to-face learning environment. It is vital to ensure that core values and beliefs of the teaching profession are promoted, which may be best accomplished in a face-to-face classroom environment.

The preparation of primary/elementary teachers in science remains problematic. A strong body of research has shown that, if they are to be effective, primary/elementary teachers of science need both strong content knowledge (CK) and strong pedagogical content knowledge (PCK) in science (Carlsen, 1993; Hashweh, 1987; Heller, Daehler, Wong, Shinohara, & Miratrix, 2012; Hill & Ball, 2009). Furthermore, even when beginning teachers have a major in science, developing strong science PCK and enacting it in practice are challenging (Attorps, 2004; Ball & Wilson, 1990; Murphy, Neil, & Beggs, 2007; Onslow, Beynon & Geddis, 1992; van Aalderen-Smeets, Walma van der Molen, & Asma, 2012). Very few teacher candidates enter the teacher preparation programs (primary/elementary) at Memorial University with a major or focus area in science. Access and time to participate in ongoing professional learning in science remain a challenge for many teachers.

One possible option to address this challenge is the cultivation of a coordinated approach to the delivery of professional development for science teachers and teachers overall. This coordination would allow a differentiated model of professional learning to emerge through sharing knowledge, adopting different approaches to professional development, and having access to the resources of key educational stakeholders. Furthermore, a collaborative model of delivery would encourage a closer examination of the purposes and types of professional development that teachers are being offered and could be offered, and an opportunity to ensure principles of effective professional learning (e.g., active learning, focus on student learning, coherence, collective participation, emphasis on discipline-based knowledge, embedded in practice) are reflected in the model (see Garet, Porter, Desimone, Birman, & Yoon, 2001; Timperley, Wilson, Barrar, & Fung, 2007). While initial teacher preparation provides a foundation for beginning teachers to start their careers, mentoring, especially in the early years of teaching, is essential.

11.9.4 Respecting Indigenous Ways of Knowing

With the release of the Truth and Reconciliation Commission of Canada report *Calls to Action* (2015), a formal national call for reconciliation has occurred. Of the 94 calls to action in the report, several that focus on education have implications for science education. Opportunities exist for survivors, Indigenous peoples, and educators to work collaboratively to ensure K–12 curricula, including science curricula, are culturally relevant. All teachers, including preservice and practicing science teachers, will need appropriate supports and learning opportunities as they develop an understanding of how to teach in ways such that Eurocentric and Indigenous ways of knowing become complementary (Murray, 2016).

11.9.5 Science Education Curriculum Reform

The K–12 science curriculum at all grade levels in Newfoundland and Labrador is currently undergoing reform. However, supporting curriculum change requires careful consideration, especially in terms of how teachers understand and respond to change initiatives. Without appropriate professional development to support change, the intended and enacted curriculum may not align (Eisner, 2002). Several factors can positively impact teachers' ability to grapple with and enact change, such as having adequate time, access to professional development that is practical and well-designed, and opportunities to see how reform can benefit students (Borko, 2004; Hord, 2004). Successful change can be achieved through careful planning at all stages in the curriculum adoption process. Moreover, individuals' readiness for change and how they deal with change vary; thus, a particular focus on providing individualized supports for science teachers is required (Noack, Mulholland, & Warren, 2013).

11.10 Conclusions

It is now 70 years since Newfoundland became a Canadian province; the social, economic, and educational landscape has changed dramatically. Once a fishing society with a way of life described by McCann (2002) as “localised, god-fearing, [and] socially-conservative” (p. 2), Newfoundland and Labrador has seen considerable economic and social diversification. Notwithstanding the current turbulence in oil and gas markets and its struggles to bring major clean energy projects online, the province has emerged as a global presence in the energy sector, with annual oil production valued at $8.6 billion, in 2014, and major clean energy projects under development (Newfoundland and Labrador Department of Finance [NLDF], 2015). Similarly, the province’s social backdrop has become more culturally diverse and decidedly more secular.

Today, demographic trends continue to present some challenges to the delivery of quality education although there is some evidence that school enrolment has begun to stabilize after years of decreasing (Galway, 2015). Since 2006, Kindergarten enrolment has been relatively stable, and, for the past several years, net migration levels have been positive (NLDE, 2015; NLDF, 2016). From the perspective of educational outcomes, over the last 25 years, Newfoundland and Labrador has made profound gains on measures of general educational attainment and postsecondary participation, particularly among younger segments of the population. Recent national data ranked the province seventh among 13 provinces and territories on completion of upper secondary programs and sixth on tertiary educational attainment among 25–34-year-olds (CMEC, 2014). In terms of achievement, results from national and international tests have been mixed but generally optimistic. For example, the 2013 Pan-Canadian Assessment Program showed Newfoundland and Labrador was one of four provinces to achieve at or above the Canadian average in science literacy (CMEC, 2013).

There is always some uncertainty in forecasting the direction of science education. However, given the recent movement to place a heavier emphasis on inquiry-based, inclusive K–12 curriculum and other opportunities (e.g., the potential to develop an integrated model of professional learning for teachers in the province), achieving high levels of scientific literacy of children and adults will continue to be important. To achieve high levels of scientific literacy, all stakeholders—educators, teachers, scientists, and the general public—will need to be actively involved in cultivating a robust science culture. Developing a strong science culture can result in many benefits for individuals and society (e.g., enhance quality of life, foster informed decision making regarding public policy, create positive economic outcomes, and encourage support for scientific research). Because society is evolving, as is science itself, the value of what counts in science education will continue to evolve as well. Thus, being responsive to these changes through critical, ongoing reflection on, and assessment of, the educational activities that impact K–12 science learning, initial science teacher preparation, and science teacher professional learning will need to remain a priority.

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Chapter 12
Science Education in the Yukon: Signaling a Time of Change for Canada

Brian E. Lewthwaite, Christine D. Tippett, and Todd M. Milford

Abstract The Yukon is the most westerly of Canada's three territories, located north of British Columbia and bordering Alaska in the United States. The territory is sparsely populated with the majority of its population residing in the capital city of Whitehorse. The remainder of the population is distributed across 14 communities, most of which are represented by a different language-based and, more recently, politically defined self-governing First Nation. These geographic, demographic, and political elements have historically impacted education in the Yukon, both negatively and positively. The continuing implications of these influences on science education in the Yukon are important considerations addressed in this chapter.

12.1 Introduction

The Yukon is the most westerly of Canada's three *north of 60* territories. It is located north of British Columbia (BC), east of Alaska in the United States, and west of the Northwest Territories; the Arctic Ocean is its northern coastline. The territory, much of which is mountainous subarctic plateau, accounts for approximately 4% of Canada's total area (482,443 km^2) but only 0.1% of its population. In 2016, the population of the Yukon was 35,874 (Statistics Canada, 2017), resulting in a population density of 0.074 people/km^2 or one person in every 14 km^2. The vast majority of the population—25,085 people—reside in Whitehorse, the capital city (Fig. 12.1).

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C. D. Tippett, T. M. Milford (eds.), *Science Education in Canada*,
https://doi.org/10.1007/978-3-030-06191-3_12

Fig. 12.1 Map of the Yukon Territory

Fourteen other communities, ranging in population from a low of 55 in Destruction Bay to a high of 1,375 in Dawson City, are spread throughout the territory's vast and sparsely populated area (Statistics Canada, 2017).

Indigenous peoples from 14 First Nations—Carcross/Tagish, Champagne-Aishihik (Haines Junction), Tr'ondëk Hwëch'in (Dawson City), Kluane (Burwash Landing/Destruction Bay), Kwanlin Dun (Whitehorse), Liard (Watson Lake), Little Salmon/Carmacks, Na-Cho Nyäk Dun (Mayo), Ross River Dena, Selkirk (Pelly Crossing), Ta'an Kwach'an (Whitehorse), Teslin Tlingit (Teslin), Vuntut Gwitchin (Old Crow), and White River (Beaver Creek)—comprise about 23% of the population (Indigenous & Northern Affairs Canada, 2010). Approximately half of the Yukon First Nations population live in Whitehorse.

It is important to note that there is great cultural variation in the Yukon as evidenced in the distribution of eight First Nations languages across 14 communities. All Yukon First Nations languages face declining use despite the Yukon's *Education Act* (Government of Yukon, 2018a) specifying that First Nations languages are required to be taught in Yukon schools. For example, Dawson City is the only Canadian community in which the First Nation language is Hän, one of several vulnerable languages spoken fluently by only a small number of citizens. There are strong revitalization efforts to ensure that all Yukon First Nations languages continue to be spoken (Government of Yukon, 2013).

The revitalization efforts are promulgated by the current political context associated with the majority of Yukon First Nations—a context that is unparalleled in Canada and the major influence on curriculum development. Historically, treaties were never negotiated in the Yukon, unlike other jurisdictions. Over the past three decades, the governments of both Canada and the Yukon have moved toward Self-Government Agreements (SGA), which are complex and wide-ranging policy relationships with First Nations. The SGAs, most of which have been finalized within the last decade, set out the powers of each First Nation to govern itself, its citizens, and its land. They also provide First Nations with lawmaking and jurisdictional authority in specific areas, including education (Lewthwaite, Owen, & Doiron, 2015). Their influence on curriculum and pedagogy is of utmost importance in the current re-imagining of science education in the Yukon and, thus, a major emphasis of this chapter.

12.1.1 History of the Yukon

First Nations inhabitation of the Yukon is estimated to date back 15,000 years (Coates & Morrison, 2005). Although the First Nations population was estimated to be approximately 9,000 in the early 1800s prior to significant European contact, the Klondike Gold Rush of the late 1800s near what is today Dawson City led to an influx of an estimated 40,000 people over a 2-year period (Coates, 1991). This influx led to the separation of the Yukon district from the Northwest Territories and the formation of the Yukon Territory in 1898, with Dawson City as its territorial capital. The *Yukon Territorial Act* created the region as a separate geographic and political entity belonging to the Canadian federation. The territory was governed by a commissioner as well as an appointed council (Wonders, Coschi, & Fong, 2011/2017). In 1953, long after the gold rush had ended and Dawson City's population had declined considerably, the territorial capital shifted to Whitehorse. As a territory, the Yukon did not have the same powers as provinces. In 1960, the Yukon became responsible for education, social services, tax collection, and community services; however, it had no authority over natural resources, and royalties derived from resource development were paid to the federal government (Wonders et al., 2011/2017).

Understanding the current political context of the Yukon draws attention to this history and is likely best considered with attention to the perspective of its First Nations (referred to as Indian bands or Indian peoples in those times) and European contact since the creation of the Dominion of Canada in 1867. The development of the SGAs was politically motivated and coincided with a pivotal document presented by the First Nations in 1973 to the governments of Yukon and Canada. This document, *Together Today for Our Children Tomorrow: A Statement of Grievance and an Approach to Settlement by the Yukon Indian People* (Council for Yukon

Indians, 1977), described four waves of historical events thrust upon its First Peoples that have defined the socioeconomic history of the territory, even prior to its inception in 1898, and the disrupting influence of these events upon the First Peoples existence. These four events were the first contact through the fur trade, the Klondike Gold Rush, the building of the Alaska Highway during the Second World War, and the more recent mineral development with an attention to oil and gas exploration in the northern half of the Yukon. The document captured the impact of these events, drawing attention to a history of economic development that had excluded First Nations participation. Specific to this chapter, the document also drew attention to the negative impact of formal education upon the Yukon First Nations and delivered a call for cultural, political, and economic reclamation through education and self-governance. *Together Today for Our Children Tomorrow* (hereafter *Together Today*) called for action in regard to the First Nations educational experience that precipitated immediate changes in education.

12.1.2 History of Education in the Yukon

Formal education in the Yukon began in the late 1800s with the establishment of day schools operated by church missionaries primarily in the Klondike region (Almstrom, 1991). In 1911, the first residential school opened, and it was followed by four more, one of which was located close to Watson Lake in Lower Post in northern BC. Indigenous students were removed from their communities and forced to attend these church-sponsored, government-funded schools that had the express purpose of encouraging the elimination of traditional languages, knowledge, and cultural practices. Closure of Yukon residential schools began in 1943, with the last school closed in 1975. The impact of these schools is well documented in Canada and the Yukon (Council for Yukon Indians, 1977; Truth & Reconciliation Commission of Canada, 2015). It is important to note that this history was exposed through the public release of *Together Today*, much ahead of other disclosures across Canada. This exposure was fundamental to precipitating an acute awareness of the formal education processes that for more than a century, both intentionally and unintentionally, have denied aspects of culture that have value and are important to Yukon First Nations children (Lewthwaite et al., 2015).

The closing of the residential schools coincided with the establishment of public schools in smaller Yukon communities (Coates, 1991). In 1951, responsibility for the education of First Nations students was transferred from the federal government to the Yukon government. In 1964, the responsibility for education of non-Indigenous students was transferred to the Yukon government, with the aim of equalizing educational opportunities for all students (Eastmure, 2011; Yukon Department of Education [YDE], 2007).

12.1.3 Final Umbrella Agreement *and SGAs*

In response to *Together Today*, Yukon First Nations have worked with territorial and federal governments to establish the *Umbrella Final Agreement* (Government of Canada, Council for Yukon Indians, & Government of the Yukon, 1993), which was the foundation for the individual First Nations SGAs. The *Agreement* and several individual SGAs contain a general jurisdictional governance statement that provides for First Nation assumption of responsibility for the management, administration, and delivery of any program or service within the jurisdiction of the First Nation, including education (see https://cyfn.ca/wp-content/uploads/2013/08/ufa-understanding.pdf for more information). While an SGA allows a First Nation to work toward autonomous control of education entirely independent of Yukon Education—an unparalleled situation across Canada—SGAs also make clear the provisions if the First Nation decides upon shared delivery of education with Yukon Education. Currently, all First Nations operate a shared delivery model, which impacts the curriculum offered to students, particularly those in rural communities.

The *Agreement* gives explicit attention to the apparent autonomy each First Nation has in deciding how education is administered. Correspondingly, the *Agreement* draws attention to aspects that broadly influence curriculum; for example, the totality of experiences provided for learners while drawing into consideration what is learned, how it is learned, from whom, and then at an epistemological level why is it learned and for what purpose (Ornstein & Hunkins, 2009).

In brief, education and science education in the Yukon are in a tenuous state. There is the potential for all First Nations to draw down education and alter, on their terms, the science experiences provided for their children. Although the authority for change rests with self-governing First Nations, it would appear there has been a variety of actions, including an emphasis on experiential education, that have challenged the orthodoxy of the school science education experience of the Yukon's young citizens over the past three decades.

12.1.4 Overview of the Education System

The first Yukon *Education Act* in 1993 (Government of Yukon, 2018a) defined a framework for public schooling through the territory by establishing the Yukon Department of Education. In addition to outlining the responsibilities, rights, and powers of the minister, the department, parents, and students, the *Education Act* identifies a vision for Yukon education, which includes specific curriculum goals, foundation curriculum competencies, and broad citizenship goals such as promoting understanding of the history, language, culture, rights, and values of Yukon First Nations and their changing role in contemporary society and increasing awareness and appreciation of the Yukon's natural environment (Government of Yukon, 2018a).

The *Education Act* also delineates the role of school councils and the process by which school councils likely will be replaced by school boards to assume greater responsibility for the academic and administrative control of their designated schools (Schmidt, 2014). With the exception of the Commission scolaire francophone du Yukon (http://www.csfy.ca/), which oversees French First Language schools in Whitehorse, there are no school boards; public schools are governed by school councils. School councils have less authority than school boards and primarily serve as an advisory group for individual schools in informing budgetary and curriculum decisions. In contrast, a school board has added responsibilities regarding decision making associated with staff hiring, school operations, and budget allocations (Wonders et al., 2011/2017). The SGAs have led to the current co-governance model of operation for most schools; that is, Yukon Education continues to oversee education but in a shared delivery model with individual First Nations. Pragmatically, this model means that all school operations, including hiring of principals and teachers as well as curriculum development and implementation, require the First Nations input and direction (e.g., Tr'ondëk Hwëch'in, 1998, p. 33).

Of the 34 educational facilities in the Yukon, 15 schools (Table 12.1) and 5 alternative learning facilities are located in Whitehorse. The schools include nine elementary, three secondary, one primary, and one French, as well as one private

Table 12.1 Enrolment at Whitehorse schools, 2017–2018

School	Language	Grades	Enrolment
Elementary and primary			
Christ the King Elementary (Catholic)	English	K–7	331
Elijah Smith Elementary School	English	K–7	256
Golden Horn Elementary School	English	K–7	227
Grey Mountain Primary School	English	K–3	73
Hidden Valley Elementary School	English	K–7	111
Holy Family Elementary School (Catholic)	English	K–7	166
Jack Hulland Elementary School	English	K–7	374
Selkirk Elementary School	English	K–7	181
	French	K–2	73
Takhini Elementary School	English	K–7	154
Whitehorse Elementary School	French	K–7	478
Yukon Montessori School	English	1–6	31
Secondary			
F. H. Collins Secondary School	English	8–12	447
	French	8–12	223
Porter Creek Secondary School	English	8–12	449
Vanier Catholic Secondary School (Catholic)	English	8–12	367
Commission scolaire francophone			
École Émilie Tremblay	French	preK–12	282
Total			**4,223**

Note. Based on data from YDE (2017e)

Montessori. Two of the elementary schools and one of the secondary schools are Catholic but are publically funded. The five alternative learning facilities are the Aurora Virtual School (Grades 8–12), the Gadzoosdaa Student Residence (Grades 10–12), the Individual Learning Centre (Grades 9–12), the Teen Parent Centre (Grades 8–12), and the Wood Street Centre (Grades 9–12). Of particular importance to this chapter is the Wood Street Centre, an experiential education centre affiliated with F. H. Collins Secondary School.

There are an additional 14 public schools in rural communities (Table 12.2). Eight schools offer Grades K–12 and four offer Grades K–8 or K–9. Watson Lake has both an elementary and a secondary school.

École Émilie Tremblay is the only school that offers school-wide and classroom-based French language instruction. Two schools offer classroom-based French Immersion and six offer French language programming (YDE, 2017b). None of the rural schools offer French language programming other than Core French, which is basic conversational French instruction; the Robert Service School offers an optional Grade 6 French language immersion experience (YDE, 2017b).

The *Education Act* gives attention to the development of curriculum experiences that incorporate specific First Nations objectives, such as the preservation of culture and language (Schmidt, 2014). The SGAs have brought critical attention to the priority of First Nations language learning in all schools. Currently, most schools offer Yukon First Nations language programs to its students. Seven of the eight Yukon First Nations languages are being taught as second-language programs, typically at the K–7 level. Several communities currently seek the extension of First Nations language learning to the secondary level, but this extension is limited by the professional capacity of language specialists. This limitation and the identified urgency

Table 12.2 Enrolment at schools in rural Yukon communities (n = 14), 2017–2018

Community	School	Grades	Enrolment
Beaver Creek	Nelnah Bessie John School	K–9	8
Carcross	Ghùch Tlâ Community School	K–12	53
Carmacks	Tantalus School	K–12	108
Dawson City	Robert Service School	K–12	284
Destruction Bay	Kluane Lake School	K–8	7
Faro	Del Van Gorder School	K–12	52
Haines Junction	St. Elias Community School	K–12	132
Mayo	J. V. Clark School	K–12	59
Old Crow	Chief Zzeh Gittlit School	K–9	38
Pelly Crossing	Eliza Van Bibber School	K–12	64
Ross River	Ross River School	K–12	52
Teslin	Teslin School	K–9	53
Watson Lake	Watson Lake Secondary School	8–12	97
Watson Lake	Johnson Elementary School	K–7	130
Total			**1,087**

Note. Based on data from YDE (2017d, e) for language revitalization have recently contributed to changes in the focus of the Yukon Native Language Centre and its transfer of operation to the Council of Yukon First Nations (Government of Yukon, 2018b).

12.2 Science Education

In terms of its education system, the Yukon Territory, in contrast to the Northwest Territories and Nunavut, has historically aligned itself with British Columbia rather than Alberta. The BC curriculum documents have recently undergone major changes to reflect contemporary educational foundations, which has immediate and substantial influence on school science education in the Yukon (see Chap. 2, BC, this volume). The new BC curriculum emphasizes the development of Core Competencies: "sets of intellectual, personal, and social and emotional proficiencies that all students need to develop in order to engage in deep learning and life-long learning" (BC Ministry of Education, 2018a, para. 1). Curriculum changes highlight the use of inquiry and project-based approaches to teach and learn science. The science K–10 curriculum emphasizes the importance of contextual elements such as place, environmental considerations, and Indigenous perspectives (BC Ministry of Education, 2018b)—all of which are particularly important in the Yukon. The emphasis on place and environmental considerations has been a longstanding feature of Yukon science education, whereas the emphasis on Indigenous perspectives has only recently been given attention. In order to graduate from secondary school and receive a Dogwood Diploma, Yukon students must meet BC requirements, which include the completion of one Grade 11 or 12 science course (YDE, 2017c). Secondary science courses are subject to both teacher availability and student demand, which are issues for rural schools.

12.2.1 Science Teaching Approaches

Although the science education experience offered to Yukon students has been heavily influenced by BC's science curriculum, there has also been local programming that challenges the orthodoxy of science education approaches. A variety of philosophical and pragmatic foundations and key individuals have influenced the development of these programs and, arguably, their long-term success in regard to contributing positively to student trajectories in science-related study and careers. A major development in Yukon education, and in science education specifically, has been a focus on experiential and place-based education. "*Experiential education* is the process of 'learning by doing' which begins with the learner engaging in direct 'experience' followed by reflection. *Place-based education* is an approach to teaching that is grounded in the context of community, both natural and social" (O'Connor, 2010, p. 4). As Yukon scholar Jickling (2009) remarked, "educational experiences do not always take place in formal settings [and educators] should make curricular space for the kinds of knowledge and/or experience that helps students to enhance abilities to be thoughtful and ethical beings" (p. 164).

Yukon experiential programs are offered primarily through the Wood Street Centre (http://www.woodstreetcentre.ca/), a satellite campus of F. H. Collins Secondary School. Started nearly three decades ago from a single Grade 10 integrated science course, the centre now offers four experiential learning programs with a science component:

- Achievement, Challenge, Environment, and Stewardship 10 (ACES-10) and French Achievement, Challenge, Environment, and Stewardship 10 (FACES-10), which integrate science, social studies, physical education, and outdoor pursuits and include 30 days of outdoor experiences
- Community, Heritage, Adventure, Outdoors, and Skills 9/10 (CHAOS 9–10) collaboratively developed with the First Nations Programs and Partnerships Unit at Yukon Education, which integrates English, social studies, ancestral technology, and outdoor education with First Nations knowledge, skills, values, traditions, and beliefs and includes a number of expeditions up to 8 days in length
- Experiential Science 11 (ES–11), which integrates biology, chemistry, geography, physical education, visual art, and applied skills and features 30 days of field studies as well as weekly sessions in Yukon College science laboratories
- Outdoor Pursuits and Experiential Science 9 (OPES-9) and Plein Air et Sciences Experientielles 9 (PASE-9), which integrate science, social studies, outdoor pursuits, and physical education and feature several overnight trips and a variety of daytrips

Students from across the Yukon can participate in these courses, although the majority of students are from Whitehorse. The Wood Street Centre's arrangement for a semester-long experience outside of the mainstream enables timetabling flexibility, which allows for activities that may range over many days and encourages curriculum integration of diverse content matter.

Alongside the substantial contributions the Wood Street Centre has made to science education, there have been other more recent developments by Yukon Education with attention to responding to the Yukon First Nations community. The Department of Education has specific goals identified in its plan, which inform the strategic context of departmental planning for First Nations. These include improving Yukon First Nations student achievement and outcomes, increasing successful transitions for all students to different levels of education and the world of work, effectively managing resources in urban and rural schools, and collaborating with Yukon First Nations governments (Schmidt, 2014). In response to these specific goals, the First Nations Programs and Partnerships (FNPP) unit within Yukon Education was established. This unit works on building productive relationships with communities, increasing the amount of First Nations perspectives in schools, improving the academic results of Indigenous students in the K–12 system, and enhancing First Nations efforts to revitalize their languages.

Ornstein and Hunkins' (2009) perspective on a co-generated and responsive curriculum informs the current work of FNPP as it collaborates with individual Yukon First Nations to determine how they prefer to develop culture- and land-based school programs. The programs focus on traditional seasonal harvest activities and encourage the participation of both Indigenous and non-Indigenous students. Working with Elders and other First Nations members alongside agencies such as Yukon Conservation, students are exposed to learning experiences that "braid" traditional ecological knowledge (TEK) with Western science (Snively & Williams, 2016). For example, through FNPP's collaboration with the Tr'ondëk Hwëch'in, three cultural camps currently operate: First Hunt, First Fish, and Spring Camp. Similar camps occur at most Yukon schools; for instance, Elijah Smith Elementary School in Whitehorse offers a bison hunt experience for its senior students, while the Individual Learning Centre in Whitehorse also offers a bison hunt along with other land-based programs for young people who have disengaged with or have been disenfranchised from mainstream secondary schooling (Lewthwaite, Wilson, Wallace, McGinty, & Swain, 2017). These programs play a fundamental role in Yukon education because they develop knowledge of and appreciation for First Nations culture and concurrently strengthen core competencies of the territory's young citizens.

12.2.2 Assessment

At present, Yukon students taking Science 10 write the BC provincial examination in science, which counts for 20% of a student's final grade in the course (YDE, 2017c). Changes to the BC graduation program, which are being adopted by the Yukon, include the replacement of current provincial examinations in 2020 with two new assessments of literacy and numeracy (YDE, 2017a). At that time, there will be no territory-wide assessment of science. In line with BC, Yukon Education is in the process of shifting away from high-stakes summative assessments based on conceptual understanding to ongoing formative assessment based on competencies as well as conceptual understanding. The attention to competencies is seen by Yukon First Nations to be a positive shift in curricular priorities (Lewthwaite, Owen & Doiron, 2015) because it mirrors the advocacy for broader personal and social development goals that was highlighted in *Together Today*.

12.2.3 Teacher Education

Political changes within the Yukon place considerable demands on practicing and prospective teachers. *Together Today* presented a critique of public education from a Yukon First Nations perspective. The document attributed the historical marginalization of Indigenous students as a product of ongoing colonial violence, characterized by curricular irrelevancy and the feeling of alienation of Indigenous students and parents. In a profound way, this critique affirmed that schooling is deeply political, with some groups having the power to declare their knowledge, values, and histories while others are marginalized (Haig-Brown, 1988).

Born of this critique in 1982, the Yukon Native Teacher Education Program (YNTEP) offered a decolonizing framework through which future teachers could develop a pedagogical approach that reclaimed and affirmed Yukon First Nations educational outcomes. Initially, YNTEP accepted only students of First Nations ancestry; however, as its role expanded, non-Indigenous students have been encouraged to apply. The program is small relative to other teacher education programs with an average of 11 students graduating each year. Many of these graduates are members of a Yukon First Nation who typically return to their home communities to become long-term teachers (Eastmure, 2011). All of the Yukon's schools have YNTEP graduates on staff; only in exceptional cases are YNTEP graduates either the principal or the majority of a teaching staff. YNTEP graduates are employed in educational roles outside of schools, for example, as policy developers or educational directors for Yukon First Nations.

Because its conceptual mandate was grounded in the manifest imperatives voiced in *Together Today*, YNTEP and its graduates are "deeply connected to the colonial history of public schools in the Yukon by making clear the impacts of this history, and the relevance it has to today's schools" (Eastmure, 2018, p. 238). YNTEP seeks to build teaching approaches that are antithetical to hegemonic neocolonial interests and, therefore, at times in direct tension with the practical professional requirements in contemporary schools (Lewthwaite & Connell, 2018). To cultivate this professional agency, YNTEP organizes its curricular experience within the paradigm of critical pedagogy, namely, seeking to facilitate a conscientization amongst teacher candidates (Freire, 1970, 1998). YNTEP privileges the perspective of Yukon First Nations Elders and community members in both general educational and curriculum courses. Students explore the historical trajectory of educational policy and the impact of that policy through a deeply personal Indigenous perspective. This dialogical process produces emotional tension, exacerbated during students' initial school-based practicum. This tension translates into an ingrained criticality, fostering the ability to analyze operational contexts and giving attention to ways that students may be marginalized (Eastmure, 2018). This criticality is expected to be enacted on subject-embedded, field-based experiences as well as a concluding 16-week internship in the final year of the program.

While many professional undergraduate programs may fulfill a socializing function within the educational space, it seems that YNTEP has a particular mandate to cultivate disequilibrium within its teacher candidates and to foster a social reconstruction orientation (Eisner, 1994). The fundamental marker of its effectiveness is the degree to which its graduates are able to utilize this disequilibrium to enunciate different ways of being a teacher and enact curriculum experiences in response to their students' cultural norms. In short, YNTEP graduates are being positioned as *teacher-leaders* who are able to utilize a critical understanding of Canada's perpetuating colonial context to develop creative, empowering, and perhaps subversive ways of *being a teacher* and meeting the needs of Indigenous students (Lewthwaite & Connell, 2018).

For many years, YNTEP has included at least two science courses. Since 2011, YNTEP has increased the experiential features associated with these courses, enhanced the Indigenous perspectives associated with learning about the natural world, and added an introductory environmental science course in the second year (Yukon College, 2017). The first-year science course is an integrated approach to outdoor education, combining lectures and field activities with a focus on experiential, place-based education. The third-year science course focuses on methods of instruction for elementary school science with attention to the recent political developments in the Yukon. In brief, the curriculum experience provided for preservice teachers seeks to question the legitimacy of current science education practice that typically gives little attention to Indigenous perspectives on the natural world. The methods course seeks to enhance preservice teachers' awareness that science as a body of knowledge reflects a particular way of understanding the world that is considered right by the majority and that rarely is there representation of the thoughtful, purposeful scientific knowing of minority cultural groups (McKinley, 2007). This exposure is substantiated through learning experiences and assessment practices that require students to provide evidence of their attention to place-based, culturally located experiences in science education.

12.2.4 Teacher Certification

A teaching certificate and membership in the Yukon Teachers' Association (YTA) are required to teach in the Yukon. To be eligible for a Yukon Professional Teaching Certificate, applicants must:

- Be of good moral character, sound judgment and, in all respects, a fit and proper person to teach school students
- Be a Canadian citizen or a landed immigrant or be otherwise qualified to legally work in Canada
- Hold a qualification document from another Canadian jurisdiction and be in good standing with the regulatory authority that issued the qualification document
  - **OR** have completed an approved bachelor of education degree at a university or college in Yukon or under the auspices of Yukon Education. (YDE, 2016c, eligibility section, para. 2)

The Teacher Qualification Board, which includes the Assistant Deputy Minister of Public Schools as well as a representative from the YTA and a professional educator, assesses teachers' academic background and years of teaching experience to determine their teaching placement across a series of pay scale categories (YDE, 2016d).

12.2.5 Professional Development

Because of recent political changes regarding Yukon First Nations self-governance and the co-operative delivery model that exists between Yukon Education and the First Nations, attention has been increasingly given to teacher orientation and development. Professional development (Pro-D) commences with an annual 3-day orientation for newly hired teachers and administrators that is co-hosted by Yukon Education and one or more local First Nation. The orientation is typically located in Whitehorse and, in the case of new rural hires, is supplemented with a local community orientation. Orientations in both Whitehorse and rural communities introduce teachers and administrators to their responsibilities under the SGAs, to key First Nation members, and to the local context with emphasis on culturally appropriate protocols and teaching practices as well as acquaint teachers with Yukon Education's personnel and processes (Government of the Yukon, 2013). With increased attention given to working with Yukon First Nations to provide locally-defined, place-based, experiential education opportunities, individual schools have some flexibility in deciding on Pro-D days. More and more frequently, Pro-D days involve school staff working collaboratively with local First Nations in decolonizing and Indigenizing curriculum, in part because one of FNPP's primary goals is to increase the amount and quality of First Nations perspectives in Yukon schools (YDE, 2016a).

At the time of writing, FNPP is aligning BC's new science curriculum with localized learning intentions and culturally located practices. FNPP seeks to use First Peoples Principles of Learning as a foundation for science curriculum development and enactment (First Nations Education Steering Committee [FNESC], 2016). Inherent in this approach is Karplus and Their's (1967) learning cycle, developed into the 5E Instructional Model (engage, explore, explain, elaborate, evaluate; Bybee, 1997). Extending this model further, FNPP encourages science teachers to draw on the local environment and First Nations Elders, through a 7E model (environment, engage, explore, Elder, explain, elaborate, evaluate) for planning and teaching science to enact learning experiences that are grounded in place-based and experiential learning contexts. The intent of the 7E model is to provide learning experiences that have a positive impact on mastery of subject matter, scientific reasoning, and interest and attitudes toward science within the context of students' lived experiences (FNESC, 2016).

Augmenting FNPP's efforts is an ongoing science education project funded by the Social Sciences and Humanities Research Council of Canada. The research was motivated by recent SGA developments and was initiated at the invitation of a Yukon First Nation education director familiar with similar work in Indigenous communities in Nunavut and Australia (Lewthwaite & McMillan, 2007; Lewthwaite et al., 2015; Lewthwaite & Renaud, 2009). The research is internationally unique in that it is grounded in effective practice as identified by First Nations students and their families and teachers. The research adds to longstanding understanding of quality teaching practice (Hattie, 2009; Tobin & Fraser, 1990) by considering the construct of quality teaching from an Indigenous perspective. Importantly, it uses quantitative measures to determine the effect of enacted practice on student learning. Although this research is ongoing, indicators are that teachers' practices, when aligned with local perspectives, can contribute to equitable learning outcomes for Yukon First Nations students (Lewthwaite, Owen, Doiron, Renaud, & McMillan, 2014). A website has been developed to support administrators, teachers, and local First Nations in systematically profiling, evaluating, and modifying current teaching practices (see www.pedagogyofconsequence.com).

Outside of these collective, community-based initiatives, teachers and administrators may apply directly to the YTA for funding support to attend local or out-of-territory Pro-D, for tuition, and for release time, or to host school-based workshops (YTA, 2016).

12.2.6 Issues and Challenges in Yukon Science Education

The Yukon is experiencing several issues and challenges, most of which have been perpetuating concerns over many years, and several were illustrated in the release of *Together Today*. As indicated earlier, the current strategic goals of Yukon Education focus on these challenges, with attention to effectively managing resources in urban and rural schools and improving achievement and outcomes for Yukon First Nations students (Schmidt, 2014).

12.2.6.1 Rural Versus Urban Education

As noted by Schmidt (2014), "data has consistently tracked a gap between rural and urban outcomes" (p. 13). Although the SGAs have resulted in some curriculum change in rural communities, these communities are challenged in terms of infrastructure and capacity with the result that rural students may have access to fewer educational options than urban students (YDE, 2016a). In response to Yukon Education's identification of rural students' limited opportunities, the Rural Equity Action Plan (REAP; YDE, 2016b) has been put in place. REAP supports alternative programming, local apprenticeships, and experiential opportunities for rural secondary school students. For example, the Rural Experiential Model (REM) provides students outside of Whitehorse with opportunities to learn alongside peers from other communities while working with rural teachers, Elders, and local experts. Hands-on REM programs range in length from 2 days to 1 week and integrate Indigenous and formal teaching. Although Grades 10–12 students can earn Fine Arts and Applied Skills credits, some REM activities are science related (e.g., robotics and *mini-med* school).

As a second example, in order to provide a range of senior secondary science options for smaller rural schools, Yukon Education (Government of Yukon, 2015) has introduced blended learning, which offers students more course options and lets them work at their own pace alongside students enrolled in the same subject from other communities. Blended learning models in Watson Lake, Haines Junction, Carmacks, and Dawson City have shown positive results in student achievement, especially in Grade 10 examination results (YDE, 2016a).

12.2.6.2 Achievement Gaps Between Indigenous and Non-Indigenous Students

Schmidt (2014) drew attention to the perpetuating achievement gaps between First Nations and non-First Nations students, especially graduation rates, inferring that this is partly due to "the result of social and economic challenges that exist in many rural communities across the North" (p. 13). In 2008, the Yukon First Nation Education Advisory Committee (YFNEAC) proposed several goals and priorities for education in the Yukon, many of which resonated with the calls to action from *Together Today*. The committee's vision emanated from inequitable education outcomes for First Nations students and led to a call "for the education of First Nation students in the public school system … [that supports] First Nation student success in academics, culture, and language, so that they graduate from high school well prepared for participation in life and life-long learning, no matter where they live and work." (YFNEAC, 2008, p. 8). The committee identified a need for improved partnerships between First Nations and school teaching personnel that could be arrived at through the weaving together of culture and curriculum. Specifically,

> education must also recognize and include the many contributors to a Yukon First Nation child's education, such as family, community, teachers, administrators, First Nation government and culture. They all contribute to the child's intellectual, physical, social, emotional, mental and spiritual development. (YFNEAC, 2008, p. 18)

Alongside the work done by FNPP in association with the Yukon First Nations to address this disparity, a significant development for supporting such partnerships has been the establishment of Community Education Liaison Coordinators (CELCs), who work in most schools throughout the Yukon. CELCs are typically First Nations community members who provide specific services:

- Support First Nations students
- Provide counseling or referrals for First Nations students and/or parents
- Assist with planning and securing resource people within the community for lesson and unit plans
- Provide guidance pertaining to First Nations curriculum content
- Plan and provide workshops and training related to cultural relevancy
- Act as a liaison between the school and the community (Schmidt, 2014, p. 21)

In response to the committee's priorities pertaining to locally-based curriculum development, a project undertaken by the University of Manitoba's Centre for Research, Youth, Science Teaching and Learning funded by the Natural Sciences and Engineering Research Council of Canada resulted in the development of science teaching resources that integrated Yukon First Nations perspectives. Researchers worked with northern Yukon schools and First Nations Elders, primarily through the mediating support of CELCs, to develop resources that had a community-based perspective on science teaching. These resources integrated First Nations content, perspectives, values, knowledge, and ways of teaching and learning into curricula. The resources supported teachers in providing learning experiences that were grounded in Yukon First Nations heritage. Discussions with community members identified a variety of principles for effective curriculum development and enactment at the school and classroom level (Lewthwaite et al., 2014). These principles included:

- Affirming cultural competencies honoured by the local community and providing two-way learning experiences by integrating traditional knowledge, beliefs, and values with contemporary scientific knowledge, processes, and attitudes
- Using traditional and contemporary cultural examples as contexts for student learning
- Including the local community in students' learning, especially in the use of narratives
- Fostering First Nations language development where possible

Several two-way science units were developed by participating school teachers in collaboration with community members, including a Grade 7 Ecology unit that considers a variety of ecological concepts, such as stewardship and guardianship, through a First Nations perspective (Tr'ondëk Hwëch'in, 2014).

12.3 Concluding Remarks

It is evident within the Yukon that there have been and will continue to be tensions around the science education experience provided for its citizens, as it tries to address the "underlying challenge in defining what it means to have an education system that promotes both traditional and modern objectives" (Schmidt, 2014, p. 18). The legacy of the residential school system marginalized possibilities for science education experiences responsive to its First Peoples. Despite this overt mechanism of eliminating any attention to place- or land-based or experiential learning, a progressive science curriculum over the past 30 years—through primarily the Wood Street Centre and, now, the co-developments between FNPP and school programming through curriculum resource development and land- and culture-based programs—signals a time of change. The introduction of the new BC curriculum with its emphasis on competencies and the advent of SGAs indicate there is a foundation for accelerating, and legitimizing, potential change. We close with the words of a Yukon Elder who questions the past and sees the possibility of a decolonizing vision dominating developments in science education in the Yukon:

In our culture there is nothing more important than the learning that makes a person wise. The main thing the southern culture wants from school is 'head knowledge.' That is what it has always emphasized. I do not know why. It intrigues me. I think about what school would look like if we had worked together from the beginning to make the learning better for our younger ones. I look to the future in believing it will be more on our terms where both worlds can be combined. It will be not just about knowledge, but how to behave and be wise, not just knowing. This is what is happening now, but we have a long way to go. (Tr'ondëk Hwëch'in, 2014, p. 11)

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Chapter 13
Science Education in the Northwest Territories: Aspiring to Culture-Based Curricula as a Foundation for Education

Dawn Wiseman and Steven Daniel

Abstract The current education system in the Northwest Territories emerges from a long history of tensions related to the processes of settlement and colonialism. Science education has been caught up in these tension-filled processes. Since the late 1960s, as power devolved from the federal government in Ottawa to the territorial government, the education system has shifted to more accurately reflect the peoples, languages, and land of northern Canada. This shift has included a focus on the development of northern teachers and northern curricula across all subject areas including science.

13.1 Introduction

> The educational process in the Northwest Territories should reflect the unique nature of this people's past … their traditions, history and values. (Northwest Territories Legislative Assembly, as cited in Hilyer, 1997, p. 316)

The history of education in the Northwest Territories (NWT) has revolved around tensions between *settler* and *Indigenous* (i.e., First Nations, Inuit, and Métis) priorities for the land and all of its learners, particularly young people, ever since initial contact. The matter of named people and peoples in the Canadian context is complex. As suggested by Vowel (2016), settler is used as a relational rather than a racial construct and refers to people who reap benefits from settler colonialism: "the

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C. D. Tippett, T. M. Milford (eds.), *Science Education in Canada*,
https://doi.org/10.1007/978-3-030-06191-3_13

deliberate physical occupation of land as a method of asserting ownership over land and resources" (p. 16). Given the link between the presence of non-Indigenous people in the NWT and resource extraction/exploitation, the term is particularly appropriate in the context of this chapter. Questions of self-determination and independence of communities having the power to decide what kind of education is best for their children have been prominent (King, 1998; McGregor, 2010). As the influence of Indigenous peoples has been reasserted and as settlers in the NWT have begun to think of themselves as northerners, significant shifts have occurred in the focus of education in general and in science education more specifically.

The NWT are attempting to implement an approach to K–12 science education that considers what scientists actually do and understand, what community knowledge holders (i.e., people with expertise in traditional and community practices such as hunting, trapping, fishing, ceremonies, medicines, etc.) and Elders actually do and understand, and how best to bring these people together with students and teachers to create understanding. Therefore, young people should work together with scientists and Elders to learn deeply about the land, culture, language, themselves, and science and—as a by-product of such learning—should meet the requirements of the K–12 science curricula.

13.2 Territorial Context and Background

To understand the current context of science education in the NWT, it is necessary to have some sense of the place, the people who live there, and its history. There is an intertwining of education, history, economics, resources, people, and tensions or relationships amongst them that makes it difficult to separate one from the other. These complexities, relationships, and tensions both constrain and inform the nature of science teaching and learning.

13.2.1 Place and Peoples

The NWT was founded in 1870 when the newly established Canadian government amalgamated land purchased from the Hudson's Bay Company, which included most of the current territory in addition to parts of what are now northern Québec and Ontario, Manitoba, Saskatchewan, Alberta, the Yukon, and Nunavut (Library & Archives Canada, 2005). Today's NWT lies directly north of Alberta and Saskatchewan, above the 60th parallel between the Yukon and Nunavut, and include a number of islands in the Arctic Archipelago (Fig. 13.1). Now considerably smaller than at its founding (the eastern part of the original territories was separated off as Nunavut in 1999), the NWT still cover over 1.3 million square kilometres (Fraser, 2010), making it the second largest political unit in Canada in terms of land base.

Fig. 13.1 Map of the Northwest Territories

While the northern part of the NWT is largely tundra and permafrost with a cold, polar climate, large parts lie south of the tree line and consist of boreal forest, where summers are brief but hot (Government of the NWT, 2017a). Significant features include the Mackenzie Mountains, an extension of the Rocky Mountains along the Yukon border; the Great Bear and Great Slave Lakes; and the Mackenzie River, Canada's longest river (Government of the NWT, 2017a; Wonders, Anderson, & James-Abra, 2011/2017). In some areas, the ground is muskeg and peat; in others, it is Canadian Shield granite. The variation of land and climate plays a significant role in locally-developed and locally-delivered science curricula.

Nearly half of the NWT's 44,000 people live in the capital city of Yellowknife (Fig. 13.1). The other 32 communities have populations ranging from under 100 in Jean Marie River and Nahanni Butte to nearly 4,000 in Hay River (NWT Bureau of Statistics, 2016); most communities have populations around 1,000 people (Fraser, 2010). Many communities are remote and physically isolated; although year-round access by air is possible, water and road access is less consistent. As climate change affects the length of seasons, both ice and water as a means of transport are less consistent (National Oceanic & Atmospheric Administration, n.d.; Northwest Territories Department of Education, Culture, & Employment [NTDE], 2009). Such remoteness and isolation offer both unique opportunities and challenges for education. With respect to science education, securing Grades 11 and 12 specialist teachers to work in remote communities is an issue.

13.2.2 Language, Culture, and Schools

Language and culture play a significant role in science teaching and learning. The NWT's political boundaries are mapped onto the traditional territories of a number of Indigenous peoples—including the Dene, the Inuvialuit, and the Métis—and about half of the territory's population is Indigenous (Government of the NWT, 2017b). In the NWT, language is a key consideration across all endeavours, particularly those connected to learning because language and understanding are emergent from the land. Watts (2013) underlined the connection between language and land as "based upon the premise that land is alive and thinking and that humans and non-humans derive agency through the extensions of these thoughts" (p. 21). Therefore, if a language disappears, so does the knowledge that lives in that language (Wiseman, 2016).

Given this understanding, the NWT emphasizes language retention and revitalization. Official territorial functions occur in 11 official languages (NTDE, 2015): five Dene (Chipewyan, Gwich'in, North Slavey, South Slavey, and Tłı̨chǫ), three Inuit (Inuvialuktun, Inuktitut, and Inuinnaqtun), one Algonquian (Cree), and two European (English and French). Nearly 17% of the population speaks an Indigenous language—a high overall percentage given the decimation of local languages. There are significant variations between communities in the percentage of people who can speak Indigenous languages, with a low of 4% in Yellowknife to well over 70% in places like Trout River, Gamètì, and Wekweètì (NWT Bureau of Statistics, 2016). In schools, there is "a moral, ethical, and cultural responsibility to ensure that Indigenous languages are being used" (NTDE, 2004b, p. 2) and a commitment to "culture-based education programs as a foundation for education in the Northwest Territories" (p. 7). The implementation of language and culturally based curricula is ongoing, given challenges around access to teachers who speak local Indigenous languages and small school size.

For the 2015–2016 school year, there were 8,367 preK through Grade 12 students registered in 49 schools located in 32 of the territory's 33 communities (NWT Bureau of Statistics, 2016). Schools are administered by eight local education councils that work in partnership with the NTDE in terms of curriculum and professional development and individually hire their own principals, teachers, and consultants (NTDE, 2016a).

13.2.3 Economy and Policy

Extraction industries (e.g., mining, oil, and gas) along with service fields (e.g., public administration, health care, and education) are the largest employers in the NWT (NWT Bureau of Statistics, 2016). Given this reality, science education with the potential to lead to further academic and technical studies is very much a need within the resource-dependent economy of the NWT. As such, the territory has articulated a science policy (NTDE, 2009) that stresses the importance of science to its future and aims to establish a more diverse economy through the priorities of "cultural sustainability, environmental science and stewardship, health and wellness, natural resource management, and sustainable communities" (p. 5). Within this process, K–12 science education is viewed as key to developing a well-informed, scientifically literate citizenry, as well as a cadre of northern scientists with the ability to bring Indigenous understandings of language, health, place, and land together with Western understandings upon which these industries tend to be based.

13.3 History of Education in the NWT

For thousands of years, education in what is currently called the NWT occurred over a lifetime, was located in language, culture, land, and community, and led to the development of competent adults who survived and thrived in what can be a challenging environment. Since contact between Indigenous peoples and settlers, it has been difficult to make similar claims (MacPherson, 1991; McGregor, 2010).

Under the Crown, and subsequently under various levels of Canadian government and its agents, education in the NWT has often been a deliberate process of disrupting and disassembling Indigenous approaches to teaching and learning in favour of Western ones (NTDE, Nunavut Department of Education, & Legacy of Hope Foundation [NNL], 2013). It has also been a process that, at times, received less attention than territorial resource development and extraction. The history of education since contact can be read as a series of tensions between central and local control, northern and southern Canada, eastern and western Arctic, European and Indigenous people and their languages, and economy versus pedagogy as drivers for education. It can also be read as a slow, ongoing journey back to the land for the peoples who reside in the territory and know it best.

As in other parts of Canada, church-run schools dominated the early history of Western education in the NWT (MacPherson, 1991) with the goal of "civiliz[ing] and Christianiz[ing]" Indigenous peoples (NNL, 2013, p. 15). The first formal school, established in 1860, was a missionary school of the Anglican Church in Fort Simpson (MacPherson, 1991). While this institution was not a residential school, residential schooling played a significant role in the territory (Truth & Reconciliation Commission of Canada [TRC], 2015). More than 50% of Indigenous people in the NWT over the age of 55 attended a residential school (NNL, 2013). Although the NWT residential school process began later and was less uniformly applied than in other parts of Canada, it also ended later and left behind a significant legacy of trauma that is still being addressed (McGregor, 2010; NTDE, 2011, 2013a; NNL, 2013; TRC, 2015).

A shift away from religious schools began in the 1940s. In 1953, the federal government took direct control of NWT education and assigned it to the Department of Northern Affairs and Natural Resources (DNANR) as a means of improving both the territorial economy and schooling (MacPherson, 1991). This period marked the beginning of significant school construction, the development of curricula specific to northern schools, and the establishment of the Northwest Territories' Teachers Association (NWTTA; MacPherson, 1991). It also underlined the challenges of "organizing and operating an education system for a largely non-English speaking school population that was scattered in small groups across a vast and hostile landscape" (MacPherson, 1991, p. 17) far removed from administrators and curriculum developers. In addition, significant levels of teacher burnout and turnover resulting from the staffing of schools with educators new to the territory led to poor educational outcomes for Indigenous students (King, 1998; MacPherson, 1991; McGregor, 2010). This situation, combined with a growing Indigenous political voice, led to introspection regarding NWT education (King, 1998; MacPherson, 1991; McGregor, 2010).

In 1966, the *Carrothers Report* (Carrothers, 1966) suggested that the responsibility for education devolve from Ottawa to the NWT through the creation of a territorial Department of Education located in Yellowknife (King, 1998; MacPherson, 1991). Though territorial control of education increased significantly when the department was established in 1969, during the 1970s Dene and Inuit peoples continued to advocate for "education as a rights claim" (King, 1998, p. 24), eventually further decentralizing educational control to communities in order to ensure their "right to pass on to [their children] their values, their languages, their knowledge and their history" (Berger, as cited in King, 1998, p. 93). This push eventually led to the establishment of the eight educational authorities currently in place. More contemporary agreements on local governance—such as the *Tłı̨chǫ Agreement* (Indigenous & Northern Affairs Canada, 2003)—enshrine local control of education.

The current educational context continues to be hampered by issues identified throughout the territory's history: values' conflicts with respect to the relative merits of Indigenous versus Western ways of knowing, being, and doing; questions about the language of instruction; insufficient resources for language and cultural programs; achievement gaps between Indigenous and settler students; and teachers with little or no cross-cultural education (Fraser, 2010; King, 1998; MacPherson, 1991; McGregor, 2010). At the same time, the schools have come a long way since 1860; and the NWT is attempting to reconcile the trauma caused by the imposition of foreign ideas about education to allow something new and local to emerge.

Nowhere in this history do conversations about science education—or any subject area, apart from perhaps language—play a role; issues of control, governance, and local priorities were more pressing. However, as these issues have been addressed, attention has turned to specific programs of study, including science.

13.4 Science Education

For a good part of the 20th century, the NWT curricula were defined by programs of study developed in other Canadian jurisdictions—most notably Alberta. There is a continued heavy reliance on Alberta programs of study across most subject areas, particularly at the high school level. Since the 1990s, however, the NWT has been developing its own curricula in order to more accurately reflect the experience of living and learning in northern Canada.

The first locally-developed documents—for Grades 1–9 *Dene Kede: Education from a Dene Perspective* (NTDE, 1993, 2002, 2003, 2004a) and for K–12 *Inuuqatigiit: The Curriculum from the Inuit Perspective* (NTDE, 1996)—were not specific to science but were intended to support teachers in integrating Dene and/or Inuit teachings into all programs of study. While *Dene Kede* is more frequently used in Dene communities of the western Arctic and *Inuuqatigiit* in Inuit communities of the northern Arctic, NTDE encourages the broad use of these documents throughout the NWT because "Aboriginal languages and culture-based education [are] recognized as an integral and essential part of the education experience for all NWT Aboriginal students" (NTDE, 2013b, p. 19). More broadly, and in current educational policy documents, NTDE uses the term *northern* when describing young people in its K–12 schools. Thus, educational documents explicitly address the territory's educational context as defined by the land, climate, communities, and the coexistence of Indigenous and Western ways of knowing, being, and doing in the north.

The NWT now implements its own K–6 science program (NTDE, 2004c) but continues to use Alberta science programs for Grades 7–12 (see Chap. 3, Alberta, this volume). The territory has developed Experiential Science courses (NTDE, 2006a) for Grades 10–12 as an alternate path to the otherwise largely Alberta-based curriculum in these grades. Both the K–6 and Experiential Science curricula are aligned with the *Dene Kede* and *Inuuqatigiit* documents; both include outcomes emphasizing Indigenous ways of knowing, being, and doing. In the K–6 science curriculum document, the front matter is explicit about the importance of involving family and using local Indigenous languages in the teaching and learning of science (NTDE, 2004c). In the Experiential Science courses, community Elders, knowledge holders, and scientists are all positioned as "subject matter experts" (NTDE, 2006a, p. 2); field experiences are encouraged and are characterized as "opportunities for community Elders to interact directly with the students to share knowledge, skills, attitude, experiences and insight" (p. 2). Furthermore, even in Grades 7–12 courses where the NWT follow the Alberta curriculum, teachers are encouraged to access *Dene Kede* and *Inuuqatigiit* to make similar connections.

13.4.1 Kindergarten Through Grade 6: Elementary

Elementary science encompasses Kindergarten through Grade 6, is outcomes-based, and was created in close consultation with community Elders. The four over-arching goals for the program are for students to:

- Understand the basic concepts of science and technology
- Develop the skills, strategies, and habits of mind required for scientific inquiry and technological design through experiential and discovery learning
- Relate scientific and technological knowledge to each other and to the world outside the school
- Appreciate the contributions and accomplishments of all people in the advancement of science and technology (NTDE, 2004c, p. 6)

Students are expected to engage in 45 hours of science in Kindergarten and 90 hours in subsequent elementary grades each year (NTDE, 2004c, p. 13).

The curriculum is structured around five strands with different topics at each grade level (Table 13.1). Each topic is organized around a big idea that is associated with General and Specific Learning Outcomes. Specific Learning Outcomes are categorized as *Understanding Basic Concepts*; *Developing Skills of Inquiry, Design,*

Table 13.1 Elementary school science topics by strand and grade level

Grade	Life systems	Matter and materials	Energy and control	Structures and mechanisms	Earth and space systems
K	Senses and the body	Creating colours	Keeping warm	Machines around us	Dinosaurs
1	Characteristics and needs of living things	Characteristics of objects and properties of materials	Energy in our lives	Everyday structures	Daily and seasonal cycles
2	Growth and changes in animals	Properties of liquids and solids	Energy from wind and moving water	Movement	Air and water in the environment
3	Growth and changes in plants	Magnetic and charged materials	Forces and movement	Stability	Soils in the environment
4	Habitats and communities	Materials that transmit, reflect, or absorb light or sound	Light and sound energy	Pulleys and gears	Rocks, minerals, and erosion
5	Human organ systems	Properties of and changes in matter	Conservation of energy	Forces acting on structures and mechanisms	Weather
6	Diversity of living things	Properties of air and characteristics of flight	Electricity	Motion	Space

Note. Adapted from NTDE (2004c)

and Communication; and *Relating Science and Technology to the World Outside the School*. For example, the Grade 1 topic Characteristics and Needs of Living Things has the big idea "Each species has unique characteristics and all have the basic needs of water, 'air' and energy for survival" (NTDE, 2004c, p. 22). The three General Learning Outcomes are:

- Demonstrate an understanding of the basic needs of animals and plants (e.g., the need for food/energy, air, and water)
- Investigate the characteristics and needs of animals and plants
- Demonstrate awareness that animals and plants depend on their environment to meet their basic needs, and describe the requirements of good health for humans (NTDE, 2004c, p. 22)

A Specific Learning Outcome in *Developing Skills of Inquiry, Design, and Communication* is "Describe patterns that they have observed in living things (plants have seeds, animals move from place to place, northern land mammals have fur/hair and many migrate)" (NTDE, 2004c, p. 23).

13.4.2 Grades 7–9

For Grades 7–9, the NWT implement Alberta programs of study. As noted, teachers are encouraged to consider these programs in relation to *Dene Kede* and *Inuuqatigiit* in order to ground student learning in place. Information on these programs can be found in the Alberta chapter (this volume).

13.4.3 Grades 10–12: Experiential Science

There are multiple paths through Grades 10–12 science. Students may follow what is considered a traditional academic path based on programs of study developed by Alberta. These programs are outlined in detail in the Alberta chapter (this volume). As in Grades 7–9, teachers are encouraged to consider them in relation to *Dene Kede* and *Inuuqatigiit.*

Development of the Experiential Science curricula (NTDE, 2006a) involved broad consultation with teachers and Elders across the NWT. The program's philosophy is that "land is a place of learning" (NTDE, 2004b, p. 8). The context of each course is a different ecosystem: terrestrial in Grade 10, marine in Grade 11, and freshwater in Grade 12 (Table 13.2). Each course includes 125 hours of instruction and explores the focus of ecosystems through four different units.

Experiential Science is better aligned with the *Common Framework of Science Learning Outcomes, K to 12* (Council of Ministers of Education, Canada, 1997) than the NWT elementary science program. It explicitly includes outcomes related to science, technology, society, and the environment along with outcomes related to

Table 13.2 Experiential science units by grade

Grade	10	11	12
Ecosystem	Terrestrial	Marine	Freshwater
Units	Geology and geomorphology Climatology and meteorology Ecology of the land Resource management and population dynamics	Introduction to oceanography Ocean ecology Habitats, population dynamics, and management Petrology and ocean environment	Structural geology Introduction to limnology Freshwater ecology Freshwater resource management

Note. Adapted from NTDE (2006a)

knowledge, skills, and attitudes—thereby addressing all four pillars of the *Common Framework*. These courses emphasize the nature of science and technology, relationships between science and technology, and social and environmental contexts of science and technology. Each unit is associated with one area; for example, the Grade 10 unit Geology and Geomorphology focuses on the nature of science and technology (NTDE, 2006a, p. 16).

Experiential Science is significantly more explicit than the elementary program about how Indigenous and Western ways of knowing, being, and doing might circulate together in science teaching and learning. For instance, Grade 11 students when examining Habitats, Population Dynamics, and Management are expected to develop understandings of three different marine habitats: the open ocean and "two habitats of local interest" (NTDE, 2006a, p. 46) from among six choices: coastal areas, estuaries, fjords, polynyas, salt marshes and lagoons, and tidal flats. These habitat choices attend to the vastness and diversity of land in the territory and allow students to learn from and about the local places with which they have living relationships. Students are expected to speak with Elders and other local knowledge holders to develop understandings about:

- Species present in the habitat
- Population trends
- The relationships among Indigenous peoples, the habitat, and species
- Changes in habitat over time
- The impacts of change in climate and species diversity on Indigenous ways of living

By combining conversations and explorations with Elders and local knowledge holders within thinking regarding concerns (e.g., petrochemical extraction in fragile ecosystems), Experiential Science links the past with the present and the consideration for the NWT's future.

The *experience* in Experiential Science is thus deeply located. While based on the importance of engaging in and reflecting on the world as a means of developing understanding, it is also connected to land and local understandings (NTDE, 2006a). An example of how these explorations are taken up is a recent collaboration between

Grade 12 students, the NWT Department of Environment and Natural Resources (NTDNR), and universities conducting research in the NWT. The students know the sites under study far better than the scientists do because they live with them year-round. As part of their course work, students gather samples following the scientists' protocols. Scientists receive and analyze the samples, returning results to the communities involved that are available to all members. Another example includes students focusing on ornithological studies with scientists and Elders, where the scientists have short-term knowledge of specific birds and habitats and the Elders have much longer-term experiences of relationships and interactions between birds and habitats in place. The understandings students develop in such engagements appear so valuable that the NTDE is in negotiations with one Canadian university to provide dual credit (high school and university) for the completion of the NWT-based university field course. The experience of working alongside scientists and Elders may impact students' ability to see themselves as scientists (Painter, Jones, Tretter, & Kubasko, 2006).

13.4.4 Grades 10–12: Electives

While there are no official, widely available science electives for students, NTDE will work with community schools, knowledge holders, and teachers to accredit locally-developed courses. Such courses must be grounded in project-based inquiry approaches to teaching and learning (NTDE, 2013b, sec. 6). For example, the Beaufort–Delta School Division has developed courses on dog mushing and animal husbandry. While effective in helping students connect their lives and communities to science, these local courses are not offered with the same frequency throughout the territory.

Another example of a local science elective is the Tundra Science and Culture Camp (TSCC) that has been offered by the NTDNR since 1985. Up to 16 students spend 10 days with scientists, Elders, and environmental/science educators at the Tundra Ecosystem Research Station in Daring Lake. Participants work together to "learn about field research methods in wildlife biology, geology, archaeology, aquatic ecology, traditional knowledge, and the Tlicho [sic] language" (NTDNR, 2016, para. 3). Students must apply to attend TSCC; preference is given to those who have completed their Grade 10 science requirements (NTDE, 2013b).

13.4.5 Graduation Requirements

With its emphasis on rich science learning experiences, local experts, and the importance of place, NTDE offers flexibility for high school students to meet science requirements for graduation. High school graduation requirements include at least one Grade 10 and one Grade 11 science course (NTDE, 2013b). Students planning to pursue postsecondary studies in the sciences must take multiple science courses at the Grades 11 and 12 levels. Because access to these courses can be challenging in remote and rural communities, there is flexibility in science requirements for graduation.

13.4.6 Assessment

In the NWT, assessment of academic outcomes for K–12 students occurs at the classroom and territorial level. At the classroom level, student progress is assessed, evaluated, and reported in relation to curricular outcomes (NTDE, n.d.). At the territorial level, students in selected Grade 12 science courses (currently, Biology, Chemistry, and Physics) write Alberta diploma examinations. These examinations constitute 30% of a student's grade (NTDE, n.d.). In terms of international assessment, no data were collected from NWT students for the 2015 PISA study (O'Grady, Deussing, Scerbina, Fung, & Muhe, 2016).

13.4.7 Resources

Teachers following the Alberta science curriculum in Grades 10–12 can use Alberta-approved resources. There are also locally-developed textbooks for each Experiential Science course (Campbell et al., 2009; Campbell, Freeman, Richardson, & Wunderlich, 2012; Campbell, MacLulich, Wheelock, Williams, & Wunderlich, 2008). Textbook development involved teams of authors with experience living and working in the NWT and Elders from across the territory. Key aspects of the textbooks are Indigenous ways of knowing, being, and doing and northern career connections. Additionally, local people are highlighted as experts and role models within these textbooks.

13.5 Teacher Education

In 1956, NWT teachers became federal employees and required "at least senior matriculation standing, one year of teaching training, and preferably two years of teaching experience" (MacPherson, 1991, p. 18) for licensing. However, many teachers in the NWT were educated elsewhere with little knowledge or understanding of northern Canada. Over time, as the influence of local Indigenous peoples has been reasserted and as the NWT gained more control over its affairs, it has been working to develop a "northern teaching force representative of the population [as a means to] ensuring the education system is reflective of the language, culture and heritage of the north" (NTDE, 2001, p. 2). As such, programs and policies have been developed to hire northern teachers and to better support all teachers in place with respect to teaching and learning in NWT schools and communities.

The only postsecondary institution physically located in the NWT is Aurora College, which was established in 1995 (Hilyer, 1997). The college has three primary campuses in Fort Smith, Yellowknife, and Inuvik, along with 25 community learning centres (Aurora College, 2016b). Aurora College offers a 3-year teaching diploma program through the community learning centres that qualifies graduates to teach Kindergarten through Grade 9 in NWT schools. Upon successful completion of the diploma, graduates may opt to complete a fourth year offered in Fort Smith leading to a Bachelor of Education (BEd) in partnership with the University of Saskatchewan (Aurora College, 2016c; University of Saskatchewan, n.d.).

Course offerings within Aurora's teacher education program focus on teaching in northern Canada in what is frequently a predominantly Indigenous context. Courses reflect the NTDE mandate of "culture-based education programs as a foundation for education in the NWT" (NTDE, 2004b, p. 7). During the program, students attend three culture camps and take courses that address Indigenous peoples' ways of knowing, being, and doing (Aurora College, 2016c). There is one 45-hour science methods course taken by students who opt for the BEd (Aurora College, 2016a). This course addresses both science pedagogy and content through inquiry and problem solving along with related content, curricular outcomes, and assessment practices, and a heavy emphasis on Indigenous perspectives. There is no program for secondary teachers—science or otherwise—in the NWT. All of the territory's secondary teachers have degrees from other jurisdictions, most from universities in the Canadian south. Qualification from postsecondary institutions outside the NWT will soon be the norm for K–9 teachers as well; in early 2017, the territorial government's budget indicated that Aurora's teacher education program would be phased out over a 3-year period (Gleeson, 2017).

13.5.1 Certification

Certification of NWT teachers is regulated by the NTDE through the NWT Teacher Qualification Service and undertaken by a four-person team consisting of two members from NTDE and two from NWTTA (NTDE, 2016b; NWTTA, n.d.-a). There are three categories of certification: Standard, Professional, and Specialty. If and how certification may change in the absence of a local teacher education program is not yet clear.

Standard teaching certificates are issued to teachers who have completed teaching diplomas from 2- or 3-year teacher education programs (NTDE, 2013b). The standard certificate recognizes that "a Bachelor's Degree is not required" (NTDE, 2001, p. 2) to teach up to Grade 10 in the NWT. Given the current priority for hiring northern teachers, school councils are precluded from requiring a BEd in K–9 job postings (NTDE, 2001). Professional teaching certificates are issued to teachers holding a BEd from a direct, concurrent, or consecutive program. All applicants for the professional teaching certificate must have completed a minimum of 12 weeks of student teaching and be eligible for certification in the jurisdiction where the degree was granted (NTDE, 2013b, 2016b). Aurora College's BEd, like other Canadian education degrees, qualifies graduates for positions in all provinces and territories (NTDE, 2001). Specialty teaching certificates are issued to vocational and Indigenous language teachers as well as to Kindergarten specialists who have completed an early childhood education program (NTDE, 2013b).

All certificates are "initially issued as **interim** for a period of three years" (NTDE, 2013b, sec. 10, p. 1, emphasis in original). Teachers apply for recertification; after the first renewal, certification is valid for up to a 5-year period (Dent, 2004). Teachers are recertified based on completion of ongoing professional development (Pro-D) related to their specialist areas, roles within schools, and/or engagement with Indigenous perspectives and languages in teaching (NWTTA, 2012). Decisions on the specifics of annual Pro-D for individual teachers are based on "the teacher, school and regional needs and should have a collective as well as individual focus" (NWTTA, 2012, para. 1). In each 5-year period, a teacher must complete 120 hours of Pro-D, with a minimum of 15 hours in each year (NWTTA, n.d.-b). Pro-D activities are logged by the teacher and then approved by both the school principal and local superintendent.

13.5.2 Teacher Induction

There is a significant focus on teacher induction in the NWT (Kutsyuruba, Godden, & Tregunna, 2014). Until recently, induction was run by NTDE and for science teachers was focused, in part, on time in the land exploring the territorial programs of study alongside Elders and other local knowledge holders (Wiseman, 2016). As the responsibility for teacher induction has devolved to education councils, there is more local specificity to the process; each teacher is matched with a more experienced teacher from the school, community, or region who can facilitate the transition to northern living and teaching (NTDE, 2013b). More recently, NTDE has committed to enhancing teacher induction by organizing and providing an intensive "New to the NWT" Educators' Conference every August. This 3-day event initiates the process of becoming professionally and personally connected to NWT culture and way of life. For these new teachers, it provides a venue to build relationships and understandings while learning together in a cultural context. An emphasis is placed on ensuring newly hired teachers understand the importance of the land, relationships, language, and community in all aspects of NWT education.

13.5.3 Professional Development

Teachers may access Pro-D through their school or education council, through the NWTTA or NTDE, as well as through various territorial, national, and international opportunities (NWTTA, 2012). Regional education councils have a number of Pro-D days each year, including a DECE-mandated, minimum 2-day cultural orientation session at the beginning of each academic year (Erasmus, 2010). These orientation sessions are intended to "help teachers understand the unique culture, history, traditions and values of the First Nations, Métis and Inuit people in the Northwest Territories … and in particular of the people in the region" (Erasmus, 2010, p. 2) where they teach. Such sessions are essential as they provide means for teachers to connect to the land and for teachers to understand how spending time learning in the land offers opportunities for addressing science outcomes (Lunney-Borden & Wiseman, 2016; Wiseman, 2016).

More broadly, there is a territorial-level Pro-D conference run by the NWTTA every 3 years. It provides a wide range of sessions, including some that are subject specific, depending on members' self-identified needs (Mallon, 2017). In addition, teachers may attend the TSCC (NTDNR, 2016) as Pro-D and may take other opportunities offered by government departments, non-governmental organizations, or charitable organizations. For example, at the 2015 NWT Geoscience Forum—an annual event that brings together government and private sector geoscientists working in the territory—Pro-D sessions on earth science were offered by the Ontario-based charitable organization Mining Matters that develops programs and resources aligned with science programs of study in Canadian provinces and territories (Mallon, 2016).

Given the remoteness of many NWT communities, the territory invests significantly in Pro-D. There are opportunities for extended, paid, and unpaid Pro-D leaves so that teachers may pursue courses. For example, teachers with 4 or more years of service can be granted up to a full academic year at approximately 60% of salary, with refund of costs related to tuition, travel, and relocation for full-time study at a recognized postsecondary institution (NWTTA, 2012). Significant levels of support are available for online or summer courses. Pro-D specific to the sciences can be pursued in this way.

13.6 Ongoing Challenges and Opportunities

The complexities involved in the delivery of education in the remote, often isolated communities of the NWT are significant. Some of the complexities specific to the teaching and learning of science have been discussed. There are, however, other tensions, challenges, and opportunities that bear further consideration, including curriculum renewal, the recruitment and retention of science specialist teachers, and the implementation of distance education.

13.6.1 Curriculum Renewal

The NWT is currently in a period of curriculum renewal where it is considering the lessons learned from processes (e.g., the development of Experiential Science). The driving force behind the change is recognition of "the need to do more than simply tweak the existing system … [but instead] think differently about the system as a whole" (NTDE, 2013a, p. 5), which includes seriously considering how the education system can be restructured to reflect northern living and learning experiences. Directions focus on competency-based programs where students learn from multiple people (as in Experiential Science) and breaking down the disciplinary division between subject areas that "impedes students from seeing the connections in the world and in their learning" (NTDE, 2013a, p. 42). While the current science programs of study developed in the territory (NTDE, 2004c, 2006a) predate the renewal process, they have been instrumental in initiating conversations around the changes now being considered more broadly. The goal of such conversations is to produce citizens of the north who, in conjunction with understanding who they are and where they come from in relation to the specificities of their personal cultural heritages and backgrounds, are grounded in and can contribute back to the north.

13.6.2 Recruitment and Retention of Teachers

The territory continues to experience challenges recruiting teachers—particularly senior high school specialists in the areas of chemistry and physics (NTDE, 2006b; Zelniker, 2015). Rates of teacher turnover can exceed 20% annually in smaller and more remote communities (NTDE, 2006b; Zelniker, 2015). The Beaufort–Delta region, which suffers some of the highest teacher turnover rates in the territory (NTDE, 2006b), is the most northern school region, literally, at the top of the world. The types of induction and Pro-D opportunities put in place by the NWT have been identified as key to teacher recruitment and retention in Canadian rural and remote communities (Alberta Learning, 2003; Kitchenham & Chasteauneuf, 2010).

Senior chemistry and physics teachers are in short supply in other areas of Canada (Kitchenham & Chasteauneuf, 2010). In the NWT, however, the recruitment issue may be exacerbated by conditions of northern living, such as housing access and cost of living (CBC, 2013; Schwartzentruber, 2013). The NTDE (2016a) clearly states that while an employer may assist in finding housing for teachers, it "does not provide housing for its teachers" (sec. 8, para. 1, emphasis in original). In a study undertaken by the NWTTA, only about a third of teacher respondents reported personal access to adequate housing (Schwartzentruber, 2013). The NWT government, education authorities/councils, and NWTTA are working together to address the housing issue but acknowledge that solutions will not be easy or short-term (Schwartzentruber, 2013).

A shortfall of high school science specialists can result in limited course offerings in these areas or in teachers teaching multiple subjects (often across grade levels) outside their area of expertise (Kitchenham & Chasteauneuf, 2010), which can impact retention. Another retention factor is the preparedness of non-Indigenous teachers and teachers from outside the territory to deal with the consequences of residential schools and ongoing Canadian colonialism (Kasam, 2015). While this issue may not seem directly related to science teaching and learning, science as a subject area can be associated with the trauma (TRC, 2015; Wiseman & Lunney-Borden, 2018) and is subjected to the issues related to colonialism (Wiseman, 2016). This issue is particularly challenging in the NWT where the historical and ongoing extractive industries have been so closely linked to education (MacPherson, 1991; McGregor, 2010; NTDE, 2011; NNL, 2013; TRC, 2015). For teachers who remain in the NWT, Pro-D and induction support do seem helpful in addressing their professional issues. Teachers who stay beyond 3 years, particularly in more remote and isolated communities, appear to begin to figure out how to bring together Western and Indigenous ways of knowing, being, and doing in science education.

While the NWT works hard to retain teachers, ultimately its strategy for dealing with recruitment and retention focuses on increasing the number of northern teachers in the system (NTDE, 2006b; Kasam, 2015). More specifically, its goal is to develop an education workforce representative of the territorial population where just over half of the teachers are Indigenous. The current 15% of teachers who are Indigenous are seen as a starting foundation from which to prepare NWT young people for the future as articulated by its peoples (NTDE, 2006b).

13.6.3 Distance Education

There is a substantial commitment to distance education in the NWT; the lack of specialist teachers combined with small schools makes it cost-prohibitive to provide specialist teachers in all subject areas to every community. While distance education provides significantly expanded course offerings for students in the sciences, there are implementation difficulties related to geography. Internet delivery typically involves expensive satellite connections. The Earth's curvature adds an additional complexity to satellite connections as it limits coverage and reliability. In a pilot project, the NTDE has purchased dedicated trunk lines so that students might connect both synchronously and asynchronously to a virtual school physically located in Inuvik. This will allow a single student in a remote school who wishes to pursue a specialized science course to do so. Depending on the evaluation results of a pilot project, trunk lines will be rolled out to other regions of the NWT.

13.7 Closing Thoughts

The history of K–12 education in the NWT—and what the teaching and learning of science looks like within that context—has been one of clarifying not just value but values. In choosing to value the ways of knowing, being, and doing of both Indigenous and settler peoples—through programs like Experiential Science, through in-the-land experiences for both teachers and students, through working towards a teaching force representative of the population, and through ensuring access to advanced science courses in remote communities (NTDE, 2013a), the NWT is clearly expressing that science education can both honour and emerge from the land.

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Chapter 14
Science Education in Nunavut: Being Led by *Inuit Qaujimajatuqangit*

Dawn Wiseman and Jim Kreuger

Abstract As the only Canadian educational jurisdiction established within contemporary memory, Nunavut represents an interesting case in terms of education generally and science education specifically. All territorial governance activities are framed by the eight principles of *Inuit Qaujimajatuqangit* (ᐃᓄᐃᑦ ᖃᐅᔨᒪᔭᑐᖃᖏᑦ, *IQ*)—an articulation of Inuit values regarding how to live and be in the world. Within education, *IQ* principles are positioned as key cross-curricular competencies that support teachers and students in negotiating curricula that are, for the most part, developed in other Canadian jurisdictions. In science, territorial curricula are adapted from programs in the Northwest Territories and Alberta. This chapter describes how the current context for science education in Nunavut developed. It highlights the importance of land and language to the teaching and learning of science in Nunavut and examines how science teaching, learning, and curricula are developing in the context of contemporary northern Canada and *IQ*.

14.1 Introduction

Founded on April 1, 1999, when the eastern Arctic split from the Northwest Territories (NWT), Nunavut is Canada's newest territory and educational jurisdiction. While the seeds of its founding were likely planted at the time of contact, their contemporary expression began in the 1960s when growing Inuit political will and voice for self-government and self-determination within a territorial land

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C. D. Tippett, T. M. Milford (eds.), *Science Education in Canada*,
https://doi.org/10.1007/978-3-030-06191-3_14

base began to consolidate (Fenge & Quassa, 2009; Freeman, 2011; King, 1998). Although this consolidation took three decades to manifest, the hopes of the process are embedded within the name of the territory, Nunavut, which translates into English as 'our land'. The land and people's connection to it play a significant role in science education in the territory; it is from and through the land that *Nunavummiut*—"the inhabitants of our land" (Légaré, 2007, p. 117)—understand themselves and the world.

Everything that occurs within Nunavut is grounded in the ethos of *Inuit Qaujimajatuqangit* (ᐃᓄᐃᑦ ᖃᐅᔨᒪᔭᑐᖃᖕᒋᑦ, *IQ*). *IQ* is sometimes translated into English as "what the Inuit know" but more accurately means "The Inuit way of doing things: the past, present and future knowledge, experience, and values of Inuit Society" (*IQ* Task Force as cited in Kreuger, 2011, p. 2). In Nunavut, the term is not referred to in English beyond the acronym, thus underlining "that what is being engaged with cannot be confined by Western theories of knowledge and is culturally- and geographically-situated, steeped in the beliefs, values, place and worldview of Inuit" (McGregor, 2013, p. 98). *IQ* existed long before the territory was founded; however, in the years leading to territorial establishment, Inuit Elders came together to articulate *IQ* as an explicit statement of values to underlie all public policy and programs in the new territory (Arnakak, 2002; Kreuger, 2011; Nunavut Department of Human Resources, 2005; Tester & Irniq, 2008). As Nunavut has developed its own governmental structures and processes, *IQ* tenets have been written into frameworks and documents to support public servants and bureaucrats in the creation and implementation of programs across all government sectors including education (Nunavut Department of Education [NDE], 2007). *IQ* encompasses eight principles:

- Inuuqatigiitsiarniq (ᐃᓅᖃᑎᒌᑦᓯᐊᕐᓂᖅ): respecting others, relationships, and caring for people
- Tunnganarniq (ᑐᙵᓇᕐᓂᖅ): fostering good spirit by being open, welcoming, and inclusive
- Pijitsirniq (ᐱᔾᑦᓯᕐᓂᖅ): serving and providing for family and/or community
- Aajiiqatigiinniq (ᐋᔩᖃᑎᒌᓐᓂᖅ): decision making through discussion and consensus
- Pilimmaksarniq (ᐱᓕᒻᒪᒃᓴᕐᓂᖅ)/Pijariuqsarniq: development of skills through practice, effort, and action
- Piliriqatigiinniq (ᐱᓕᕆᖃᑎᒌᓐᓂᖅ)/Ikajaqtigiinniq: working together for a common cause
- Qanuqturniq (ᖃᓄᖅᑐᕐᓂᖅ): being innovative and resourceful
- Avatittinnik Kamatsiarniq (ᐊᕙᑎᑦᑎᓐᓂᒃ ᑲᒪᑦᓯᐊᕐᓂᖅ): respect and care for the land, animals, and the environment (Government of Nunavut, 2004, pp. 3–4)

These principles have been visibly at play since the territory's earliest incarnations in people's minds. Both together and individually, they provide a fertile landscape from which science teaching and learning might emerge.

Science education in Nunavut has an interesting connection to the manner of the territory's creation. In 1973, the Inuit Tapirisat of Canada, the national body representing Inuit across the country, commissioned the Inuit Land Use and Occupancy

Project (ILUOP) to provide evidence of long-term and extensive Inuit presence in and title to significant portions of the Canadian north (Fenge & Quassa, 2009; Freeman, 2011). Over the 3-year project, more than 1,500 Inuit knowledge holders from over 30 communities provided details regarding current and historical Inuit tenure in terms of hunting, fishing, seasonal camps and communities, burial grounds, and sacred sites (Freeman, 2011). The sites, migration routes, and trap lines identified from these conversations were layered as data over physical maps to evidence ongoing occupancy and use of land for at least 4,000 years and likely much longer (Freeman, 2011). The ILUOP was highly influential in several ways both nationally and internationally (Fenge & Quassa, 2009; Freeman, 2011); in terms of science education, the project underlined the power of *piliriqatigiinniq* (ᐱᓕᕆᖃᑎᒌᓐᓂᖅ) (working together for a common cause). By bringing together Indigenous and Western ways of knowing, being, and doing in terms of mapping evidence, ILUOP is perhaps one of the earliest examples of what parents, Elders, and other community members wish for K–12 education in general and science education in particular: that it be grounded in *IQ* while allowing their children to “walk … in two worlds” (McGregor, 2013, p. 88) and draw upon “both worlds” (Lewthwaite, McMillan, Renaud, Hainnu, & MacDonald, 2010, p. 1). As such, the territorial expression of science teaching and learning is based in *IQ* but also accounts for Western understandings. Because Nunavut is only 20 years old, the manner in which this coming together occurs in schools is still a work in progress.

14.2 Territorial Background

The principles of *IQ* cannot be separated in any way from the land, people, or history of the territory; they both emerge from and inform them. In order to understand the current context of science education, it is necessary to understand more about these intertwined relationships.

14.2.1 Land and Environment

Nunavut’s borders were proposed based on findings of the ILUOP but were subject to two public referenda and significant negotiation before being finalized (Fenge & Quassa, 2009; Légaré, 2007). While Inuit people populate northern Canada from Labrador to the Yukon and the ILUOP provided clear evidence of Inuit claim into northern regions of Saskatchewan, Manitoba, Ontario, and Québec (Légaré, 2007), the final decision on the territory’s borders drew on *aajiqatigiinniq* (ᐋᔩᖃᑎᒌᓐᓂᖅ, decision making through discussion and consensus) and on *inuuqatigiitsiarniq* (ᐃᓅᖃᑎᒌᑦᓯᐊᕐᓂᖅ, respecting others, relationships, and caring for people). It thus maintained existing provincial boundaries and drew the border through the NWT in a manner that closely follows the tree line—the traditional division between Inuit

Fig. 14.1 Map of Nunavut

and Dene territory (Légaré, 2007). Nunavut has two major land borders, one with Manitoba to the south and the other with the NWT to the west; it has a few, very small land borders with Ontario and Labrador on islands in Hudson Bay and Ungava Bay. Greenland lies east of the territory across Baffin Bay. Mainland Québec and Ontario lie to the south across the Hudson Strait and Hudson Bay, respectively. In the far north, Nunavut's islands lie within the Arctic Ocean (Fig. 14.1).

Nunavut is Canada's largest jurisdiction, covering slightly less than 2.1 million square kilometres (Kikkert, 2007). More than half of its land base lies on islands in the Arctic Archipelago, some of which are shared with the NWT. The climate is polar; temperatures vary by region with a range of -50 to +30 °C (Nunavut Tourism, n.d.) depending on the time of year. It is dry and windy with low precipitation year-round. The whole territory lies on the Canadian Shield, which is primarily exposed rock with coarse sandy soil and very small areas of topsoil (Mallory & Aiken, 2012). The combination of climate and rock results in a landscape that is largely tundra, with many often-frozen lakes and rivers; but there are also small areas of taiga (i.e., subarctic forest) and, at higher elevations, ice cap. Being so far north, Nunavut communities experience significant periods of 24-hour light in summer and darkness in winter. As McGregor (2013) underlined, despite being a thoroughly contemporary territory populated by thoroughly contemporary peoples, “the geography and ecology continues to pervade life in the Arctic through a complex matrix of challenges and opportunities in physical, emotional, mental and social realms” (p. 91). The land writ large thus plays a significant role in Nunavut science education (Kreuger, 2011; Wiseman, 2016) through *avatittinnik kamatsiarniq*.

14.2.2 Communities and Language

As of July 1, 2017, the population of Nunavut was 37,996 (Nunavut Bureau of Statistics, 2017). Most recent data available from the 2011 Canadian National Household Survey indicate that 85% of the population self-identified as Inuit (Nunavut Bureau of Statistics, 2013). While the Inuit have been subject to some of the worst manifestations of Canadian colonialism through forced settlement and relocation, the mass killing of sled dogs, and Christian residential/day schools (McGregor, 2013; Nunavut Teacher Induction Program [NTIP], n.d.-b, history of education), they have largely maintained their language and traditions through their majority population.

It is important to note that the processes of colonialism run deep in all Canadian jurisdictions and education systems. Without minimizing the impacts of these processes on any person or peoples, there is insufficient room in this space to adequately address them. Readers are referred to the broad body of work focused on colonialism in the Canadian educational context, for example, Aikenhead (2006), Battiste and Henderson (2000), McGregor (2010), and McKechnie (2015).

The Inuit have been and are actively working to ensure Nunavut is a thriving, contemporary territory by decolonizing education for all children (McGregor, 2013). This process accounts for *tunnganarniq* (ᑐᖖᒐᓇᕐᓂᖅ, fostering good spirit by being open, welcoming, and inclusive) and *pijitsirniq* (ᐱᔨᑦᓯᕐᓂᖅ, serving and providing for family and community); thus, it is driven by the Inuit but includes *Qallunaat* (ᖃᓪᓗᓈᑦ, non-Inuit) residents of Nunavut as well. In fact, the collective name *Nunavummiut* (ᓄᓇᕗᒻᒥᐅᑦ) is an inclusive “civic form of identity” (Légaré, 2007, p. 114) that identifies all people in the territory.

Lewthwaite et al. (2010) noted that “in no [Nunavut] context was there greater resonance of voice for self-determination than in the domain of education” (p. 2). While a large part of the resonance is certainly the wish to replace colonial practices in schools, another reason is the age distribution of the territory’s population. In 2015, over 30% of the population was under the age of 15, and almost 50% was under 30 (Nunavut Bureau of Statistics, 2016a). Nunavut consistently reports the highest birthrate of any Canadian jurisdiction, almost two times the national average

(Statistics Canada, 2016). With so many young people, what happens in the territory's schools is a key concern.

Nunavut's education system is divided into three geographically defined Regional School Operations (RSO) areas—Kitikmeot, Kivalliq, and Qikiqtani (Fig. 14.1)—and one Francophone school board (NTIP, n.d.-a, n.d.-b). These bodies administer 43 schools spread over 25 dispersed and mostly coastal communities. There are no roads between communities; access is primarily by air, although water access is possible during the short, ice-free summer season. Communities are small, ranging from slightly under 200 people in Grise Fiord to just over 7,500 in Iqaluit, the territorial capital (Nunavut Bureau of Statistics, 2016a). The school population is similarly small; enrolment figures for September 2014 reported 9,889 students in Grades K–12 (Nunavut Bureau of Statistics, 2016b). Small school size means that educators can be assigned to teach multiple grade levels and subjects and at high school levels may be assigned courses outside their subject matter speciality. In terms of science, high school streams that lead to university admission tend to be offered in only two or three communities, generally Iqaluit, Rankin Inlet, and sometimes Arviat.

Another important issue is bilingual education. Currently, schools offer education in Inuktitut from Kindergarten through Grade 3 and then switch to English or French instruction (Office of the Languages Commissioner of Nunavut, n.d.). The *Education Act* (Government of Nunavut, 2008) states that Inuktitut education will be available as an option for all learners in all courses K–12 by the 2019–2020 school year. There is some question whether implementation by this date is feasible, given a shortage of Inuktitut-speaking teachers across the school system ("Nunavut's single language", 2015). Alongside the current challenge in offering senior high school science courses in English and French, the likelihood of the territory offering all science courses in Inuktitut in the foreseeable future is low.

The challenge around language in Nunavut science education is complex. It is not solely—or even primarily—about the language of instruction; rather it is about translation and the livingness of language. Livingness is used here as a means of expressing how Indigenous languages are not solely means of communication but are repositories of the histories, values, and understandings of particular nations and deeply rooted in specific geographical locations (Hermes, 2005). Battiste and Henderson (2000) referred to "the illusion of benign translatability" (p. 80)—the assumption that every word and meaning can be translated from one language to another; they underline that this one-to-one correspondence from many Indigenous languages into Western languages (or vice versa) is not possible. In Nunavut, translation is complicated by the multiple dialects of Inuktitut; even when people who speak one dialect might agree on an acceptable translation of a scientific term, people who speak other dialects may dissent. These challenges raise issues about the fundamental ability (or lack thereof) of Nunavut young people to come to understand epistemologically and ontologically. Given the importance of language to understanding within Indigenous contexts (Hermes, 2005; McGregor, 2010; Wiseman, 2016), without access to science education in Inuktitut, the understanding of science within the territory is seen as incomplete. Such access is a question key to the future of the territory and will require *qanuqturniq* (ᐱᓕᕆᖅᑎᑦᓯᓐᓂᖅ, being innovative and resourceful in seeking solutions). If the strength and resiliency of the past are to be honoured, however, it seems that Inuktitut will have to have a growing presence in the territory's schools.

14.2.3 History of Education in Nunavut

Formal schooling in Nunavut has only been in place for about 70 years (NTIP, n.d.-b). The land and environment of the north protected the Inuit from significant *Qallunaat* encroachment until after World War II (McGregor, 2010). In the late 1800s, there were some teaching missionaries who intermittently worked out of Hudson's Bay Company posts and travelled by sled to seasonal camps until World War II (MacPherson, 1991; McGregor, 2010). Inuit youth largely learned from their family and community the skills and understandings necessary to live in a mutually sustaining relationship with the land. Some young people currently in school have family members who remember learning in this manner. Some students have family members who remember the period of enforced federal government residential and day schools that began in the mid-1950s (NTIP, n.d.-b).

Between the end of World War II and 1999, the history of education in Nunavut is that of the NWT (see Chap. 13, NWT, this volume). Even within the larger territory, however, there were always differences between the eastern and western Arctic related to the distribution and concentration of various Indigenous and settler populations. McGregor (2010) noted how, as the NWT moved to local control of education through the 1980s and 1990s, three regional boards of education were created in the eastern Arctic. The first was the Baffin Divisional Board of Education (BDBE) serving what is now Nunavut's capital region. In the late 1980s, BDBE undertook an in-depth, iterative consultative process that was led by bilingual Inuit educators and involved teachers, Elders, and parents in the development of *Piniaqtavut*, a K–9 framework for education. The framework prioritized bilingual education (i.e., Inuktitut with English or French) along with "pride in cultural identity, and responsibility and independence" (McGregor, 2010, p. 124). In terms of content, *Piniaqtavut* was structured around four themes (i.e., sky, land, community, and sea) that recurred around a set of core beliefs: "experiencing Inuit beliefs … [K–3,] learning Inuit beliefs … [Grades 4–6, and] living Inuit beliefs" Grades 7–9 (McGregor, 2010, p. 125). In the framework, science (and other fields) were embedded within the themes where, for example, local plants or animals might be the focus of teaching and learning. While the values of *IQ* can be read into *Piniaqtavut*, they were not explicit within it, and so there were challenges for teachers, particularly *Qallunaat* teachers, in terms of implementation. The framework nonetheless served as an early example for how culture and language might drive teaching and learning. Lessons learned from BDBE's process were foundational in the development of the NWT-wide document, *Inuuqatigiit: The Curriculum from the Inuit Perspective* (Northwest Territories Department of Education, Culture, and Employment [NTDE], 1996), which was more explicit about beliefs and values. *Inuuqatigiit* subsequently informed curricular work in Nunavut.

The more recent history of education in Nunavut is about consensus around big ideas. The first territorial government mandated the Department of Education to rewrite all K–12 curricula and develop a bilingual education system that would support students in pursuit of postsecondary education and Nunavut's future. In 2004, several mandates were added to the developing program including flexibility of delivery based on local needs and the creation of a territorial education act. Big ideas take time; a document outlining what *IQ* looks like with respect to education was published in 2007 (NDE, 2007); the *Education Act* was finalized in 2008 and is currently under review (NDE, 2016b); and made-in-Nunavut curricula are still under development in many subject areas including science. So, the question of what science education looks like in Nunavut is still unsettled.

14.3 Science Education

The experience of Nunavut is unique within the current context of Canada. It is a jurisdiction that, while still caught up in legacies of the past, has a clear marker when people in the territory could begin to question those legacies and make different collective decisions. The primacy of *IQ* is one of those decisions. In Nunavut education, *IQ*-based programs of study are intended to render the "norms, values and beliefs that are transmitted to students through the underlying structure of meaning" (Giroux & Penna, 1979, p. 22) explicit rather than hidden and, in fact, explicitly Inuit. This choice affects both the overall structure of the curricula and the specifics of science curricula delivery.

14.3.1 Overall Structure*: IQ*

The overall structure supporting curricula can be challenging for *Qallunaat* to parse because it emerges from an Inuit worldview and loses something in translation to languages other than Inuktitut. The elements within the structure are mutually defining; they both emerge from and define the system in a dynamic fashion that is not necessarily evident in most other North American curricula; that is, the structure both supports the articulation of *IQ* principles from K–12 and is supported by them.

The Nunavut learning continuum emerges from an Inuit understanding of lifelong learning and focuses on becoming capable. It positions K–12 students as going through multiple stages as they move through school. The earliest stage is "*Qaujilisaaqtuq* ᖃᐅᔨᓕᓵᖅᑐᖅ 'becoming aware'" (NDE, 2007, p. 41) of the world around them, which occurs in early childhood. This is followed in early elementary years by "*Tukisiliqtuq* ᑐᑭᓯᓕᖅᑐᖅ 'beginning to understand'" (NDE, 2007, p. 41) and in later elementary years by "*Tukisinaqsiliqtuq* ᑐᑭᓯᓇᖅᓯᓕᖅᑐᖅ 'beginning to make sense to others'" (p. 42). In middle years, students enter the stage where they are

"*Pinasugunnaq* ᐱᓇᓱᒍᓐᓇᖅ 'now ready to experiment'" (NDE, 2007, p. 42), which speaks directly to science but also to deep and ongoing engagement with learning in the world. Finally, students in senior high school are considered "*Pijunnaqsijuq* ᐱᔪᓐᓇᖅᓯᔪᖅ 'now capable'" (NDE, 2007, p. 43) of applying what they have learned or are learning and continuing to learn from what they have already mastered. Each stage is not so much descriptive of understanding but of what students are capable of and how they are or act at school and in the world. While there is specific content to be learned through the stages and while cognitive processes are seen to play a role, the focus is more ontological. One visual metaphor offered for the process is building an *iglu* (ᐃᒡᓗ) where the blocks are spiralled in from a base to create a coherent whole that emerges from and ultimately gives back to the place in which it is located (NDE, 2007, p. 19).

IQ principles are positioned as key cross-curricular competencies that are being developed throughout the learning continuum. They are pulled together into four strands that students and teachers revisit at each grade level (NDE, 2007, 2016a). *Nunavusiutit* (ᓄᓇᕗᓯᐅᑎᑦ) focuses on how particular subjects are related to, interact with, and present within Nunavut history, culture, and language and to the broader world. *Iqqaqqaukkaringniq* (ᐃᖅᑲᖅᑲᐅᒃᑲᕆᖕᓂᖅ) focuses on analytical and critical skills through which the world, locally and globally, can be understood and improved. *Uqausiliriniq* (ᐅᖃᐅᓯᓕᕆᓂᖅ) focuses on the creative and expressive with a particular connection to the arts and language although simultaneously recognizing the importance of creativity and expression as a part of all learning. *Aulajaaqtut* (ᐊᐅᓚᔮᖅᑐᑦ) focuses on "wellness, safety, and one's place in society" (NDE, 2007, p. 49) in both an individual and collective sense. The *IQ* principles inform these strands differently at each grade level but are always at play, with a focus on doing and being from which understanding emerges. At the elementary and middle school levels, the strands are usually wound together reflecting the more integrated nature of K–9 curricula. In high school, certain courses may be more associated with specific strands. Science courses are frequently associated with *nunavusiutit* and *iqqaqqaukkaringniq* (ᐃᖅᑲᖅᑲᐅᒃᑲᕆᖕᓂᖅ, NDE, 2016a).

Nunavut positions formally trained educators, Elders, and other community knowledge holders as teachers within schools. The teacher's role is to support, facilitate, and scaffold students through the learning continuum. The foundations of instruction include a focus on:

- Bilingual education with a key role for Inuktitut
- Inclusion that addresses not only the needs of individual students but also honours what each student brings to the collective
- Dynamic assessment that involves students and parents in goal setting
- Critical pedagogy that supports young people in developing the understandings and skills needed to become capable, adult *Nunavummiut*, and citizens of Canada

14.3.2 Science Programs of Study

When Nunavut separated from the NWT, it inherited all of the curricula in effect at that time. Given the immense scope of replacing all curricula in all subject areas from Kindergarten through Grade 12, Nunavut has had to prioritize which subjects to focus on first; science has not been and is not currently the priority. The science curricula used in Nunavut schools come from a variety of sources, primarily the NWT and Alberta, although students may take distance courses from various jurisdictions including Québec and Saskatchewan. At this time, Nunavut follows the current NWT program for K–6; a local adaptation of the current Alberta program for Grades 7–9; and programs from Alberta, Experiential Science 10–20–30 from the NWT, and/or locally-developed Applied Physics 11–12 for Grades 10–12. External programs have been presented in other chapters of this volume (see Chaps. 3 & 13, Alberta & NWT, respectively). Here, we focus on some of the challenges in terms of science curricula and how the territory works to adapt externally developed programs within its own context.

14.3.2.1 Elementary Science

Until 2010, Nunavut followed the NWT K–6 science curriculum that had been developed in 1986. When it became apparent that a local replacement was not forthcoming, the Nunavut Government approved the more recent NWT *Grades K–6 Science and Technology Curriculum* (NTDE, 2004) for use in schools (Government of Nunavut, 2014). The newer program rolled out in the 2011–2012 school year, a full 7 years after its implementation in the NWT. The NWT-approved resources for supporting the curriculum were already out of print when Nunavut adopted the program, with the result that many schools do not have access to these resources. Teachers have not received any inservice training in terms of course delivery and implementation. The NWT is currently in the process of developing new curricula for elementary science. It is expected that Nunavut will adopt this program once it is in place.

14.3.2.2 Grades 7–9

Until recently, the middle school curriculum in Nunavut was based on a 1991 NWT program that has been out of use in that territory for many years. In 2014, an adaptation (NDE, 2014) of the Alberta Science Grades 7–8–9 program (Alberta Education, 2003a) was put in place. The modified program is seen as a more seamless progression for moving students into the senior high school courses that mostly originate in Alberta.

In some ways the adaptation does not appear that different from the Alberta program. It is clearly based on the four foundations of the *Common Framework of*

Science Learning Outcomes, K to 12 (Council of Ministers of Education, Canada, 1997): science, technology, society, and environment (STSE); knowledge; skills; and attitudes. However, *IQ* underlies the whole as a means for entering into teaching and learning. While the *Common Framework* foundations do not map directly onto *IQ* principles, they can be considered a part of them. For example, STSE and knowledge outcomes are seen "as a part of *Pilimmaksarniq*" (ᐱᓕᒻᒪᒃᓴᕐᓂᖅ 2014, p. 21), that is, the development of skills through practice, effort, and action.

As a Nunavut educator (J. Kreuger, personal communication, December 3, 2011) pointed out, this shift in assumptions underlying the program makes a significant difference in terms of how science is taught in territorial classrooms.

> Certain activities actually draw the principles out, like anything that's land-based will draw out most the *IQ* principles of working together, creative problem solving, taking care of the environment, that just naturally spills out. … [But] I mean you can apply all of these principles to something as … unAboriginal [as] an egg drop. It's not the content, it's the process. It's the [*IQ*] values that are part of the activity. But then you could also take actual content that appeals to a given culture, and in the north it's bringing into the classroom what's part of the day-to-day life of the kids. So, if they live on the coast and they hunt beluga, then make beluga whales part of your science. If they live inland, like where I live and caribou is [present,] then make caribou part of your science. And, so, the kids realize that what they are learning at home from their parents and from their grandparents is important too and of value. And that the qamutik [a traditional Inuit sled] is a great piece of technology. So, you ask, what is the science of the qamutik? … Our last student to win an award at the national science fair was on a study of qamutiks. And what length of qamutik requires the least amount of force per weight of qamutik, so is there an ideal length … or ideal size of a qamutik? So, yeah, she built little models and used Newton balances and went to the rink and tested them all and came up with the conclusion that it was, I think 19 feet [5.8 metres].

The importance of relevance is explicit within the Grades 7–9 program. It states that "students in Nunavut, by studying traditional cultural knowledge side-by-side with Western pure science, will find their studies more relevant to their lives and potentially future careers in the north" (NDE, 2014, p. 10). However, such curricular implementations are not necessarily obvious, particularly to teachers who are not *Nunavummiut*. To help, the program includes some changes of sequence to better fit the Nunavut context and adds content to both general and specific outcomes. For example, in the Grade 9 unit on Biological Diversity, the outcome "evaluate the success and limitations of various local and global strategies for minimizing loss of species diversity" (NDE, 2014, p. 65) has had caribou and polar bears added to suggested local foci. In addition, there are plans for the development of modules specific to Nunavut to further support teachers in delivering the adapted program.

14.3.2.3 Senior High School

Given the mix of curricula that supports science in Grades 10–12, NDE has laid out two main science pathways leading to graduation. There are also alternatives for scaffolding, bridging, or Individualized Education Programs that students may follow with permission from their school principal. At a minimum, graduation requires

Table 14.1 Science pathways for Grades 10–12 students

Pathway	Grade 10	Grade 11	Grade 12	Leads to:
	At least one of:	At least one of:	Optional, but required for postsecondary	
1	Science 10	Science 20 Biology 20 Chemistry 20 Physics20	Science 30 Biology 30 Chemistry 30 Physics 30	University or advanced college placement
2	Science 14 Experiential science 10	Science 24 Experiential science 20 Applied Physics 11	Environmental science 35 Experiential science 30 Applied physics 12	Trades school or college

one Grade 10 science course and at least one Grade 11 science course. Depending on students' goals, multiple science courses may be taken in Grades 11 and 12. The pathway that students choose depends on their plans for postsecondary education (Table 14.1).

Pathway 1 follows the Alberta study program (Alberta Education, 2003b, 2005, 2007a, 2007b, 2007c, 2007d). These courses meet advanced college and science-specific university program entrance requirements and are subject to Alberta diploma examinations in Grade 12 (NDE, 2015). Pathway 2, more often chosen by students, is a mix of courses from Alberta (Science 14–24) and locally-developed courses (Applied Physics 11 & 12 and Experiential Science 10, 20, & 30). Applied Physics is a locally-developed option offered in a hands-on modular format. In Applied Physics 11, students complete three modules (i.e., energy; machines, forces, and motion; structures) and a culminating project (NDE, 2016a, p. 90). In Applied Physics 12, students complete four modules (i.e., sustainable energy, light and heat, fluids and pressure, electricity and electromagnetism) and a culminating project on renewable energy (NDE, 2016a, p. 105). In each module, teachers and students are encouraged to explore problems and content through local contexts. Pathway 2 meets the entrance requirements for some trades and university programs and does not involve any final examinations.

14.3.2.4 Distance Education: *It's Not as Easy as It Sounds*

Given limited access to advanced science courses at the senior high school level, it can be challenging for students who wish to pursue postsecondary education programs in the sciences to complete prerequisites. Distance education is an option for all students; however, it requires a significant level of self-guidance and self-reliance that not all young people possess. In one attempt to provide structure and support within distance education courses, the Kivalliq Region ran a pilot program from 2000 to 2003 where it identified students with an interest in and aptitude for science (Kreuger, 2002). A distance education science teacher was hired to work with these students, and a computer dedicated to the project was provided for each participating school. At the beginning of the school year, participating students from several Kivalliq hamlets and the distance education science teacher were flown to Rankin Inlet for an intensive weeklong camp. The purpose of the camp was to generate a sense of community, outline the scope and expectations of the program, and complete the first module of Science 10 (Alberta Education, 2005) together. After the camp, students returned home to complete the remaining course modules with the support of their distance education teacher and peers through email and conference calls. While the first year of the program was relatively successful in that students from smaller communities obtained Science 10 credit, participation in subsequent years for 20- and 30-level science courses fell off and became concentrated in Rankin Inlet, a large community with the resources to offer these courses. At an annual cost of nearly $50,000, the program was not scaled up to other regions or continued in Kivalliq. While the lack of local mentorship for each student was certainly a contributing factor, one of the biggest hurdles was language and literacy. Distance education, even with online support, remains print-intensive in terms of instruction; this reality combined with the highly technical and specialized version of English in science courses rendered the course extremely difficult for Inuktitut first-language students.

14.3.2.5 Local Program Adaptations and Modules

Often more effective in terms of student engagement and success in science are local adaptations to the curriculum and the development of science modules located in northern contexts. NDE encourages teachers to adapt science curricula at the local level in order to make them relevant to students and account for *IQ*. In one community, this flexibility allowed a teacher to develop a kayak-building program that spanned multiple subject areas, including mathematics, science, and physical education when the kayaks were completed. It should be noted that such development requires significant time and effort as well as local connections. The teacher in question had more than 10 years' experience at the community school, significant pedagogical content knowledge, deep understanding of the territorial curricula, the wherewithal to fundraise for the project, and support in the community that would be less available to a newer teacher. While the territory does try to supply resources and support that can lead to such local innovations, course offerings are somewhat dependent on individual educators.

The territory has a series of science modules specific to the northern context designed by teachers in Qikiqtani on Baffin Island. The modules include:

- Science of *Igunaq* (ᐃᖕᑯᓇᖅ, walrus): The biology and chemistry of the production of fermented walrus meat
- Science of *Qamutiit* (ᖃᒧᑏᑦ, sleds): The physics of the construction and use of Inuit sleds
- Science of Caribou: The biology and ecology of the caribou

- Science of *Qulliit* (ᖁᓪᓖᑦ, lamp/stove): The chemistry of the operation of the Inuit lamp/stove

The modules can be used within existing courses along with other more recent cultural practice-based modules such as fox trapping, parka making, and seal skin preparation (NDE, 2016a). These newer modules do not contain explicit connections to science in their outlines, but science skills and understandings emerge from cultural practices in place, and teachers are encouraged to use the modules within the sciences (Kreuger, 2011; Wiseman, 2016).

14.3.3 Resources

Every school year, NDE publishes an approved list of resources for all K–12 courses (NDE, 2016a). Approved resources for science include the textbooks for courses imported from Alberta and the NWT. In addition, and key to science teaching, are locally-developed materials from NDE and other agencies.

NDE has developed print and electronic resources to support science teaching in the territory. Electronic resources are generally distributed on CD-ROM as Internet access in Nunavut can be unreliable. At the elementary and middle school levels, a number of resources, such as *Common Plants of Nunavut* (Mallory & Aiken, 2012), support teachers in adapting curricula so that it is specific to local flora and fauna. Other resources, like *Inuillamisiurniq: Surviving Out on the Land* (NDE, 2016a), focus on leveraging land-based skills within the curriculum. At the high school level, the resource package *Nuulluni Qaujisarniq: Learning Science Away from the Classroom* (NDE, 2016a) helps teachers organize cross-cultural science camps that involve students, Elders, and teachers learning together in the land. It also provides sample modules for exploring comparative anatomy, biophysical monitoring, and rocks and minerals during these camps. This resource is used by the Kivalliq Science Educators' Community (Kreuger, 2011) to formulate their annual Science Culture Camps and has been shared with other science teacher collectives like Science for Kitikmeot Youth and Elders in the Kitikmeot Region.

The Nunavut Bilingual Education Society has been responsible for the development of a number of elementary and secondary science teaching resources that support the use of Inuktitut in science teaching and learning and that address some of the issues around translation. Titles include:

- *Science Ideas for Nunavut Classrooms* (Christopher, 2005)
- *Common Birds of Nunavut* (Mallory, 2013)
- *Common Plants of Nunavut* (Mallory & Aiken, 2012)
- *Terrestrial Mammals of Nunavut* (Anand-Wheeler, 2002)

Manitoba's Centre for Research in Youth, Science Teaching and Learning (CRYSTAL; University of Manitoba, n.d.-a) was one of five centres funded by Canada's Natural Sciences and Engineering Research Council from 2005 to 2010.

Building on the expertise and relationships within the Manitoba CRYSTAL, Nunavut was one key site for research. A dozen elementary science education resources specific to the territory were developed in collaboration with Nunavut educators (University of Manitoba, n.d.-b). These resources covered topics such as light, sound, the moon, and rocks and landforms and are still in use in Nunavut schools. Several other territorial agencies, including the Nunavut Energy Secretariat and the Nunavut Research Institute, have also developed resources relevant to the teaching and learning of science in the territory (NDE, 2016a).

14.3.4 Assessment

The philosophy for assessment in Nunavut is laid out for teachers in *Ilitaunnikuliriniq: Foundation for Dynamic Assessment as Learning in Nunavut Schools* (NDE, 2008). Assessment is based on the Inuit continuum of learning that recognizes people "develop and learn at different rates, both physically and intellectually" (NDE, 2008, p. 26); thus, it is primarily formative and viewed as assessment for learning. *Ilitaunnikuliriniq* is clear that schools should set high expectations for students and that achievement of those expectations should be measured:

- Over time
- For an intended purpose
- In ways that are fair and appropriate
- Taking into account the *Inuit Qaujimajatuqangit* perspectives of the people of Nunavut (NDE, 2008, p. 17)

Currently, there are no territorial-wide assessments except for the high school students required to write the Alberta diploma examinations in select Grade 12 courses, which include Biology 30, Chemistry 30, Physics 30, and Science 30. As in Alberta, the results from these examinations constitute 30% of the final course mark with the balance from assessment of in-class term work (NDE, 2015). The Auditor General of Canada has found that there was a significant difference between classroom-level results and the Alberta diploma examination results for Nunavut students (Ferguson, 2013). In some courses, class-based grades were more than 25% higher than examination grades, an indication of a mismatch between local and more global assessments. There are a number of possible reasons for the mismatch. Externally developed assessments sometimes present situations with which Nunavut students have little or no experience. In addition, Nunavut ESL students take the same examinations that were developed for English first-language Alberta students, so issues of understanding related to language can impact student performance. NDE has established a working group to address the issue and develop an action plan that includes inservice assessment training for teachers (Ferguson, 2013).

14.4 Science Teacher Education

Like other levels of education in Nunavut, teacher education is a work in progress. Changes are implemented in an ongoing manner as thinking about territorial priorities coalesces. The legacy of the territory's history as a part of the NWT is still relevant. At the same time, *IQ* provides guidance that contributes to the manner in which teacher education for *Nunavummiut* might be framed.

14.4.1 Initial Teacher Education

Teacher education in Nunavut is subject to the same challenges facing the territory's K–12 schools, including small populations and isolated, remote communities. There is one postsecondary institution in the territory, Nunavut Arctic College (NAC). It was established in 1995 when the former Arctic College of the NWT split in two in order to serve the then-larger territory. The college has five campuses: one each in Clyde River, Iqaluit, and Cambridge Bay and two in Rankin Inlet (NAC, 2016c; Fig. 14.1). Given the challenges and expense of travel, NAC has established Community Learning Centres in each of the territory's 25 communities. The college is tasked with all adult education in Nunavut, including basic education, skills upgrading, trades, and academic postsecondary programs. While a number of programs require completion at partner institutions in southern Canada, NAC offers two degree programs in nursing and education that allow students to complete their entire degree in the north (NAC, 2015).

NAC's Nunavut Teacher Education Program (NTEP; NAC, 2016b) is offered in affiliation with the Faculty of Education at the University of Regina (UofR; 2017b). There are two paths to graduation: a 4-year program leading to a Bachelor of Education (BEd) and a 2-year post-degree program leading to a Bachelor of Education After Degree (BEAD). Students are admitted based upon successful completion of Grade 12 with a 65% average across five core subject areas including science and mathematics. Applicants must pass NTEP admissions tests in Inuktitut, English, and mathematics. Mature students over the age of 21 can be admitted without the prerequisite academic requirements; however, they must pass NTEP admissions tests and be approved for admission through the UofR (NAC, 2016a).

NTEP's BEd and BEAD programs generally follow the structure of the UofR K–9 elementary education programs (see Chap. 4, Saskatchewan, this volume) with some adaptations to reflect the context of teaching in the north, including Nunavut-specific courses such as Inuit Culture and History, Inuit Educational Cultural Studies, and Inuktitut (NAC, 2016a). In terms of science education, students in both degree programs are expected to take one natural science course in astronomy, biology, chemistry, geology, physics, or another approved area (UofR, 2017a); NAC offers Human Biology and Environmental Science to meet this requirement (NAC, 2016a). Students in both programs also take a science methods course that focuses on bringing science pedagogy and content together. Along with considerations of planning, class management, and assessment, locally-developed resources to support the teaching and learning of science are introduced in the science methods course.

14.4.2 Southern Teachers in the North

Despite the existence of a local teacher education program at NAC, most teachers, and nearly all subject area specialists at the high school level, come to the territory from teacher education programs in southern Canada (Newbery, 2013). In some cases, southern Canadian universities have adapted to this reality as a means of better preparing their students. For example, over the last decade, Mount St. Vincent University in Nova Scotia has partnered with the Government of Nunavut and Qikiqtani School Operations in the Baffin Region to offer preservice teachers a course on teaching in Nunavut that can be followed up with a 4-week practicum in territorial schools (Mount Saint Vincent University, 2016).

Queen's University and Lakehead University in Ontario have had successful practicum programs that gave student teachers an opportunity to do practice teaching in the Kivalliq Region of Nunavut. Kivalliq School Operations and local District Education Authorities supported the program by providing housing for preservice teachers. These programs provided an understanding of the culture, context, and challenges of education in the territory; consequently, those preservice teachers who subsequently took on teaching positions in Nunavut tended to remain in these positions longer than teachers recruited directly from the south. Many graduates of the Ontario programs are still teaching in Nunavut today, more than 15 years after the Nunavut practicum was discontinued as a result of Ontario's revised teacher education program requirements.

14.4.3 Certification

While the NTEP program focuses on preK through Grade 9 and most graduates teach at these levels, a BEd or BEAD from NAC does allow teachers to be certified for K–12. However, most secondary science specialists come from teacher programs in southern Canada. Secondary science specialists are expected to have a Bachelor of Science with a concurrent or consecutive education degree that leads to certification.

Teacher certification is overseen by the Nunavut Educators Certification Service (NDE, n.d.). Given the territory's ongoing need for teachers, certification can be issued after a candidate has completed 1 year of a teacher education program (Nunavut Teachers' Association [NTA], 2013). Teachers are certified based on level of education. Levels 1 through 3 require 1 to 3 years of postsecondary teacher education but no degree; levels 4 through 6 require a BEd or other teaching degree, along with varying levels of experience. There is also a specialty teaching certificate available for teachers of Inuit language and culture.

14.4.4 Professional Development

In general, professional development (Pro-D) in Nunavut is intended to contribute to student learning, teacher professional growth, and school improvement (NTA, 2013). There are 5 funded days, known as PD Week, built into the school calendar each year (NTA, 2017). PD Week takes place at the same time for all teachers in the territory. It includes events at local, regional, and territorial levels with larger events generally including at least one session focused on science. While funding for Pro-D is quite generous and can include travel outside the territory provided it has been preapproved by NTA's Pro-D Coordinators (NTA, 2017), the designated week does not necessarily align with subject-specific Pro-D opportunities offered outside the territory. For science teachers, this timing issue means access to events that might support their teaching, such as the Alberta Teachers' Association Science Council Conference or the US-based National Science Teachers' Association regional or national conferences, may not be possible. Given the cost of travel within and from Nunavut, there are generous Pro-D allocations for distance learning by correspondence or digital means and provisions for yearlong leaves to pursue graduate work (NTA, 2013).

The Nunavut Science Educators' Community (NSEC) has recently been approved as a specialist council by NTA. In examining means for leveraging more effective use of available funds for science Pro-D, NSEC is considering several possibilities. In 2016, it sent representatives to a regional conference of the National Science Teachers Association who shared what they had learned with colleagues throughout the territory.

14.4.5 Teacher Induction

Teaching in Nunavut comes with the challenges of living in northern, remote, isolated communities. Teachers new to the territory—no matter their level of experience as educators—can find themselves in situations where their life experiences do not provide adequate preparation for the northern context, leading to significant levels of teacher turnover. Retention is important because, as experienced Nunavut educators will point out (J. Kreuger, personal communication, June 3, 2016), it takes upwards of 4 years for science educators to begin to ask the right questions about what it means to teach science in Nunavut and to begin teaching more than they are learning. Retention is important because young people need a commitment from their teachers, without which they can languish.

Teacher induction has been identified as a priority in order to increase retention and reduce turnover rates among teaching staff. As of 2016, NDE rolled out the Nunavut Teacher Induction Program, which includes a website (http://ntip.gov.nu.ca/), a school-based orientation kit, and a mentorship program. The orientation kit and mentorship program are still in development stages, but the website is operational and includes elements such as new hire checklists, FAQs, community profiles, and government directories that help answer the initial questions that can consume new teachers.

In addition to NTIP, each RSO provides teachers with curriculum and program support. For science educators in Kivalliq, an annual science culture camp organized by Kivalliq Science Educators' Community (KSEC) takes place shortly after Labour Day for new and returning teachers, students, and Elders; it supports new teacher understanding of teaching in the north (Kreuger, 2011; Wiseman, 2016).

14.5 Discussion

Nunavut's unique challenges and opportunities for science teaching and learning are related to its northern location, the isolation of its communities, the majority Inuit population and related commitment to bilingual education, a reliance on externally developed curricula, and its newness as a territory. Throughout their history, *Nunavummiut* have remembered who they are, where they come from, and how their relationship with the land and the north define what goes on in the territory. In this remembering, the founding of Nunavut has provided some significant lessons about honouring that past in the present in order to build for the future. These lessons are being applied within science teaching and learning; as such, this final section focuses on local science educators' communities and the impact they have had on science education in the territory.

14.5.1 The Nunavut Science Educators' Community

In the 1990s, prior to the founding of Nunavut, teachers in two of the territory's three regions, Kitikmeot and Kivalliq, established professional learning communities related to the teaching and learning of science. Science for Youth and Elders (SCYE) in Kitikmeot serves communities in the central Arctic region including much of the Arctic Archipelago, whereas KSEC serves communities in southern areas of the territory. Both programs began as a means of supporting the development of community among science teachers who were physically isolated from their subject-area colleagues. They provide orientation around what to expect when teaching science in Nunavut, information about how to build local relationships that help in science teaching and learning, and a general lifeline for asking questions when issues arise. Although SCYE was the first program to offer a science culture camp where teachers, students, and Elders considered science together out in the land, KSEC has a longer history.

With a larger population and slightly easier travel, KSEC has had the more consistent delivery and development of programming. In 1995, KSEC began running the Science, Engineering, Technology (SET) Challenge and the Kivalliq Regional Science

Fair (KRSF). The SET challenge is now one of the most anticipated events in its schools (KSEC, 2015b); in 2010, 2,155 students participated (Kreuger, 2011). The KRSF, which is KSEC's flagship event, prioritizes bilingual (Inuktitut and English) projects that explore northern-relevant topics (KSEC, 2015a). It is a recognized competition feeding into the Canada-Wide Science Fair. Students from Kivalliq have participated on a national level for more than 20 years and won more than a dozen awards with projects exploring topics such as Inuit plant medicines, fuels derived from sea mammal fat, and natural versus synthetic sinew (KSEC, 2015a). KSEC has built on the SCYE camp model to create a start-of-year highlight for students, teachers, and Elders (Kreuger, 2011). The experience values culture and science and is validated by the NDE; students receive two high school credits for their successful completion of the camp program.

All KSEC programming is run by teacher and community volunteers; it has gained official recognition for its events from NTA and NDE. KSEC focuses on the primacy of *IQ*. Rather than incorporate *IQ* into a science camp, KSEC incorporates a science camp into *IQ*; this difference is important. Lewthwaite et al. (2010) have shown that, while commitment to *IQ* in science education exists at the community level in Nunavut, it can vary in implementation between the science teachers. KSEC works with science teachers from their arrival in the territory to ensure that *IQ* is prioritized.

Organizations such as KSEC and SCYE are important because they support science educators in adapting to the teaching and learning of science in Nunavut. By creating community around science and by drawing on the principles of *IQ*, they make a difference in terms of teacher retention in the territory. Successful schools, and successful science teaching and learning, emerge in places where community develops because teachers and administrators have stayed. The KSEC model encourages this type of commitment; as such, it is the model upon which the NSEC is being developed.

Since 2014, NSEC has developed a structure, created a sense of purpose among members, and coordinated a conference on project-based learning. Future goals include organizing a conference on experiential land-based learning, implementation of a robotics program, and establishing the Qikiqtani Science Educators' Community so that each Nunavut region has a locally-based science education community. It is the hope that the successes of KSEC will scale up on a territorial level, because when teachers stay in Nunavut and when they form community, remarkable things can happen. As one teacher explained,

> KSEC has helped me create a classroom of success, and my students' small successes have now turned into a community [of] success. Our students are becoming leaders, graduating high school, and moving onto post secondary institutions, and I believe KSEC has been a driving force in our students' success. (Kreuger, 2011, p. 15)

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Chapter 15
Epilogue: The Current Context of Canadian Science Education and Issues for Further Consideration

Christine D. Tippett, Todd M. Milford, and Larry D. Yore

Abstract This chapter summarizes the characteristics of science education in Canada and identifies pressing issues deserving further consideration, development, and research. Although Canada borders the United States, and the two nations share many economic and cultural relationships, Canada is a unique country with its own approaches to science education. Canada's science results throughout the six implementations of PISA (2000–2015) have been consistently strong, and educators from Canada are often asked what accounts for this performance. Authors of the preceding 13 chapters—one for each province and territory—have outlined aspects of science education and identified points of interest that might help clarify the complex influences on science education performance. Collectively, these chapters provide readers with a common starting point from which to infer causal relationships associated with Canada's successes. However, the diverse nature of Canadian science education makes simple, causal identifications elusive. A thematic analysis of policies, structures, and pedagogical approaches across these jurisdictions revealed nine themes that were categorized as consistencies, commonalities, or distinctions within and amongst the various jurisdictions as a basis for a macro-level overview of science education in Canada. This chapter contextualizes these themes and presents emerging and pressing issues in policy, practice, and research.

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C. D. Tippett, T. M. Milford (eds.), *Science Education in Canada*,
https://doi.org/10.1007/978-3-030-06191-3_15

15.1 Introduction

The geographical, political, historical, and cultural attributes of a country determine its approach to education. Canada is a large country with a small and unevenly distributed population, a rich Indigenous heritage, and growing ethnic and linguistic diversity. The country is a federation of 10 provinces and three territories, with specific allocations of jurisdictional and federal responsibility. Education is a provincial or territorial portfolio with one exception: children residing in Indigenous communities. In this case, the federal government is responsible; although in the last 30 years, there has been substantive movement towards Indigenous-led education. These contextual factors vary across and within jurisdictions and influence education policy, school organization, curriculum, assessment, and teacher education programs and certification.

Canada's sparse population of 37 million people is unevenly distributed across nearly 9 million square kilometres. Large expanses of the country are unpopulated, with two-thirds of its inhabitants living within approximately 4% of its area, a region encompassing the 100 kilometres north of the Canada–United States border (Statistics Canada, 2017e). Since the early 1900s, the proportion of the population residing in Ontario and Québec has remained stable at 60–64% of the country's total, with Ontario accounting for nearly 40% in 2016 (Statistics Canada, 2017e). Conversely, the three northern territories of the Yukon, the Northwest Territories, and Nunavut account for less than 1% of Canada's population (Statistics Canada, 2017d). Travel within the country is expensive and time-consuming, which can isolate Canadians, limit opportunities for face-to-face collaborations, and contribute to differences in education policies and practices.

According to Canada's *Constitution Act*, *1982*, the term *Aboriginal peoples*—now typically replaced by the term *Indigenous peoples*—"includes the Indian [more commonly referred to as First Nations], Inuit and Métis peoples of Canada" (Department of Justice Canada, 2012, p. 63). Indigenous peoples are the fastest growing segment of the population, in part because "more people are newly identifying as Aboriginal on the census—a continuation of a trend over time" (Statistics Canada, 2017a, para. 6). Indigenous cultures and languages provided the historical foundation of Canada's identity. Centuries of complicated interactions between Indigenous peoples and settler peoples resulted in the "destructive legacies of colonization" according to the Truth and Reconciliation Commission of Canada (TRC, 2015b, p. 114). The TRC, established in 2008, was a recent effort to make amends for this deleterious relationship. The calls to action included in the TRC's final report (2015a) position the revitalization of Indigenous languages and cultures as central to Canada's reconciliation with Indigenous peoples.

Canada has a reputation as an ethnocultural mosaic with its large immigrant population having a range of linguistic and religious backgrounds (Statistics Canada, 2016). Between 2011 and 2016, immigration accounted for 66% of Canada's population growth (Statistics Canada, 2017c). During this period, Canada welcomed more than 1.2 million immigrants; the top 10 countries of origin in order were the Philippines, India, China, Iran, Pakistan, the United States, Syria, the United Kingdom, France, and South Korea (Statistics Canada, 2017b). Nearly two-thirds of immigrants settle in the metropolitan cities of Toronto, ON, Montreal, PQ, or Vancouver, BC, although only one-third of the total population resides in those cities. Additionally, it is common for immigrants to settle in communities where they have pre-established cultural ties, leading to towns or neighbourhoods with distinctive demographics. Regional differences make it difficult to generalize on a national level about ethnocultural characteristics that impact educational policy.

15.2 Science Education in Canada

It is similarly difficult to make generalizations about educational policy as a whole because there is no federal ministry of education. The lack of federal oversight contributes to the variations in school organization, curriculum, teacher education programs, and certification regulations described in the preceding chapters. This diversity at the general level of educational policy, organization, and practice is equally pronounced in science education.

In the 1960s and 1970s, Canadian science curricula were influenced by reforms in the United Kingdom and the United States following the launch of Sputnik and driven by the economic and political goals to become a leader in science, mathematics, and engineering (Murray, 2015). Curricula in several provinces were imports of American inquiry-oriented science modules and programs that did not always align well with Canadian goals and contexts.

However, there have been several historical efforts to seek common ground in Canadian science education: *Science for Every Student: Educating Canadians for Tomorrow* (Science Council of Canada, 1984) and *Science Education in Canada* (Connelly, Crocker, & Kass, 1985, 1989). *Science for Every Student* reported on:

> an analysis of science curriculum policies from all provinces and territories; an analysis of 33 commonly used textbooks; a survey of more than 4000 science teachers; and eight case studies of science teaching. (Science Council of Canada, 1984, p. 11 of Summary)

This study identified the following concerns: the inadequacy of science education at the elementary level; a lack of challenge for high-achieving science students; a lack of attention to science, technology, and society; girls not pursuing science careers; limited or ineffective science professional development (Pro-D) for teachers; and limited opportunities for new science teachers entering the profession. It made eight recommendations, in three broad areas, for renewing science education:

Science Education for All

1. Guaranteeing science education in every elementary school
2. Increasing the participation of young women in science education
3. Challenging high achievers and science enthusiasts

Redirecting Science Education

4. Presenting a more authentic view of science
5. Emphasizing the science-technology-society connection
6. Setting science education in a Canadian context
7. Introducing technology education

Monitoring Science Education

8. Ensuring quality in science education (Science Council of Canada, 1984, p. 33)

Science Education in Canada (Connelly et al., 1985, 1989) reported on an International Association for the Evaluation of Educational Achievement study that documented (a) provincial/territorial policies, practices, and perceptions and (b) classroom instruction, student achievement, and correlates. This study utilized some of the same data as *Science for Every Student* but with the goal of developing "a body of solid descriptive data on Canadian curriculum policy and science classroom practice that would provide empirical knowledge" (Connelly et al., 1989, p. 270). Additionally, more than 20,000 students, almost 2,000 teachers, and nearly 800 principals from every jurisdiction in Canada except Québec were involved in an assessment of science learning and surveys of attitude towards science, teacher background, instructional approaches, and school characteristics.

Both studies drew upon stakeholder input, document analyses, measures of science achievement, and complex and deliberative data interpretation processes. Their summary reports were widely accepted by diverse stakeholders and set the stage for defining a framework for 21st century science education in Canada: the *Common Framework of Science Learning Outcomes, K to 12* (Council of Ministers of Education, Canada [CMEC], 1997), sometimes referred to as the *Common Framework* or the *Pan-Canadian Framework*. The *Common Framework*, involving participation from almost every jurisdiction, was developed using a collaboration of ministry of education staffs, science educators, science teachers, parents, students, and other stakeholders under the guidance of English and French coleaders. The *Common Framework* articulated a vision of scientific literacy; emphasized the interrelationships amongst science, technology, society, and the environment (STSE); and detailed K–12 learning outcomes.

Although there is little evidence that the recommendations in *Science for Every Student* (Science Council of Canada, 1984) and *Science Education in Canada* (Connelly et al., 1985, 1989) had direct impacts on science curricula and instruction, the *Common Framework* (CMEC, 1997) that arose from those studies did shape K–12 science education curricula, as evidenced in previous chapters. Additionally, Milford, Jagger, Yore, and Anderson (2010) found that the *Common Framework* was used regularly in curriculum development across the country during the decade that followed its publication.

15.3 Consistencies, Commonalities, and Distinctions in Issues Across Canada

A thematic analysis of the provincial and territorial chapters revealed that the *Common Framework* (CMEC, 1997) was not the only consistent aspect of Canadian science education. The editors iteratively coded the 13 chapters for aspects of curriculum, pedagogy, teacher education, and professional development. Coding was done independently but synchronously via Skype™, meaning that, when a potential new code was identified, its addition to our comprehensive list of codes was discussed in real time. As new codes were accepted, chapters were re-examined to ensure that the final analysis was for all 39 codes across all chapters. Codes were then compiled into nine themes, which in turn were categorized as being consistent (i.e., discussed across all jurisdictions with little variation, regional or otherwise), common (i.e., discussed/described across the majority of the jurisdictions but with unique local or regional interpretations), or distinct (i.e., appearing in fewer jurisdictions with large variation in interpretation or consideration, limited in scope). Consistencies were a low priority of science and influences on curricula; commonalities were Indigenous perspectives, inadequate science teacher education, issues of language, and assessment practices; and distinctions were locally-developed courses or alternative formats, instructional approaches, and environmental considerations. The following sections highlight how these nine themes are enacted across the country.

15.3.1 CONSISTENCY: Low Priority of Science

The first consistent theme identified was low priority of science. That science education has a low priority in Canada may be surprising, given the country's demonstrated success on international assessments of science achievement. However, our analysis of the jurisdictional chapters suggests that across the country science is viewed as less important than numeracy and literacy. Indications of science education's low priority include authors specifying that that was the case, outdated science curriculum documents and national policy documents framework, limited funding and/or resources, limited Pro-D opportunities, lack of assessment in comparison with, for example, mathematics and literacy, and no mandated minimum instructional time.

Authors from several jurisdictions explicitly noted that science education was not a high priority within their province or territory, while other authors positioned science education as an area that should be a priority but is not. Only New Brunswick reported science education in its list of educational priorities.

The use of outdated curricula was evident across the country. Only six jurisdictions have any science curriculum documents that have been updated within the last 5 years, and only British Columbia and Newfoundland and Labrador have fully revised (or are currently revising) science curriculum documents for all grade levels. Even jurisdictions that seem on the surface to support science education through Pro-D opportunities were reported to emphasize mathematics, with several authors noting that curriculum specialists for science were often the same people supporting mathematics, which typically led to mathematics opportunities rather than science opportunities.

Only three jurisdictions reported province-wide science assessments: Alberta at Grades 6, 9, and 12; New Brunswick at Grades 4, 6, and 10; and Saskatchewan at Grade 12 depending upon teachers' levels of qualification. Occasionally, authors made the link to a lack of formal assessments in science leading to a lower priority for science education (Prince Edward Island); however, Ontario points out that such assessment typically leads to reduced time for higher-order thinking opportunities and has had a detrimental effect on elementary science education.

Some authors explicitly noted a lack of a minimum required time allotment for science. Nova Scotia expects science will be integrated with language and mathematics, which is leading to *only* teaching science in the context of required mathematics and language outcomes; Québec used to have minimal time allotments, but those disappeared in 2000. Many provinces do not specify how much time should be spent on science although some (British Columbia) make recommendations. Several jurisdictions call for increased funding and additional resources.

15.3.2 CONSISTENCY: Influences on Curricula

The second consistent theme was influences on the curricula. The far-reaching impact of the *Common Framework* (CMEC, 1997) is evident, with all chapters except Québec and the Yukon (which uses British Columbia documents), explicitly referring to the document. Chapter authors highlighted various aspects of the *Common Framework* appearing in jurisdictional curriculum documents, with the four foundations of scientific literacy—knowledge, skills, attitudes, and STSE relationships—appearing to be particularly influential. Authors for British Columbia, Alberta, Saskatchewan, Nunavut, and Northwest Territories reported these foundations as goals, pillars, or outcomes within their own curriculum documents. A comparison of the curriculum topics reported by chapter authors shows that all provinces and territories closely parallel the suggested topics found in the somewhat dated *Common Framework*.

The four eastern provinces of New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador all reported the influence of another document, the *Foundation for the Atlantic Canada Science Curriculum* (*FACSC;* Atlantic Provinces Education Foundation, 1998), which was in turn based on the *Common Framework*. *FACSC* and the *Common Framework* include identical definitions of scientific literacy; both documents emphasize a constructivist approach to scientific inquiry, problem solving, and decision making; and the curriculum outcomes outlined in the *FACSC* are the general learning outcomes outlined in the *Common Framework*.

Other reported influences on jurisdictional curricula include US reform programs (e.g., *Biological Sciences Curriculum Study*, *Benchmarks for Science Literacy*: *Project 2061, CHEMstudy*, *Physical Sciences Curriculum Study*) and various stakeholder groups. New Brunswick reported that, while the *FACSC* was an influence primarily on its English language science curriculum, its French language science curriculum was informed by *Project 2061* and European curricula. Many authors reported the influence of various stakeholder groups, which vary by jurisdiction, on science curriculum. Identified stakeholders included K–12 teachers, school division personnel, university faculty, Indigenous communities, Elders, industry (e.g., mining, agriculture), outreach organizations (e.g., science centres, Let's Talk Science), and parents.

15.3.3 COMMONALITY: Indigenous Perspectives

A common theme running across most jurisdictions with regional variations emerging was attention to Indigenous perspectives, particularly Indigenous knowledge about nature and naturally occurring events. Most science curriculum documents emphasize a view of science based on modern Eurocentric perspectives although they might include general guidance for meeting the needs of Indigenous students.

In the western provinces (British Columbia, Alberta, Saskatchewan), the main goal of integrating, incorporating, or including Indigenous perspectives is to enhance science education and the understanding of Indigenous world views for *all* students (Alberta Learning, 2002; BC Ministry of Education, 2005; Saskatchewan Ministry of Education, 2009). In the central provinces (Manitoba, Ontario, Québec), the focus seems to be on improving science education for Indigenous students (ON Ministry of Education, 2007). In the chapters on these six provinces, authors reported that Indigenous perspectives might be included as outcomes or expectations for particular science topics, the front matter of curriculum documents might describe how Indigenous perspectives are connected to the science curriculum, instructional resources might be developed in collaboration with Elders, teacher education programs might include required Indigenous education courses, and governmental bodies might release policy documents regarding issues of Indigenous education. However, in most cases, these efforts do not go far enough to meet the needs of teachers trying to navigate making science "more authentic, exciting, relevant and interesting for all students" (BC Ministry of Education, 2005, p. 12).

The inclusion of Indigenous perspectives in science education was hardly mentioned in the chapters about the eastern provinces (New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador). This omission is likely because the science curriculum in the Atlantic Provinces is based upon the *FACSC*, which does not address Indigenous perspectives. The Nova Scotia chapter, while mentioning the importance of integrating Indigenous perspectives, did not point out how that integration might transpire.

The territories are far more progressive in their approach, placing greater emphasis on Indigenous perspectives and on the decolonization of science education. Few jurisdictions are more explicit about the foundations for Indigenous education than Nunavut, where policy and curricula are grounded in *Inuit Qaujimajatuqangit* (*IQ*). Rather than merely incorporating Indigenous perspectives, Nunavut curricula are built upon eight principles of *IQ*, which is "Inuit beliefs, laws, principles and values along with traditional knowledge, skills and attitudes" (Nunavut Department of Education, 2007, p. 22).

15.3.4 COMMONALITY: Inadequate Science Teacher Education

Another common theme that emerged was inadequate science teacher education, particularly for elementary teachers. From British Columbia to Newfoundland and Labrador, the situation was reported similarly. Authors suggested that teachers may be unprepared, lack confidence, feel uncomfortable, find it challenging to remain current, and even neglect to teach science.

In most cases, elementary teacher education programs require only one science methods course; as well, incoming teacher candidates may need only one postsecondary science course for admission to a teacher education program. Even where programs include two science methods courses, authors reported that elementary teachers do not feel comfortable teaching science. However, even secondary science teachers—with substantial science backgrounds—may be underprepared because many jurisdictions require only a general science methods course rather than a domain-specific chemistry or physics methods course. Programs may or may not have room for elective courses, and science electives may or may not be available.

Another issue related to science teacher preparation is new science teachers' lack of understanding regarding the demands of rural teaching situations in areas such as northern Canada. Many teachers have grown up and attended universities in urban areas only to find that their initial teaching placement is in a rural area. Adjusting to these settings often requires considerable effort, support, and mentoring that is not always readily available.

15.3.5 COMMONALITY: Issues of Language

Another common theme that emerged was the issue of language, which was evident in a number of chapters, although with a great deal of variation in the particular issue. Highly regionalized because of historical and political events and, more recently, because of patterns of immigration, the issues range from English language learners (ELL), French Language Learners (FLL), French immersion, Francophone and Anglophone minority communities, and Indigenous language revitalization. Although Canada is a bilingual country (French/English), only New Brunswick is officially bilingual. French is the primary language of communication in Québec, while English is the primary language in all other jurisdictions. In the three territories, Indigenous languages are officially recognized: Nunavut recognizes the Inuit language in addition to French and English, the Northwest Territories recognizes nine Indigenous languages, and the Yukon recognizes seven Indigenous languages.

All students, regardless of where they reside, are entitled to publicly funded education in either French or English, subject to conditions outlined in the *Canadian Charter of Rights and Freedoms* (CMEC, 2008). The federal government has recently proposed an *Indigenous Languages Act*, which may establish similar rights for Indigenous students. However, these provisions do not address the importance of language in learning science where students who are learning a second language may be lacking language-accessible instructional resources and literacy strategies to negotiate, construct, represent, and communicate scientific ideas using the terminology and genres of science.

One pressing issue for science education in Canada is meeting the needs of ELLs and FLLs. Nowhere is this issue more apparent than in the country's three largest cities that are experiencing the highest rates of immigration: Vancouver, BC, and Toronto, ON, are primarily English speaking and Montreal, PQ, is French speaking. Not surprisingly, both British Columbia and Ontario chapter authors identified high numbers of students for whom English was an additional language, with Ontario authors giving special attention to the challenges faced by ELLs learning science. The Québec chapter authors identified a high rate of immigration leading to challenges of culture, language, and science learning; because most students immigrating to this province must enter the French language school system, the issue is FLLs. The dominant use of science textbooks can limit access to science ideas for ELLs and FLLs. Even hands-on inquiry approaches can place high linguistic demands on students.

Language issues are further complicated by a phenomenon known as *minority language learning*, which can be defined as education in an official language that is not the one most widely spoken in a particular province or territory. For example, students in an English language school system in Québec or students in a French school system in Alberta would be considered minority language learners. There is evidence that students who are minority language learners score lower on assessments such as the Pan-Canadian Assessment Program and the Programme for International Student Assessment (PISA) than their majority language counterparts (O'Grady, Deussing, Scerbina, Fung, & Muhe, 2016; O'Grady & Houme, 2014; Rivard & Gueye, 2016). Language and science are intimately interlinked, causing the three-language problem (Yore & Treagust, 2006)—meaning that when students are learning science in a minority language environment, they are negotiating between the multiple languages of home (language 1), school (language 2), and science (language 3). In minority language communities, the situation is further complicated because students are surrounded by the majority culture; therefore, their day-to-day experiences and prior knowledge of science may not match the language of instruction, which in turn may not align with the language of science. Students in a minority language situation may not have access to a wide range of science-related resources in the language of instruction. The shortage of French language resources for science education is a problem faced by most teachers working within French language programs. Even in bilingual New Brunswick, most ministry-developed science resources are in English and designed to support the English program. Some provinces, such as Alberta, are beginning to increase their attention to creating French language science resources to meet the needs of Francophone and French Immersion learners.

One recommendation in the TRC's final report (2015a) deals with Indigenous language revitalization efforts that were described in detail in the territories' chapters. In the Yukon, Indigenous language programs are offered in most K–7 schools. In Nunavut, students in K–3 are typically taught in Inuktitut, with the goal that Inuktitut education eventually be available for K–12. In the Northwest Territories, Indigenous language programs are encouraged in all schools, but the extent of those programs is dependent upon the availability of fluent instructors. The only provincial chapter to mention Indigenous languages was Québec, where Indigenous children who live on reserves might begin school in Cree or Inuktitut before continuing in French or English at about Grade 3. Clearly, these Indigenous language barriers delay or limit experience-based and language-rich science instruction for these students.

15.3.6 COMMONALITY: Assessment Practices

The common theme of assessment is comprised of three subthemes: assessment *for*, *of*, and *as* learning; global competencies; and province-wide assessments. Five chapters addressed moving beyond summative assessment *of* learning, whether that is adding a formative assessment piece (assessment *for* learning) or taking an explicit *for–of–as* approach where assessment *as* learning includes student self- and peer-assessment. This shift in emphasis is mirrored by a shift from assessing knowledge to assessing skills and competencies.

Global competencies—critical thinking and problem solving; innovation, creativity, and entrepreneurship; self-directed learning; collaboration; communication; citizenship (ON Ministry of Education, 2017)—can be considered as multidimensional capacities that allow individuals to explore issues, understand different perspectives, engage positively with others, and take responsibility for personal and societal well-being (Organisation for Economic Co-operation and Development [OECD], 2018). Several jurisdictions identified a shift in science education towards a competency-based education model. For example, Prince

Edward Island is moving towards the inclusion of 21st century skills in their curriculum, Saskatchewan has introduced cross-curricular competencies, Nunavut *IQ*'s principles are positioned as key cross-curricular competencies, and British Columbia and the Yukon are shifting attention to both curriculum competencies (science inquiry skills) and overall core competencies.

Only two provinces currently offer province-wide assessments in science: Alberta at Grades 6 and 9 and New Brunswick at Grades 4, 6, and 10. Both British Columbia and Newfoundland and Labrador recently halted their respective Grades 10 and 9 science assessments. However, some jurisdictions still require assessments across secondary science electives, typically in Grade 12; for example, all students enrolled in Physics 12 would take a provincially-mandated assessment.

15.3.7 DISTINCTION: Locally-Developed Courses or Alternative Formats

The idea of locally-developed courses or alternative formats emerged as the first distinct theme because of the large variations in application. Locally-developed courses reflect the flexibility of the science curriculum in Canada. Each jurisdiction may establish its own curricula; and many jurisdictions allow for locally-developed courses, which leads to even more relevant science options for students. Locally-developed courses are typically offered at the secondary level and tend to be interdisciplinary, for example, courses about forensic science, Lake Winnipeg, or *Igunaq* (fermented walrus meat). Often locally-developed courses will meet general graduation requirements but frequently do not meet science-specific graduation or university entrance requirements. The number of courses and their availability depend entirely upon teachers' interest. Locally-developed courses were described in particular detail in all three territorial chapters with great detail and tended to emphasize culturally relevant approaches to science education. The prominence of these courses in the territories is likely a response to the current situation, wherein most of their science curriculum is imported from southern provinces, thus giving little attention to issues of importance in the north.

Alternative formats such as e-learning or distance education provide students in rural or remote locations with access to science courses and teachers that are not available in their own community. Chapter authors mentioned a variety of ways in which distance learning can or might occur, for example, fly in fly out, completely online courses, synchronous models where remote students could participate real time in a class in another distance school, and blended learning approaches. Although the cost of such programs was reported as a challenge, the ability to offer more courses to more students is a definite benefit. It is worth noting that New Brunswick maintains two e-learning programs, one in each official language.

15.3.8 DISTINCTION: Instructional Approaches

The second distinct theme that emerged was instructional approaches, including inquiry, science and technology (S&T), experiential approaches, and curricular integration. An inquiry approach is recommended by the *Common Framework* (CMEC, 1997), and the emphasis in science teacher education courses is almost always an inquiry approach to teaching. However, while inquiry was mentioned in many chapters, it was elaborated only in three: Alberta, Newfoundland and Labrador, and Saskatchewan. This limited attention does not imply that the jurisdictional curriculum documents that guide science pedagogy—and that are, in fact, legally mandated with respect to outcomes—do not emphasize inquiry, because they do; however, these curriculum documents seldom provide sufficient support for teachers who have limited experience with this pedagogical approach.

An S&T approach to science education was presented in three chapters: Alberta, Ontario, and Québec. In fact, some of their curriculum documents are S&T rather than science. However, whether science is actually taught through an integrated S&T approach is questionable. An S&T approach is muddied by an outdated use of terminology where *technology* typically, but not always, means engineering (Tippett, Wiseman, & Mendoza, 2017). There is also some confusion about the relationship between STSE as described in the *Common Framework* (CMEC, 1997)—and most science curriculum documents—and S&T.

An experiential approach was the most thoroughly described instructional approach and was an emphasis in the Yukon and Northwest Territories chapters. This regional emphasis may be related to the thoughtful incorporation of teaching practices that are aligned with local cultures and Indigenous ways of knowing.

The final instructional approach that was identified across chapters was teaching science through integration with other subject areas. Several chapter authors wrote about STEM, although almost always in conjunction with teacher education programs rather than in the context of classroom teaching. A single chapter, Nova Scotia, specifically addressed the idea of science being taught in an integrated manner with mathematics and language arts.

15.3.9 DISTINCTION: Environmental Considerations

The third distinct theme was environmental considerations, which included STSE, sustainability education, and elements of teacher education and science curriculum documents. STSE was mentioned across chapters because it is one of the four foundations of scientific literacy as conceptualized in the *Common Framework* (CMEC, 1997). However, with the exception of the Alberta chapter, which presented the social and environmental emphases within the science curriculum, STSE received only minimal attention. The authors of three chapters gave more substantial attention to environmental considerations, reporting that sustainability education figures

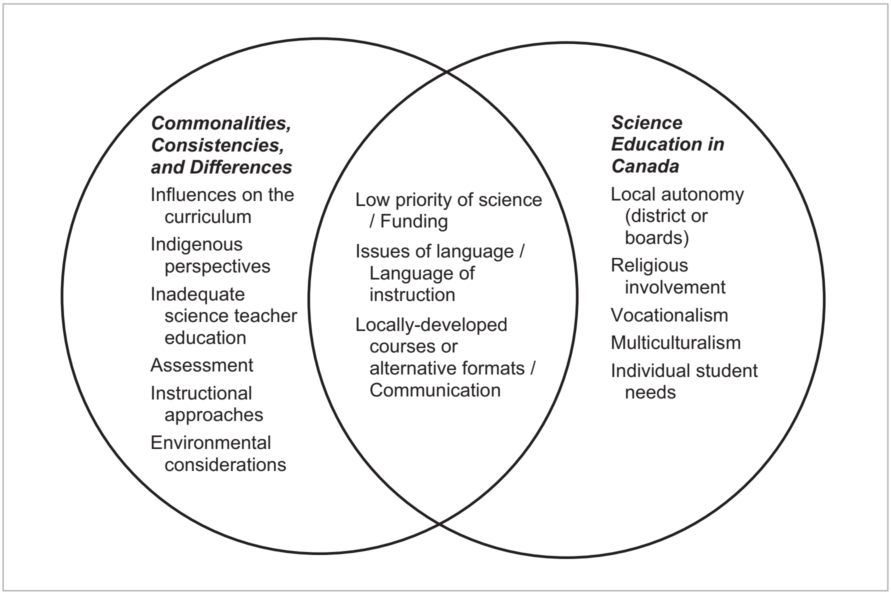

Fig. 15.1 A comparison of the nine themes emerging in this book and the eight issues reported by Connelly et al. (1985)

highly in educational policy (Manitoba); infusing environmental considerations throughout the chapter and comparing environmental education and STSE (Ontario); and highlighting the importance of environmental responsibility and environmental stewardship (New Brunswick). It should be noted that many jurisdictions include environmental education or environmental science courses within their respective curricula, regardless of whether chapter authors mentioned that inclusion.

Comparison of the nine themes that emerged from our analysis with the eight issues identified in *Science Education in Canada* (Connelly et al., 1985)—language of instruction, local autonomy, religious involvement, funding, communication (i.e., communication systems, distance education, exploring technology), vocationalism, multiculturalism, and individual student needs—reveals some areas of overlap (Fig. 15.1). However, clear differences exist, which suggests that needs and context have changed. Indeed, Murray (2015) reported that the expert panel in his 2014–2015 Delphi study identified 11 global trends they considered to be influencing Canadian science education: developing skills for the 21st century, globalization of the international community, integration of Indigenous perspectives/knowledge, national/international standards, national/international student assessments, new learning technologies, reconceptualizing the purposes of science education, relevance of science education to students, science and education for sustainability, science education for economic competitiveness, and STEM. These trends are quite different from the eight contexts described by Berg (1985): characteristics of elementary and secondary education; diversity in Canada's educational foundations, national agencies, and organizations; variations in student enrolment; teacher demographics; provincial and federal financial responsibilities; importance of vocational training; and types of postsecondary education.

15.4 Pressing Issues for Policy and Practice

It is difficult to make defensible generalizations about Canada and its science education policies, practices, and performances. There is variation across the provinces and territories but less variation within jurisdictions (Yore et al., 2014). This variation across the country is highlighted in the thematic analysis of the 13 jurisdiction-specific chapters that, along with recent literature on science education in Canada, suggests a network of policy and practice issues warranting further consideration. The use of a network analogy illustrates that the issues are interrelated; advancements in one area can illuminate other areas. Research activities can, and should, inform policy and lead to evidence-based teaching practices; policy changes can lead to related changes in practices and identify research that may be needed; promising instructional practices can influence policy and research agendas.

15.4.1 POLICY: Refresh the Common Framework

Other countries have recognized Canada for its consistently strong performance on PISA science assessments and have inquired about possible explanations for this performance. Part of Canada's success is likely attributed to the *Common Framework* (CMEC, 1997)—a basic protocol for science curriculum and instruction that was utilized by most jurisdictions over the last two decades (Milford, Jagger, et al., 2010; Tippett & Milford, 2017a). Given the changing contexts of science education, the age of the *Common Framework* and its continuing influence upon jurisdictional curriculum documents, we call for a nationwide deliberative process for its refresh. This call includes an updated definition of the central focus of the original framework (scientific literacy), explicit inclusion of Indigenous perspectives, and thoughtful consideration of STEM in the Canadian context.

15.5 Scientific Literacy

Scientific literacy has been the focus of many international reforms over the last six decades and continues to be the central goal of Canadian science education, as indicated by science curriculum documents. The *Common Framework* (CMEC, 1997) provided a definition that was originally adopted by most jurisdictions:

> Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge [that] students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them. Diverse learning experiences based on the framework will provide students with many opportunities to explore, analyse, evaluate, synthesize, appreciate, and understand the interrelationships among science, technology, society, and the environment that will affect their personal lives, their careers, and their future. (p. 4)

This definition is more than 20 years old; it may not provide policymakers, curriculum developers, and science educators with the architectural framework on which to build and critique curricula, instructional experiences, and learning resources. Therefore, it behooves stakeholders to consider more recent perspectives in a refresh of the *Common Framework*. Unfortunately, there is a lack of consensus on what scientific literacy means, although current theoretical discussions suggest that it is a multidimensional construct (Dillon, 2009). Additionally, since Roberts (2007) proposed Vision I, "the products and processes of science itself" (p. 730), and Vision II, "science-related situations" (p. 730), of scientific literacy, a number of authors have proposed a Vision III that would emphasize civic action (e.g., Liu, 2013; Sjöström & Eilks, 2018; Yore, 2012).

A multidimensional version of scientific literacy in the context of engaged 21st century citizenship could provide design, planning, and critique principles for K–12 science education as well as a foundation on which to address postsecondary science programs. In the interest of initiating discussion, we put forward the model shown in Fig. 15.2.

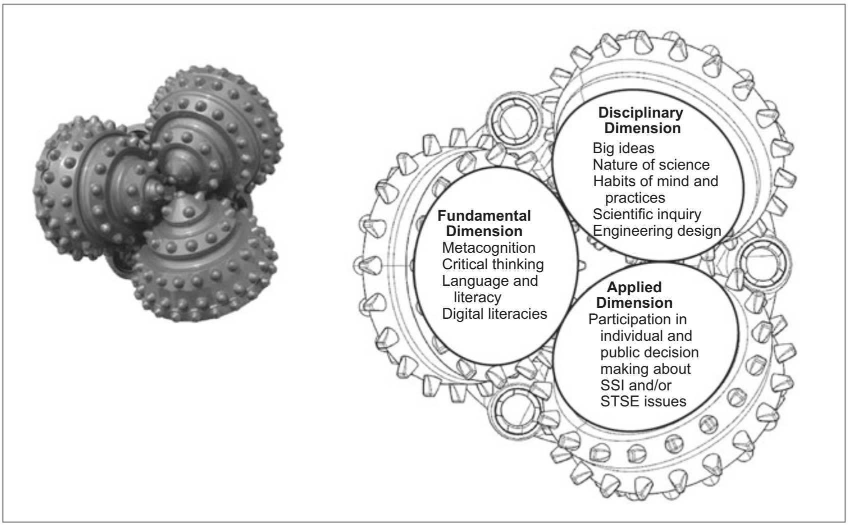

Fig. 15.2 The basic architecture of a 3-dimensional model of scientific literacy: a tricone bit used in mining. This model incorporates the work of Hurd (1958), Shen (1975), Norris and Phillips (2003), Roberts (2007), Yore (2012), Liu (2013), and Sjöström and Eilks (2018), and explicitly addresses personal and public civic action

The specific aspects of each of the three dimensions—fundamental, disciplinary, and applied—provide a starting point for reconceptualizing the definition of scientific literacy. The *fundamental dimension* is the abilities needed to engage with experiences, data, and information sources (metacognition, critical thinking, language and literacy, digital literacies), the *disciplinary dimension* is knowledge about and understanding of the discipline (big ideas, nature of science, habits of mind and practices, scientific inquiry, engineering design), and the *applied dimension* is actions based on knowledge and abilities (participation in individual and public decision making about social scientific issues [SSI] and/or STSE issues).

Situating these three dimensions as crucial for scientific literacy for the 21st century, we turn our attention to the definitions currently in use by the OECD and CMEC. The OECD's definition begins: "Scientific literacy is the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen" (OECD, 2017, p. 22). This statement seems to encompass the applied dimension of civic action, but the remainder of the definition suggests fundamental and disciplinary aspects:

> A scientifically literate person is willing to engage in reasoned discourse about science and technology, which requires the competencies to:
>
> - **Explain phenomena scientifically** – recognize, offer and evaluate explanations for a range of natural and technological phenomena.
> - **Evaluate and design scientific enquiry** – describe and appraise scientific investigations and propose ways of addressing questions scientifically.
> - **Interpret data and evidence scientifically** – analyse and evaluate data, claims and arguments in a variety of representations and draw appropriate scientific conclusions. (OECD, 2017, p. 22)

The most recent iteration of PISA addressed these three competencies while considering knowledge (content, procedural, epistemic), contexts (personal, local/national, global), and attitudes (interest in science, valuing scientific approaches, environmental awareness).

An initial comparison of the OECD definition with the most recent definition from CMEC, which is used in the Pan-Canadian Assessment Program, suggests a misalignment:

> a student's evolving competencies of understanding the nature of science using science-related attitudes, skills, and knowledge to conduct inquiries, to solve problems, and to reason scientifically in order to understand and make evidence-based decisions about science-related issues. (CMEC, 2016, p. 42)

However, when the intentions behind the definition are clarified, the alignment is clear:

> [S]cientific literacy includes more than information recall. … [It emphasizes] an understanding of the nature of science and the use of scientific knowledge and skills within societal and environmental contexts … [and] acknowledges that the disposition to use scientific knowledge and skills is mediated by a student's attitudes toward science and the importance of engaging in science-related issues as a reflective citizen. (CMEC, 2016, p. 42)

These two current definitions, one international and one national, go beyond science knowledge and skills in context to include decision making about scientific issues; however, there is still a noticeable lack of emphasis on fundamental literacy and civic engagement. Everything addressed in the definitions could be accomplished in the classroom, without requiring action on the part of the students either now or in the future.

Deliberations on refreshing the *Common Framework* (CMEC, 1997) would be well-advised to highlight the fundamental, disciplinary, and applied dimensions of scientific literacy, with particular attention to evidence-based public action as a desired outcome of science education. It is also critical that the roles of language in science (negotiating, constructing, representing, and communicating) and the constructive–interpretative language pairs (speaking–listening, writing–reading, representing–interpreting) be made explicit in a refreshed definition of scientific literacy (Tippett, 2011; Yore, 2011).

15.6 Indigenous Perspectives

A refresh of the *Common Framework* (CMEC, 1997) needs to address Indigenous perspectives, which emerged as a common theme across chapters. Other scholars (e.g., Kim & Dionne, 2014) have previously noted the need for the inclusion of Indigenous perspectives in science education. However, the TRC's (2015) calls for action and Canada's 2016 commitment to the *United Nations Declaration on the Rights of Indigenous Peoples* (United Nations, 2007) provide momentum for the recognition of Indigenous Sciences.

Indigenous Sciences—including Indigenous knowledge, traditional ecological knowledge and wisdom, and ways of living in nature (Aikenhead & Michell, 2012; Snively & Williams, 2016)—are shaped by epistemic and ontological characteristics of perspectives on nature and naturally occurring events that include lengthy observations of phenomena and captures accumulated cultural histories and lived experiences. Differences between Indigenous and Western (Eurocentric) sciences can include social and intellectual goals, relationships with human actions, conceptions of time, validity, and general perspectives, which are "holistic, accommodating, intuitive, spiritual *wisdom* versus reductionistic, manipulative, mechanistic *explanations*" (Aikenhead, 2006, p. 113).

Despite these differences, there are multiple models of how Indigenous Sciences and Western science might coexist, including:

- Two-Eyed Seeing, which requires "learning to see from one eye with the strengths of Indigenous ways of knowing and from the other eye with the strengths of western ways of knowing" (Hatcher, Bartlett, Marshall, & Marshall, 2009, p. 146)
- The Two Row Wampum belt, a model that "permits each side to retain its integrity through undertaking its own process according to its own world view. At the

same time, the two sides share information and work in partnership on issues of common concern" (McGregor, 2008, p. 150)
- Braiding, where "each strand remains a separate entity, a certain tension is required, but all strands come together to form the whole" (Snively & Williams, 2016, p. 4)

Each of these models respects the epistemic rigours, recognizes the unique ontological requirements, and engages the cultural experiences of Indigenous and non-Indigenous peoples, which will enrich their learning opportunities and help reconcile differences and injustices.

The infusion of Indigenous Sciences is considered by many science educators as offering *all* students—Indigenous and non-Indigenous—more authentic, relevant, and motivating examples and insights that would help address participation and achievement gaps, engage rich cultural resources, and provide broader perspectives of science (Abrams et al., 2014). There are many ancillary resources that provide ideas for integrating Indigenous perspectives into science education. For example, Aikenhead et al. (2014) developed a Pro-D handbook about culturally responsive science teaching and its four dimensions of curriculum, instruction, evaluation, and patterns of interpersonal interactions; how to build on individual pedagogical strengths; challenges that might be encountered when combining Indigenous sciences with Western science; culturally valid assessment; and teaching to benefit all students (Indigenous and non-Indigenous). However, the only resources we can be assured that teachers have access to are their respective curriculum documents. With minor exceptions, such as Nunavut and Northwest Territories, these documents provide minimal support for teachers, which is typically limited to information provided in the front matter. Even in Saskatchewan, where the definition of scientific literacy includes Indigenous and Western perspectives (see Chap. 4, Saskatchewan, this volume), the learning outcomes themselves barely mention how Indigenous perspectives might be included.

The refreshed framework needs to include specific learning outcomes related to Indigenous Sciences. It could also provide suggestions for recommended locally-developed Indigenous Sciences resources.

15.7 STEM

Perhaps not as urgent in a refresh of the *Common Framework* (CMEC, 1997) as scientific literacy and Indigenous Sciences, but still important, is consideration of STEM education and how it fits with science education. STEM education has garnered attention internationally (e.g., 2017 special issue of the *International Journal of Science and Mathematics Education*) and nationally (e.g., Canada 2067, n.d.), but its place in our distinctive Canadian context is unclear. However, Borden and Wiseman (2016) posited "that a uniquely Canadian take on what STEM education might be is emergent in bringing Western and Aboriginal ways of knowing, being, and doing into conversations with each other in the land that we share and listening carefully to the teachings that arise from it" (p. 141).

Despite the increased attention that STEM has received in Canada, there is no common operational definition or national strategy (DeCoito, Steele, & Goodnough, 2016; Shanahan, Burke, & Francis, 2016). Some advocates position STEM as a means to economic growth and career advancement, often in the separate silos of individual disciplines. However, the economic argument is questioned by those individuals who frame STEM as essential for day-to-day living in an increasingly technological society. Some people view STEM as an integrated disciplinary cluster or at least the purposeful overlap of two or more of the four disciplines (Moomaw, 2013). A holistic definition of STEM could provide a foundation for curriculum, pedagogy, and assessment that might engage a wider range of students than science or the other disciplines on their own, thus enhancing the relevance of instruction.

Given the undefined nature of STEM in Canada, it is not surprising that there is currently no national strategy for STEM education. However, Canada 2067 (2018), an initiative sponsored by Let's Talk Science, is promoting an ongoing discussion of the particular challenges and opportunities that Canadian STEM learning might entail and is developing policy documents with an action plan. What still seems to be missing in this discussion, however, is a clear definition of STEM, what STEM learning might be, and a well-described relationship between STEM education and science education.

Despite this uncertainty, there is a growing body of research on STEM education in Canada. For example, in a survey of middle school students in the Maritime provinces, Franz-Odendaal, Blotnicky, French, and Joy (2016) explored predictors of student interest in STEM careers, which they defined as careers that typically require high school mathematics and science courses as well as postsecondary education. They found that participation in informal STEM activities such as visits to science centres, participation in science summer camps, or STEM fairs was the strongest predictor in STEM career interest although students had a limited understanding of how much science and mathematics were involved in these careers. Tippett and Milford (2017b), who defined STEM experiences as being designed to emphasize at least two of the four disciplines, claimed that findings from a small case study situated in a preK classroom "provide support for the inclusion of STEM-based learning experiences for young children" (p. S67). Unfortunately, in a synthesis of Canadian STEM initiatives and programs, DeCoito (2016) found that "no single or comprehensive overview has been conducted that takes into account the impact of these STEM initiatives on teaching/learning outcomes in K–12 education" (p. 114).

The inclusion of integrated STEM education in K–12 science education would need to be coordinated with changes in teacher education programs and in Pro-D efforts. Teachers face challenges when asked to integrate science and technology, often because they lack a background in one of the two areas (Samson, 2014). Because meaningful and effective STEM education experiences are likely not part of most science teachers' backgrounds, those experiences would need to be incorporated into preservice programs and inservice Pro-D. History is full of examples of excellent science education reform ideas that go unrealized because of insufficient curricular resources and professional preparation; without system-wide changes, STEM could become another such example.

The refresh of the *Common Framework* (CMEC, 1997)—or the creation of a similar pan-Canadian document—requires careful consideration of the three aforementioned areas. The need to redefine scientific literacy is apparent, and possibilities for that redefinition are fairly well established. It is also apparent that Indigenous Sciences must be emphasized in a refreshed framework, although it is less clear just what that emphasis might look like. Despite the attention currently being given to STEM, the relationship between STEM education and science education is not yet clear, making it difficult to determine whether STEM should be part of the refresh or considered separately. Full participation of all jurisdictions and input from multiple stakeholder groups will be essential in a refresh process. This process should focus on the commonalities across the jurisdictions as a foundation, while retaining flexibility for unique regional and local needs and solutions within the final product, to ensure the fullest participation of the ten provinces and three territories.

15.7.1 PRACTICE: Improvements in Teacher Education

Internal dynamics within education ministries, teachers' unions, universities, and faculties of education influence teacher education programs and, therefore, science teacher education. Most decisions regarding the structure of teacher education programs and the requirements for teacher certification are made by ministry of education staff and connected agencies. However, programming and specific funding decisions are frequently influenced by university politics and fiscal constraints. Likewise, departmental politics influence faculties of education when setting course requirements and allocating units. Science education often does not fare well in these internal decisions.

A combination of content knowledge (CK), pedagogical knowledge (PK), and pedagogical content knowledge (PCK), along with sufficient practicum placements, is crucial for well-prepared science teachers (Krepf, Plöger, Scholl, & Seifert, 2018) and should be central to building credible and accreditable science teacher education programs. In regard to CK, many chapter authors pointed to a lack of science content courses in program prerequisites, particularly at the elementary level. Although the number of science prerequisites should be increased, some programs are including one or more science content courses in order to address this shortcoming. However, there has been a lack of commitment from science, mathematics, and engineering departments to offer relevant and authentic disciplinary content courses for teacher education students. On the other hand, PK appears to be very well addressed in most programs and was not an area of concern for chapter authors. PCK, which is developed through experience (Goodnough, Azam, & Wells, 2018), was the area of most concern for chapter authors. The reasons for concern were numerous: there are not enough science methods courses in most teacher education programs, science methods are sometimes taught with other content area methods in a single course, and secondary science teachers often complete a single generic science methods course when they would be better served by either discipline-specific or multiple methods courses. A key component of PCK is field experience; and even though the length of practicum placements meet or exceed accreditation requirements, elementary preservice teachers too often do not get the opportunity to teach—or even observe—science instruction during those placements.

Field experiences are related to preservice teacher efficacy, which can increase when one's teaching is validated by others, when one experiences success with teaching, and when one has a confident and supportive mentor teacher (Cantrell, Young, & Moore, 2003; Palmer, 2006). Most worrisome is that teacher efficacy has been described as "an affective affiliate of PCK" (Park & Oliver, 2008, p. 261). As aspects of PCK are strengthened, teacher efficacy is enhanced, which in turn leads to further growth in PCK. Currently, most teacher education programs are not structured for optimal development of either science teacher PCK or science teacher efficacy. Mandating science teaching placements is difficult, so universities would be better served to focus on what can be controlled, which is improvements to science methods courses. Along with quantity (i.e., more than one required course), methods courses need to emphasize current conceptions of scientific literacy, model inquiry instruction, provide opportunities for peer teaching, and include Indigenous perspectives.

15.8 Closing Remarks

Canadian science curriculum maintains the national intentions of the *Common Framework* (CMEC, 1997) while reflecting regional needs and values. Similarly, science teacher education programs across the country share commonalities while supporting regional perspectives. Regional differences are evident in the challenges faced by individual jurisdictions; even when issues are the same across the country, their relative importance varies according to local context. These regional and national tensions provide the context for future developments in science education.

How has Canada maintained consistently high science performance over multiple iterations of PISA? Answering this question was an underlying motivation for our meso-level analysis of demographics, science curricula, teacher education programs, and pedagogical practices across Canada's 13 jurisdictions, which resulted in nine themes that were categorized as consistent, common, or distinct. These themes provide a starting point for further national deliberations like those that led to *Science for Every Student: Educating Canadians for Tomorrow* (Science Council of Canada, 1984), *Science Education in Canada* (Connelly et al., 1985, 1989), and the *Common Framework* (CMEC, 1997). Such deliberations are once again needed to provide a cohesive set of national recommendations for science education that reflect current sociocultural and sociopolitical influences while allowing room for jurisdictional flexibility. These updated recommendations will provide a structure that continues to support Canada's high science achievement in international assessments.

The fresh perspectives of current science educators and science teacher educators along with input from key stakeholders, particularly those groups that have not previously been well represented, such as Indigenous peoples, will provide rich insights for these deliberations. *Honouring the Truth, Reconciling for the Future* (TRC, 2015a) articulated actions involving Indigenous language, culture, identity, and contributions; knowledge and wisdom about nature and naturally occurring events; culturally appropriate teacher preparation; and curricula that provide momentum for developments in science education.

Future science education research could consider these same themes while exploring causal relationships, identifying statistical associations, and establishing foundations for evidence-based policies and practices. The complexity of this research will be magnified because the identified themes suggest contradictory associations. For example, there may be positive associations between science education performance and the influence of the *Common Framework* (CMEC, 1997) on jurisdictional curriculum, the degree of inclusion of Indigenous perspectives, or the number of locally-developed courses; and there may be negative associations between performance and low priority of science or inadequate science teacher preparation.

One productive research trajectory would be secondary analysis of existing datasets from international, national, and provincial/territorial science assessments. Such secondary analysis could reveal important achievement patterns and relationships amongst and between students, schools, communities, and larger jurisdictions (Milford, Ross, & Anderson, 2010). Datasets from the Pan-Canadian Assessment Program and PISA offer potential avenues to explore these relationships across multiple iterations of these assessments. These datasets are frequently used in secondary analyses; however, relationships across the assessments are not often explored. Both assessments collect jurisdictional-level science achievement data that may allow in-depth exploration of some of the themes identified in this book. Such explorations will be a challenging undertaking because "as school programs differ from one part of the country to another, making comparisons of results is complex" (CMEC, 2018, para. 1) and moves beyond our initial goal for this book: identify potential reasons for Canada's consistent high performance on international science assessments. We intended to set the scene for the next stage of more fine-grained analyses by other researchers and in our own follow-up work.

This book, which puts forth a meso-level analysis of science education in Canada, can support future research in three ways. First, it can provide a context to support metasyntheses of the large body of micro-level studies that examine topics such as science curriculum, representations of science in the media, alternative learning environments, Indigenous perspectives, science learning, and environmental concerns. Second, it can provide a foundation for future meso-level studies such as multijurisdictional research endeavours undertaken by Canada-wide networks of researchers. Third, it can provide a calibration point for macro-level analyses such as international assessments and comparisons. However, we caution that the diverse nature of Canadian science education makes any simple, causal identifications elusive.

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C. D. Tippett, T. M. Milford (eds.), *Science Education in Canada*,
https://doi.org/10.1007/978-3-030-06191-3

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