# Crowding the Curriculum? Changes to Grades 9 and 10 Science in British Columbia, 1920–2014

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## Abstract

In recent years, educators and academics across North America have argued that science curricula have become increasingly crowded, rendering it almost impossible for teachers to address the multitude of learning outcomes mandated in any given document (e.g., Fortner, 2001; Hacker, 1997). Unfortunately, an analysis of the research literature has failed to substantiate this claim with empirical evidence. This study investigated the claim of crowding in the Science 9 and 10 curricula of one jurisdiction: British Columbia (BC). A content analysis of the Grades 9 and 10 science curricula issued by BC's government between 1920 to 2014 revealed curricular change characterized by the expansion

**Canadian Journal of Education / Revue canadienne de l'éducation 38:3 (2015)**

**www.cje-rce.ca**

and reconfiguration of content, persistent attempts to respond to social and educational needs, and constant oscillations between student-centred and subject-centred teaching approaches. This study also illustrates that the potential crowding of the science curriculum suggested by a pattern of constant curricular expansion has as much to do with changing educational theories and ideologies as with scientific developments.

*Keywords:* curricular change, crowding, science curriculum

## Résumé

Ces dernières années, des enseignants et des universitaires d'un peu partout en Amérique du Nord soutiennent que les programmes des sciences deviennent de plus en plus chargés, d'où la quasi impossibilité pour les profs d'atteindre la multitude des objectifs d'apprentissage imposés (par ex., Fortner, 2001; Hacker, 1997). Malheureusement, une analyse de la littérature de recherche n'a pas permis d'étayer ces observations empiriques. Cette étude porte sur le contenu jugé trop chargé des programmes de sciences en 9e et 10e années en Colombie-Britannique. Une analyse du contenu des programmes mis en place par le gouvernement de cette province entre 1920 et 2014 dévoile ce qui suit : expansion et reconfiguration du contenu, essais répétés de répondre aux besoins sociaux et pédagogiques et oscillation constante entre des approches centrées sur l'élève et des approches axées sur la matière. Cette étude illustre aussi que la surdensité potentielle du programme de sciences suggérée par une expansion constante de ce programme a autant à voir avec l'évolution des théories et idéologies pédagogiques qu'avec les avancées de la science.

*Mots-clés :* changement du curriculum, surdensité, programme de sciences

## Introduction

In recent years, educators and academics have argued that science curricula everywhere have become increasingly crowded, rendering it almost impossible for teachers to address the multitude of learning outcomes mandated in any given document (e.g., Fortner, 2001; Hacker, 1997). An analysis of the research literature has failed to substantiate the claim of an overcrowded curriculum with empirical evidence. The current literature tends to have the preconceived notion that science curricula are overloaded, thus stating it as a proven fact. For instance, Gayford (2002) claimed that "there was general agreement that the science curriculum [was] already crowded with little scope for extending enquiries outside the topics already prescribed" (p. 1196). However, he did not provide any evidence as to where this general agreement came from, but rather presented it as a fact. In Czerniak, Weber, Sandmann, and Ahern's (1999) study, participating teachers felt there was no room or time for enacting an interdisciplinary curriculum between science and math in the current overcrowded curriculum. Yet it was not clear from the study why teachers thought the science and math curricula were too crowded. Turner (2008) has noted that there has been frequent criticism that science curricula everywhere are crowded with too much content. These claims ought to be addressed, as they have important implications with respect to teachers' abilities to manage their workload as well as students' capacities to learn.

By examining the changes to British Columbia's Science 9 and 10 curricula through a content analysis of curriculum guides, the purpose of this research was to detect if there has been any pattern/trend of curriculum expansion over time, which is an important indicator of crowding (National Council for Curriculum and Assessment, 2010). In addition, we sought to find possible accounts, either social or educational, that might explain curriculum expansion/changes. More importantly, this study is timely in that British Columbia's government has recently proposed sweeping changes to current curricula with a broad goal of better preparing learners for the demands of the 21st century (British Columbia Ministry of Education [BCMOE], 2012). More specifically, BC's government has proposed to replace the vast number of prescribed learning outcomes with fewer, more broadly conceived topics and competencies that would alleviate curricular crowding and enable learners to probe more deeply into areas of personal interest (BCMOE, 2013).

The specific research questions guiding this study were as follows: (1) Have the Science 9 and 10 curricular requirements in British Columbia (BC) expanded over time? That is, have the scope, size, and depth of science material to be taught and learned increased over time? (2) If so, what accounts for this increase? (3) Can we find antecedents to proposed revisions to the BC 2014 curriculum in past curricula?

## Historical and Contemporary Concepts of Curriculum

This research draws from two main bodies of knowledge: curriculum theory and curriculum history. The search to articulate the meaning and form of "curriculum" is as old as the very notions of learning and teaching when educators—formal and informal—first began to question what should be taught and who should decide. Indeed, the roots of the word "curriculum" originate from the Latin word for "race course": that is, "a place of deeds or a series of deeds" (Bobbitt, 1918). Transferred to an educational context, the broadest conception of curriculum has been defined as all planned learning for which the school is responsible. Planned learning can be long written documents specifying content, shorter lists of intended learning outcomes, or simply the general ideas of teachers about what students should know (Marsh, 2009; Miller & Seller, 1990). Connelly and Xu (2011) divided curriculum studies into subject-matter studies, studies on topics and preoccupations of curriculum, and the study of curriculum theory. For the purposes of this study, we focused on science curriculum guides, also referred to as the curriculum "as planned" (Aoki, 1999). The main reason for this emphasis is that very little exists in the historical record by which to gauge the "curriculum-as-lived" (Aoki, 1999) in classrooms of the past. Furthermore, this research study was exploratory and aimed to set the groundwork upon which future—perhaps classroom-based—research might build.

Historically, the early 20th century served as a curricular battleground between practical-driven education and academic-driven education for numerous educators and philosophers, and was the most productive era in terms of the development of educational ideologies, curriculum theories, and the administrative and pedagogical reforms in schools (Ravitch, 2000). Various educational interest groups—ranging from humanists and developmentalists to social efficiency educators and meliorists—struggled for control of administration, the curriculum, and the philosophy of schools (Calahan, 1962;

Johnson, 1964; Urban & Wagoner, 2000). Ideas and practices that originated from the above-noted interest groups in the United States permeated the Canadian education system in a timely manner. Investigations of Canadian education, such as British Columbia's Putman-Weir Survey published in 1925, brought Canadian curriculum in line with its American counterpart (Lawr & Gidney, 1973).

By the 1930s, curriculum reform in America reached a peak and was characterized by what was labelled as "progressive education," which advocated a child-centred curriculum. Progressive education soon made its way to Canada in the first half of 1930s by way of Alberta, where classrooms became active labs as programs became more student-oriented and experiential (Tomkins, 1986). British Columbia introduced progressive curricula in 1936 to make materials more "meaningful" to children. By the late 1930s, Ontario's revised curricula incorporated three core progressivism principles, including active learning, individualized instruction, and the link between school and society (Christou, 2012).

Another major upheaval in curriculum reform was closely associated with the Second World War and the Cold War that followed. Connelly (2013) pointed out that the Soviet launching of *Sputnik* and the surrounding Cold War conditions created subsequent reforms in the education system in general and in the curriculum more specifically. During the 1950s and the early 1960s, the Space Race drove school reforms toward a subject-centred curriculum that reflected the dictates of academic professional associations in mathematics, physics, biology, and chemistry. Pinar, Reynolds, Slattery, and Taubman (1995) referred to curriculum development during this era as driven primarily by politicians, textbook companies, and subject-matter specialists in the university, rather than by teachers and scholars in curriculum studies. Technological expansion and preoccupations with national security led to increased prominence for science teaching, also known as science literacy, which replaced progressive ideals of students' personal development and life adjustment (DeBoer, 2002).

Historical trends in curriculum development have always been intertwined with broader social and political developments. In the United States, a case in point is the release in 1983 of *A Nation at Risk*, a report from the National Commission on Excellence in Education. Published within a context of slow economic development, the report alleged that American schools were failing due to low expectations, inadequate time to learn, and curricula that failed to challenge students. The report—combined with stagnating economies—subsequently triggered concerns around the world for higher standards, more time devoted to learning, and more challenging curricula and graduation requirements. In Britain, by the late 1980s, a national curriculum was legislated by Parliament (Goodson, 1992). In Canada, the development of Pan-Canadian science curricula was initiated in 1993 following the "nationalization" of curricula in the United States and Britain (Hodson, 1987). The Pan-Canadian science curriculum framework gave primacy to science, technology, society, and the environment (STSE). By the end of the decade, education officials in various jurisdictions across Canada had called for far-reaching curriculum change that would emphasize the nature of scientific inquiry through constructivist approaches. Calls for more constructivist methods for learning were rooted in research indicating that learners do not passively "consume" knowledge but rather actively construct their own learning (cf. Driver, 1988).

## Methodology

This study was historical in nature and used the most common of historical methods: document analysis. The documents examined in detail were Grades 9 and 10 science curriculum guides issued by BC's government between 1920 and 2014. Document analysis is the historical equivalent of *content analysis*, a technique for examining artifacts of social communication such as written documents and transcriptions of recorded verbal communications. In content analysis, thematic patterns are identified, and explanations of the inferences of those patterns are presented. The sampling of content and units of analysis in this study are at multiple levels from words, phrases, and sentences to ideological stance, subject matter, and similar elements relevant to the context (Berg & Lune, 2004). The various curricular documents were examined for scope (the knowledge, skills, and attitudes laid out for students to learn); size (how much content within each domain should be covered); and depth (the level of sophistication or ability required for working with the content). More specifically, the curriculum guides were analyzed for the following: language use at the levels of words and sentences; topics; learning outcomes; assessment strategies; program goals and rationales; and instructional suggestions, where applicable. Furthermore, supplementary historical documents (government directives, circulars, newspapers, memos, secondary sources) were also examined in order to situate curricula in their relevant social contexts.

Document analysis can also reveal trends and patterns over long periods of time. For this study, we analyzed curriculum guides dating from 1920 to 2014. We found that the time span under investigation divided easily into three periods: 1920 to 1936; 1937 to 1969; and 1970 to 2014. The timeline breaks between these eras reflect the natural breaks marked by major reforms in the history of education such as the introduction of progressivism in the 1930s, the implementation of Bruner's spiral-type discovery learning during the 1960s, and the Neo-Progressive Revival in the late 1960s, epitomized by Ontario's *Hall Dennis Report* aiming to shift from subject-centred curricula to progressive child-centred curricula, driven by major social and political changes including the Great Depression, the Second Word War, the Cold War, and neoliberalism.

Figures 1 and 2 plot the changes in page numbers alone, which not only serve as indicators of expansion but also shift during certain pivotal years: 1920, 1937, and 1969. Each dot in these figures represents a year when curricula were revised. It can be seen from the two figures that the curriculum guides experienced the two sharpest volume increases in the late 1930s and the late 1960s. The implications of curriculum guides' change in volume will be elaborated upon later in the article.

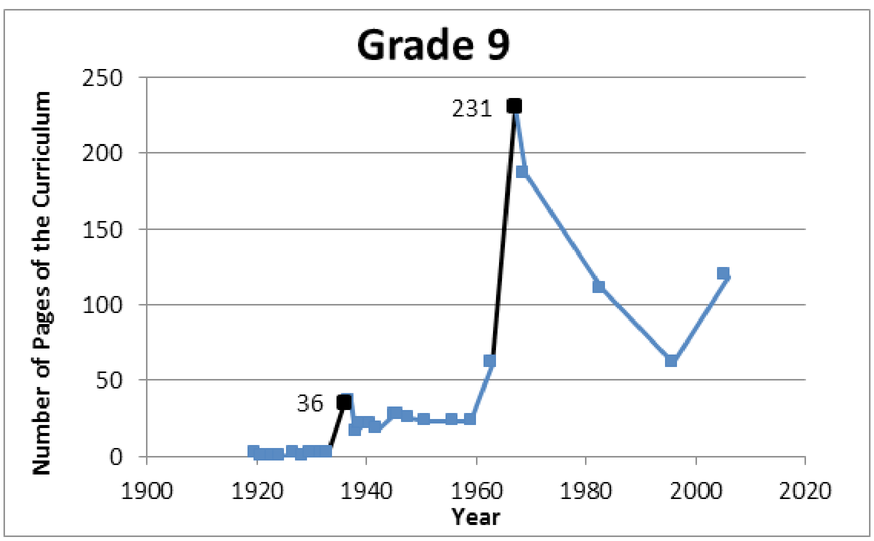


*Figure 1.* Number of pages of Grade 9 science curriculum guides from 1920 to 2006. The black lines indicate years of major curriculum expansion.

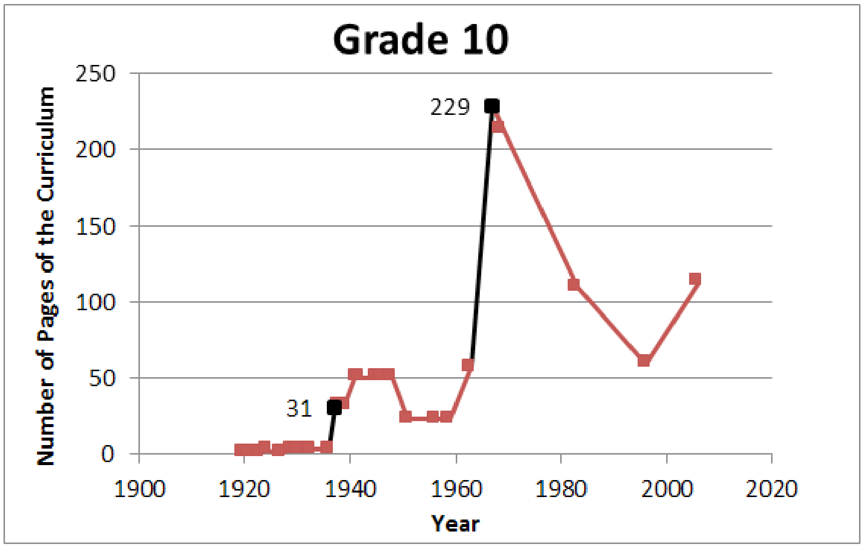


*Figure 2.* Number of pages of Grade 10 science curriculum guides from 1920 to 2006. The black lines indicate years of major curriculum expansion.

# Findings

## Curricular Change: 1920 to 1936

British Columbia experienced a period of brief economic prosperity during the 1920s. The Panama Canal had realized its full potential and BC's traditional exports, such as lumber, as well as new exports like Okanagan apples and prairie grain, were transported through the canal to trading partners such as Britain and continental Europe. Vancouver led the province in economic growth, and its residents' wages increased by 12% between 1922 and 1928. As the economy grew, concern over the welfare of children, particularly with regard to schooling, also increased. The number of years that children stayed in school climbed, and by the late 1920s a majority of children were completing a full term of elementary schooling with regular attendance (Barman, 2007; Ormsby, 1958). As society changed, so too did the province's curricula from 1921 to 1936, in three key ways. First, newly revised curricula included more content and learning activities. Second, teachers' pedagogical guidelines expanded and became more elaborate. Third, teachers were increasingly instructed to guide students toward the development of higher level skills and more in-depth exploration of subject matter.

At both Grade 9 and Grade 10 levels, curricula witnessed the addition of content with virtually nothing being removed. Science curricula of the early 1920s were in very primitive form and merely provided a list of prescribed textbook chapters within which the content prescribed by educational authorities could be found. The first additions to this content were made in 1921, when salt and its products (as well as carbon) were added to the chemistry section of the Grade 10 curriculum. In the Grade 10 curriculum of 1923, the botany section introduced a new topic on plants of economic importance in British Columbia, while more chapters of the textbook continued to be added to the chemistry section. The agriculture section added livestock study and the physics component gained three additional experiments. By 1924, Grade 10 science included four more chapters of physics compared with that of 1923 and prescribed 20 mandatory experiments to be conducted by students.

An expansion of the Grade 9 science curriculum in 1927 was characterized by a unification of multiple science disciplines (i.e., Earth science, physics, and biology) into *general science*, which increased to include 10 comprehensive topics (for example, work and energy, electricity, and reproduction in plants and animals, to name but a few). Until 1927, the chemistry component of Science 10 advised teachers to omit "questions requiring numerical calculation" (British Columbia Department of Education [BCDOE], 1924, p. 9). However, that year, numerical calculations became mandatory. In keeping with the progressivists' emphasis on child-centredness, the 1927 program offered "constants" (such as English, social studies, health, and physical education), which were required for all students, and "variables" (such as French, science, agriculture, and mathematics), which were electives for individual choice. Furthermore, the Science 9 curriculum of 1927 touched on topics such as the economic and social importance of internal combustion engines, which helped students to understand the economic shifts that were shaping their society.

In 1929, more chemistry content was added to Science 10, which required students and teachers to work through more required book chapters. The gradual expansion of the secondary chemistry curriculum in the early 20th century was in line with the expansion of the manufacturing industry triggered by the advent of the First World War.

Manufacturing sectors, such as the iron and steel industry, involved a variety of chemical reactions on a large scale, calling for workers and technicians equipped with extensive chemistry knowledge (Chemical Institute of Canada, 1969).

In 1930, botany was taken out of the curriculum when biology first entered as an elective. Biology, of which botany was a branch, entailed a more comprehensive study of living forms, including both animals and plants. By 1932, the Grade 9 science curriculum featured problem-based learning (PBL) which incorporated Dewey's ideas of learning through active inquiry. This inquiry-based approach caused major concepts previously expressed in the form of statements to be transformed into scientific questions, such as "How does water work for me?"; "What is the source of energy?"; and "How does man use electrical energy?" Each scientific question was followed by a list of subject matter that aided in understanding the question. Significant new topics of subject matter, such as wireless communication, cell differentiation, and application of electricity in daily life, were also introduced. In particular, the topic of cell differentiation in multi-cellular organisms was an extension from the previous topic of cell division of single-celled organisms in the 1927 curriculum.

The Grade 9 science curriculum experienced the biggest expansion in 1936 with the introduction of the "unit" system, which represented "large comprehensive topics" built around "central thought or fundamental principles" (BCDOE, 1936, p, 1). In essence, the program adopted the student-centred approach advocated by progressivists, and was designed to assist the child in his or her growth and self-realization, and in adjusting to and modifying his environment. Topics related to biology, chemistry, environmental science, Earth science, and physics were categorized into 10 units. In addition, the program in 1936 further provided more pedagogical information for teachers, reflecting the rise in the field of psychology and its nascent understanding of information processing as well as adolescent motivation. For instance, there was suggestion to teachers that students should not be required to memorize a particular formula but should know how to use it. Within each unit, the "timeline of unit," "statement of unit," "aims," and "references" were laid out, and they were followed by tables of "Subject matter," "Approaches and Methods," and "Activities and Notes" (BCDOE, 1936).

## Curricular Change: 1937 to 1969

After 1936, the science curriculum continued to expand with the inclusion of more subject matter, the development of instructions on teaching and learning as well as the requirement for teachers to help students develop higher level skills. Climate science and meteorology first came into the secondary science curriculum in 1937, through a unit introducing the topic of the atmosphere's role in climatic and weather conditions. It was a time when weather forecasting, particularly numerical weather forecasting, had been developing in the United States, due perhaps to the drought that had ravaged North America during the Depression years (Nebeker, 1995).

In 1941, the subject matter prescribed by the curriculum did not increase significantly; however, as many as 20 to 30 educational films were recommended to be shown to students at the end of each unit for enrichment purposes. This fit with the recommendation of progressive educators to bring the community to the classroom. Furthermore, during the Second Word War, British Columbia grew economically in such areas as railway building, mining and smelting, and pipeline construction, to name but a few (Barman, 2007). Correspondingly, in 1942, Grade 9 Science introduced two units of topics on the use of sandstone and other minerals for construction, and the extraction of coal and petroleum as important sources for energy and other industrial products.

In 1951, the Grades 9 and 10 science curriculum underwent another major reorganization and reconstruction. The section consisting of elements and compounds was organized into its own unit that year, whereas previously it had been embedded in the unit relating to the composition of the Earth's crust. The topic of house construction was transferred to Grade 10 science, and two biology units were merged into one. The previous unit of "application of scientific principles to housing instruction" was eliminated and was replaced by the study of energy and electricity, reflecting a shift in the provincial economy. Furthermore, the curriculum included many new topics aimed at familiarizing students with the new economic and social environment. A unit on power development and its application to transportation was included in 1951, which was likely a response to the major expansion in highway and vehicle sectors in BC during the 1950s (Gillen, 2012). The fourth unit of Grade 9 science sought to provide students with comprehensive knowledge related to the mining industry, and introduced topics of mineral deposits, ore-body, and metallurgy, among others. In fact, throughout the units of Grades 9 and 10 science of 1951, man's control over—and uses of—the environment were heavily emphasized. As the petrochemical industry developed, the curriculum reflected the use of chemicals in peoples' everyday lives, such as how to use salt in cooking and cleaning, as well as the use of chemical compounds in cosmetics. The fifth unit of Grade 10 science summarized methods for protecting and making wise use of the Earth's natural resources. Forest industries, fishing, mining, and agriculture were all identified as industries that extensively used our natural resources for improving our standards of living. In turn, the curriculum also recognized the problem of conservation posed by the alleged progress of civilization.

Bruner's discovery approach started to permeate science curricula throughout the 1960s, following the Soviet Union's launch of the *Sputnik* satellite. Educators and policy makers feared falling behind in the global Space Race and set about encouraging young people to become scientists (Newton, 1988). Bruner believed that each academic discipline could arouse curiosity in children, thus rendering it unnecessary to relate subject matter to children's daily experience in order to attract their interests (Bruner, 1963). He further believed that through discovery learning approaches, students could learn best the underlying structures of each discipline they encountered—including science. The focus shifted from experiential learning, an essential approach of progressive education intending to associate education with children's daily activities, to understanding the knowledge and subject matter within disciplines. The discovery approach made its debut in BC Science 9 and 10 curricula in 1963, when two alternative physics units assumed a predominant laboratory-centred paradigm, in which a series of experiments either to be demonstrated by teachers or to be conducted by students directed the course of study. Later in 1967, the entire curriculum guide, to a great extent, became a sequence of experiments with an emphasis on skills and processes of science.

During the 1960s, the introduction of the Space Science unit was a sign of Canada's endeavour in the development of space science, goaded by the post-*Sputnik* space technology competition between the US and the USSR. Also, it was timely in that Canada launched the satellite *Alouette* in 1962, becoming the third country to design and build its own satellite. By 1967, a remarkable expansion of chemistry units had occurred through a dramatic increase in the space and time allotted to the chemistry section of the curriculum. The chemistry unit in the Grade 9 science program was increased by 28 pages, accompanied by a 52-page surge for Grade 10. More challenging topics demanding analytical skills or mathematical mastery, such as chemical reactions and equations, required more effort being put into teaching and learning to achieve the desired goals in the allotted time. Additionally, Canada's investment in the nuclear industry, such as developing nuclear power reactors that were later used to generate low-cost electricity, likely contributed to the presence of the radioactivity unit in Science 10 program in 1967. The unit focused on basic theories and concepts in nuclear physics such as radioactive decay and nuclear fission and fusion, but had not introduced much about the application of nuclear power, possibly since the nuclear industry was still in its infancy.

Prior to 1969, the biology curricula had advised teachers to break the class into groups and assign each group to conduct a different experiment and pool results with others. In 1969, the biology unit required all students to do all the prescribed experiments. Furthermore, in 1969 BC's science curricula designers first acknowledged that too much material had been prescribed in the curriculum and counselled teachers to adapt material in accordance with their teaching competencies and students' capabilities (BCDOE, 1969).

## Curricular Change: 1970 to 2014

In 1970, the unit entitled "Electricity, Magnetism and Radioactivity" was split into two separate units—"Electricity and Magnetism" and "Radioactivity," with both units covering additional subject matter. As well, mathematical skills (such as solving linear equations), which were not necessary for most enquiries in the previous curriculum, were now required in several investigations. Revisiting the student-centred approach of the 1930s and 1940s, BC's 1983 curriculum replaced the description of subject matter with a series of learning outcomes addressing multiple facets of science education, including attitudes, skills and processes, and knowledge and thinking abilities, the meeting of which would lead to the achievement of curriculum goals. This was a major shift in how curriculum was conceptualized. A wide variety of activities, including group work, field trips, experiments, multimedia presentations, and research projects—among others—were suggested for use in conjunction with the teaching of factual information prescribed by textbooks. Being investigative in nature, the program went beyond the learning of facts and attempted to draw upon higher thinking abilities and scientific attitudes, thus necessitating teaching and learning in greater scope and depth. In 1983, when nuclear power was increasingly used across Canada, the curriculum recommended teachers implement various activities such as class debates on the pros and cons of nuclear power plants and films on nuclear energy, as a way to raise awareness of the multifaceted social and industrial outcomes of this new source of energy.

Additionally, the 1983 Grade 9 science curriculum introduced the topics of renewable and non-renewable sources of energy. The introduction of Canada's controversial National Energy Program in 1980 and the dependence of BC on hydro power, likely influenced the inclusion of these topics into the science curriculum. BC Hydro and Power Authority had built six large hydro-electric generating projects between 1960 and 1980. Canada's National Energy Program was created by the federal government in response to the energy crisis that had commenced a year earlier. Its goals included increasing Canadian ownership of the oil industry, achieving oil self-sufficiency and gaining a greater share of energy revenues (Helliwell, MacGregor, & Plourde, 1983).

By the 1990s, the context of schooling in North America had shifted yet again—as did the science curriculum. Parental pressure, as well as the collapse of various manufacturing industries, prompted the public to question whether our schools were preparing students to compete with rising global economic powers. Educational policy makers around the world shifted their focus from curricular inputs—in the form of specific proposed learning—to outputs or prescribed levels of achievement. Accountability became the watchword and achievement indicators and graduation requirements became more rigorous (Calderhead, 2001). Whereas curriculum designers recommended only general assessment strategies in prior curricula, by 1996 they were recommending multiple ways to gather information—sometimes referred to as "data" —about students' achievement (Earl & Torrance, 2000). In the science curricula, teachers were advised to look for evidence that students could apply standard graphing conventions for line graphs and identify the basic patterns within the periodic table. The detailed assessment strategies aimed to evaluate the extent to which learning outcomes were met to ensure that teachers were adhering to the curriculum.

By 2006, students were required to meet all prescribed learning outcomes (PLOs) laid out in the curriculum as opposed to previous curricula where teachers might have choices in meeting PLOs. These were to be monitored constantly by teachers through a multitude of assessment strategies, which not only expanded the amount of work that students were required to complete, but inevitably increased teachers' workloads. In

1996, science curricula stated that prescribed learning outcomes should be expressed in observable terms but the reworded 2006 curriculum stated that prescribed learning outcomes should be expressed in observable terms as well as measurable terms, emphasizing the measurability of learning outcomes. Reflecting policy makers' preoccupation with accountability, assessment processes were introduced through the incorporation of a *student achievement indicator* section. Additionally, the 1996 curriculum provided the learning outcome statement only to assist teachers in making their own choices of PLOs based on their context and their students' needs; on the other hand, the 2006 curriculum clearly stated that "[s]chools have the responsibility to ensure that all prescribed learning outcomes in this curriculum are met" (BCMOE, 2006, p. 27).

The new emphasis on measurement was clearly evident in the 2006 science curriculum that plainly stated which activities should be used to achieve a particular learning outcome, what students should be able to do to show their achievement of the learning outcome, and what processes and strategies should be employed to assess students' work. The *prescribed learning outcome*, *student achievement indicators*, and the *assessment strategies* sections were closely linked to each other to ensure that every single prescribed learning outcome would be met. For example, one prescribed learning outcome under the organizer Life Science required students to explain the process of cell division. One of the corresponding suggested achievement indicators was that students describe cancer as abnormal cell division. The assessment strategies suggested the teacher have students write a "What Is Cancer" booklet and assess the booklets on the extent to which students included information about how cancer relates to cell division, potential contributing factors to cancer, and terminology such as benign, malignant, and metastasis.

## Moving Forward?

Partially in recognition of crowded and somewhat unmanageable curricula, government released "The BC Education Plan" in October, 2011. The Plan aimed—among other things—to simplify curricular requirements. Over the past few years, BC's government has consulted extensively with provincial educational advisory groups, held provincial and regional conferences, and held inquiries regarding best practices for transforming education to address the needs of all learners more effectively. Not surprisingly, a recommendation emerging from the above process was that "the Province needs a more flexible curriculum that prescribes less and enables more, for both teachers and students" (BCMOE, 2013, p. 2).

The proposed science curricula are designed to facilitate: more personalized (less standardized) instruction, critical thinking skills, cross-curricular/interdisciplinary competencies, and inquiry based learning, all of which can find their antecedents in past curricula. Each of these is discussed below with reference to our historical findings.

## Personalized Learning

The curricula of 1936 stated that instruction should be adjusted within the course of study to fit to the needs of the individual. Although the science curriculum was outlined in considerable detail, teachers had the freedom to make their own choice in selecting the appropriate subject matter most relevant to students' interests and appreciations, and to the formation of attitudes and ideals. This differentiation of instruction is similar to the philosophy of the new curriculum of 2014 where instruction is personalized and is made more relevant to learners.

## Critical Thinking Skills

Critical thinking skills were stressed by the secondary science curriculum in as early as 1936, when students were required to apply the learnt ideas and theories in solving real problems. The curricula of 1983 also required students to develop higher levels of thinking abilities, for example, by deducing the nature of the interior of the Earth with seismic data. The new curricula of 2014 transcended the idea of critical thinking skills and put forward creative thinking competency. New ideas and concepts are encouraged to solve existing and emerging real world problems. In fact, the goal of developing critical thinking skills in science has been popular since the 1940s.

## Cross-Curricular and Interdisciplinary Competencies

Integrated teaching approaches were extensively used in the 1983 curriculum to facilitate interdisciplinary and cross-curricular learning, which is also emphasized by the draft 2013/2014 curricula.

The 2014 curriculum aims to support teachers in organizing learning outcomes in integrated or thematic units, a teaching method that was used extensively in the 1983 curriculum. This curriculum was designed to facilitate interdisciplinary and cross-curricular learning. The six curriculum organizers—Astronomy and Space Science; Changes in Matter; Changes in the Environment; Ecology and Resource Management; Energy; and Life Functions—each characterizing a specific subject area, were taught in one or two thematic units in an integrated manner. For example, the six organizers could be reorganized into two themes: Human Body: Maintenance and Care, and Changing Ideas about the Universe. The first theme incorporated a selection of topics and learning outcomes from the Changes in Matter organizer (e.g., topic: nutritional components of food, learning outcome: develop a curiosity about the composition of matter), and the Ecology and Resource Management organizer (e.g., topic: food sources, learning outcome: describe the local biome), as well as the Energy and Life Functions organizer (e.g., topic: conservation of energy in agriculture, learning outcome: demonstrate an understanding of the law of conservation of energy). It can be seen that food, which fell under the theme Human Body, could be investigated from multiple perspectives, and in a way that integrated the learning outcomes from different organizers. The second theme also incorporated a variety of topics and learning outcomes across the six organizers. The combination of both themes included almost all topics and learning outcomes prescribed under the six organizers, and presented the topics in a logical and integrated fashion.

## Inquiry-Based Learning

An inquiry-based approach advocated by the new draft science curriculum of 2014 aims to facilitate a comprehensive inquiry process including questioning and predicting, planning and conducting, processing and analyzing data and information, and evaluating and communicating. Such an inquiry-based approach has also been adopted in past curricula such as those of 1932 and 1967.

The most significant feature of the 1932 program was problem-based learning (PBL) structure. For example, the former description of the unit "Electricity" in the statement form was transformed into the question: "How does man use electrical energy?" This problem-based learning paradigm marked a departure from lecture-based learning and emphasized child-centred learning. It also became the antecedent of inquiry-based learning. In 1967, the discovery approach evident in the curriculum supported scientific inquiry-based learning through hands-on experiments. For example, when studying electrolytes, students were not given a set of previously identified solutions. They were required to recognize the existence of a set of solutions, such as hydrogen chloride and hydrogen acetate, having certain properties in common, from their own observations and experimentation, and summarize those properties after they identified them. They would only be informed of the class of the solutions (such as acid) after they had conducted their own explorations.

# Conclusion

The findings from this historical content analysis reveal that British Columbia's Science 9 and 10 curricula have witnessed (1) an increase in the amount of prescribed topics and learning activities, (2) a deepening of the knowledge and skills that students must demonstrate, and (3) an expansion of the ways in which teachers must undertake instruction and facilitate learning. The constant expansion of the science curriculum did not only result from educational reforms. Historical documents and media information showed that science education was sensitive and responsive to a variety of social, economic, and environmental changes and therefore included a variety of more issues and topics in the science curriculum. Following is a summary of further reflections on the three major findings.

## A Long-Term Trend of Curriculum Expansion

The Grades 9 and 10 science curriculum of BC expanded in the following three ways: (1) the inclusion of more subject matter and learning activities, (2) more detailed guidance on teaching and instructions, and (3) the requirement of higher-level skills and exploration of subject matter at a greater depth. It was evident that the science curricula of the second half of the 20th century prescribed much more than those of the first half of the century. For example, the curricula after the 1950s generally prescribed 15 to 20 topics while the curricula before 1936 generally covered only 5 to 10 topics. More importantly, unlike the early curricula which focused solely on knowledge acquisition, the later curricula gradually incorporated requirements on a variety of educational outcomes, including skills, attitudes, critical thinking abilities, social responsibilities, and interdisciplinary studies, among others. Furthermore, the curriculum makers themselves admitted in as early as 1969 that programmes of study consisted of too much material, including but not limited to knowledge, skills, processes of science, and attitudes. The findings of this research provide empirical evidence to support the curriculum designers' own observations. Another simple and direct way to probe the vastness of science curricula is to look at the volume of each curriculum in terms of page numbers. The number of pages for each Grade 9 and Grade 10 science curriculum from 1920 to 2006 (Figures 1 and 2) gives us a general idea of curriculum growth in terms of sheer volume. For example, before 1936, the Grade 9 science curriculum generally had just one or two pages, but with the advent of the unit system, the curriculum expanded to 36 pages. This was the first major expansion of the science curriculum. Since then, the volume of the curriculum fluctuated by a small amount and almost stabilized until 1967 when the page number surged to 231. This reform turned science curriculum guides into lab manuals, featuring more than 60 experiments described in detail, and was a direct result of an adherence to Bruner's discovery approach. If the curriculum had been better structured and the detailed descriptions of experiments had been moved to a lab book, the curriculum would have been around 50 to 100 pages. As we can see from the following years, a total page number of 50 to 100 is the norm for science curricula after 1960. A robust conclusion from this analysis is that the volume of pages in the curricula in the second half of 20th century is much more than that of the first half of the century, indicating a substantive expansion of prescribed material.

## Expansion Driven by Changing Social Contexts and Pedagogies

The constant expansion of curricula was one of the outcomes of reforms in educational ideologies and pedagogies led by various educational interest groups and influential educators. Among all the educational reforms, progressive education in the 1930s and the discovery learning movement in the 1960s led to the biggest changes in the Science 9 and 10 curriculum of BC. The implementation of John Dewey's notion of experiential learning greatly expanded the science curriculum during the late 1920s to 1930s. The curriculum suggested that students should learn the facts and laws of scientific subject matter through familiarity with everyday social applications. Following this principle, curricula began to include not only a vast amount of subject matter but also activities pertaining to valuable life experience such as the use of facilities that utilize electricity, heat, and light. Also, curriculum makers intended to choose subject matter and experiences that were conducive to assisting children in fitting into society and acquiring capacity for readjustment should his/her environment change. As a result, the science curriculum included such topics as "man using electrical energy to satisfy human needs," "man improving the quality of the plants and animals which he needs by learning to control some of the biological factors in his environment," and "man making advances in the field of chemistry towards supplying his needs by learning the laws of chemical reaction," among others (BCDOE, 1936). This reflected the desire of educational policy makers to reach more diverse students who were required to remain in school for longer (Barman, 2007). The massive implementation of Bruner's discovery learning approach during the 1960s and 1970s, which emphasized learning through problem solving, turned the science curriculum guide into a voluminous laboratory manual which included a sequence of more than 60 experiments.

Furthermore, supplementary analysis of historical documents and media information indicated that public education was responsive to social, economic, and environmental changes, and therefore tended to include more issues and topics in the science curricula. The latest example is the inclusion of topics relevant to climate change in the draft curriculum of 2014. As the causes and impacts of climate change and global warming are more understood, many governments around the world, including Canada, are beginning to take steps to address it. Developing policies and actions on climate change is on the government agenda, as is educating the young generation of the science of climate change. The draft 2014 BC Science 9 curriculum incorporated topics such as the carbon cycle, forms of carbon, and the interactions between the lithosphere, atmosphere, biosphere, and hydrosphere. Knowledge of the above paves the way for a more thorough investigation of climate change in later grades and in university: the knowledge of carbon cycles and forms of carbon are conducive to the understanding of the sources and sink of carbon dioxide, which is the most important anthropogenic greenhouse gas. Understanding interactions among various components of the Earth contributes to the learning of the concept of the climate system which replaced an earlier, more simplistic view of climate in the current secondary science curricula—mainly the notion of the average state of the atmosphere being the climate. Climate modelling, an essential tool used to investigate the causes and consequences of climate change, is based on developing a quantitative description of different components within the Earth system, along with their interactions.

## A Revival of Child-Centred Learning?

The pendulum of the BC science curriculum has been swinging between focusing on addressing the child's needs and interests and placing emphasis on the learning of prescribed subject matter (Figure 3). The goal of the curriculum after 1950 became fairly responsive to various competing demands such as personal development, mastery of subject matter, and social construction. Furthermore, both child-centred and student-centred pedagogy were always interwoven in the curriculum with the aim of striking a balance between the two. Therefore, what is presented in Figure 3 is debatable and serves as the basis for further discussions on the practices of the two types of pedagogy in science education.

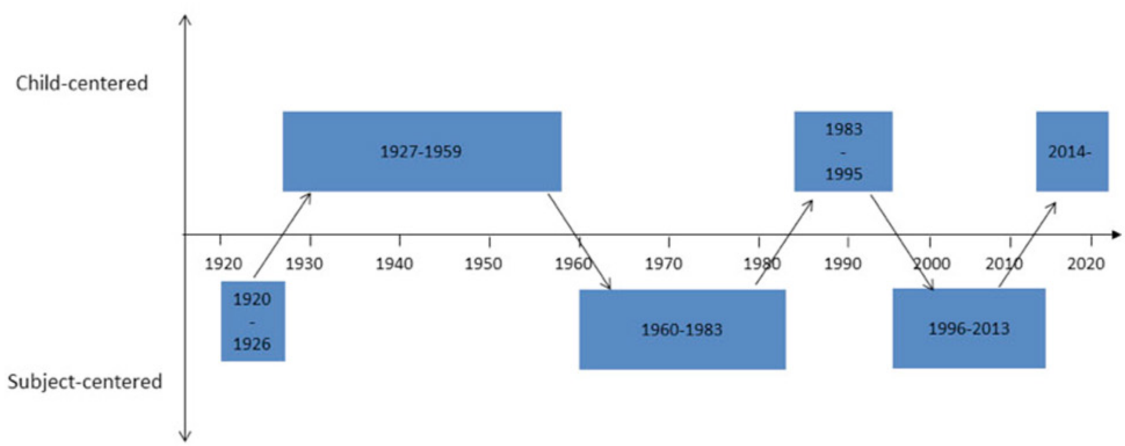


*Figure 3.* Timeline: Oscillations between child-centred and subject-centred curricula from 1920 to 2014. Curricula in years above the temporal axis are more child-centred; those in years below the axis are more subject-focused.

During the 1920s, the science curriculum guide was in very primitive form and generally just provided a list of chapters and experiments from prescribed textbooks. Emphasis was placed on the learning of subject matter, mastery of knowledge, and comprehension of principles. Individual interests and differences were not considered in the curriculum of the early to mid-1920s. The first critical turning point of public education in BC was during the late 1920s and 1930s, when the philosophy of progressive education, particularly the idea of child-centred learning, was infused in the science curricula. The goal of the program of 1927 was to draw upon facilitating experimental direction of pupils' interests, inviting more flexibility in curriculum organization and administration, and providing career guidance through individual diagnosis. The curriculum of 1936 emphasized the importance of making provisions for individual differences. Teachers were required to focus on the quality of work rather than the quantity of it, and to make informative selections of subject matter that were relevant to the child's interest and appreciations, and to their formation of attitudes and ideals.

The second critical reform of science education in BC coincided with the publication of the report of the Royal Commission on Education in 1958 and the prevalence of Bruner's discovery learning pedagogy during the 1960s. Part of the broad mandate imposed by the report included intellectual development within academic disciplines, such as acquiring useful facts and information, as well as instrumental skills. This period of subject-centred education was a response to the fast-growing economy and international competition in facilitating scientific literacy in public and fostering talented young scientists.

Laboratory-centred science education lasted for more than a decade before the child-centred approach, which the discovery approach had once replaced, took over again in 1983. The new program of 1983 was designed to help students understand the physical world and how humans fit in to it. Hands-on activities such as group work, field surveys, and research projects, to name a few, were extensively employed by the new program, which aimed to assist students in directing their own studies on fundamental ideas and concepts of science, as well as the application of science, all of which are of personal and practical nature to learners and of importance to society. The fact that the curriculum of 1983 was student-centred is especially interesting as the back to basics movement, which demanded more rigorous and traditional curriculum, prevailed in late 1970s and 1980s in North America (Pines, 1982). However, a child-centred curriculum does not necessarily mean subject-matter learning is de-emphasized. In fact, the curriculum of 1983 is the first curriculum that formalized the section labelled as prescribed learning outcomes (PLOs), providing a comprehensive description of the attitudes to be developed, the skills to be practised, the knowledge to be understood, and the thinking ability to be achieved.

The way that the curriculum was tailored more toward students' needs was that the listed learning outcomes were designated as either essential or optional. The essential learning outcomes applied to all students while the optional learning outcomes were selected by teachers based on their locale. The science program in 1983 was labelled child-centred more in the sense of going in the opposite direction to the previous curricula in the 1960s and early 1970s in which disciplines were separated rather than integrated and there was no flexibility for addressing students' interests and needs at all.

The 1996 and 2006 science curricula prescribed significantly more learning outcomes and assessment strategies for students' achievements than ever before. As a result, there was little room left for teachers to personalize instruction or to encourage students to develop their own interests, even though the curricula also stated that students should do so. The new curriculum of 2014 proposes to reverse this trend toward overcrowding and shift away from subject-centred education toward a new era of child-centred education. However, we believe that the question of whether the newly drafted curriculum will, in fact, reduce overcrowding is debatable. We suspect that the science curriculum will remain crowded. Our assertion is based first and foremost on the results of this study that have tracked a long-term trend of expansion over almost a century. Secondly, as indicated in Tables 1 and 2 (see Appendix), the Science 9 curriculum of 2006 consisted of 20 topics whereas the newly drafted curriculum consists of 18, a reduction of merely 10% of the former content. Given that curricular reductions are meant to enable more in-depth learning, we recommend further research to determine whether the 2014 draft curriculum has significantly "prescribed less and enabled more" (BCMOE, 2014). Additionally, as Connelly (2013) pointed out that curriculum policy illuminates school boards, teacher organizations, planning committees, parent groups, and the media, this study needs to be complemented by an investigation into curriculum policy for forces behind curriculum reform. Further studies on the understanding of the gap between what Ted Aoki (1999) referred to as "curriculum as planned" and "curriculum-as-lived" will shed light on the actual curriculum implementation in the classroom.

Finally, this study raises an important question for further consideration. It is unclear why science curricula have become more descriptive and prescriptive over the same time period as teachers have become better educated. That is, there appears to have been less government direction in earlier curricula when teachers had very little formal pedagogical preparation before entering the classroom. Today, the extent of formal direction over teachers' work far exceeds that of the early 20th century, despite the fact that high school science teachers today have between four and six years of postsecondary education. This phenomenon, too, is worthy of future inquiry.

# Appendix

**Table 1.** List of Topics in the Science 9 Curriculum of 2006.

| Scope \ Sequence | Science 9 Topics | References |
|---|---|---|
| Life science | Process of cell division | Refer to the curriculum |
| | Relating the processes of cell division and emerging reproductive technologies to embryonic development | |
| | Comparison of sexual and asexual reproduction | |
| Physical science | Modern atomic theory | |
| | Periodic table | |
| | Chemical symbols of elements and formulae of ionic compounds | |
| | Changes in properties of matter | |
| | Static electrical charges | |
| | Electric current | |
| | Series and parallel circuits | |
| | Electrical energy | |
| Earth and space science | Understanding of universe and solar system | |
| | Traditional perspectives of a range of Aboriginal peoples in BC on the relationship between the Earth and celestial bodies | |
| | Astronomical phenomena with reference to the Earth/moon system | |
| | Implications of space travel | |
| Processes of science (skills and processes of science will mostly be developed as part of work related to the other curriculum organizers) | Safe procedures | |
| | Performance of experiments and interpretation of information using scientific method | |
| | Scientific literacy | |
| | Ethical, responsible, and cooperative behavior | |
| | Use of technologies specific to investigative procedures and research | |

**Table 2.** List of Topics in the Science 9 Curriculum of 2014.

| Sequence / Scope | Science 9 Topics | References |
|---|---|---|
| Micro-organisms | Viruses and bacteria | Refer to the curriculum |
| | Microbiomes | |
| | Immune system | |
| | Vaccination | |
| | Antibiotics | |
| Elements | Element properties as organized in the periodic table | |
| Four fundamental forces and quantum theory | Gravitation | |
| | Electromagnetism | |
| | Weak nuclear force | |
| | Strong nuclear force | |
| | Types of radiation | |
| | Wave-particle duality of photons | |
| | Energy transmission (quanta) | |
| Four interacting spheres of Earth | The carbon cycle | |
| | Forms of carbon | |
| | The nitrogen cycle | |
| | Hazardous chemicals | |
| | The interactions between the lithosphere, atmosphere, biosphere, and hydrosphere | |

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