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Integration of Coding and Computational Thinking in Compulsory Education: The Landscape in Canada - A Report.

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In 2018, a report on the integration of computational thinking, programming, and coding across the Canadian provinces was published (Gannon & Buteau, 2018). As education in Canada is determined at the provincial/territorial level, the report addressed the various levels of integration in the provinces such as having mandatory courses, elective courses, optional online resources, or no current plans of integration. This report aims to update those levels of compulsory integration, ranging from kindergarten to grade 12, to the current year (2024). This report is written with information on the curriculum from the respective Ministry of Education, and does not look at the actual implementation in the classroom. Figure 1 exemplifies an overview of the level of integration each province/territory was at in 2018 (left) versus the level of integration they currently reside at (as of April 2024). Moreover, it indicates which curriculum the coding and/or computational thinking integration occurred/occurs in.

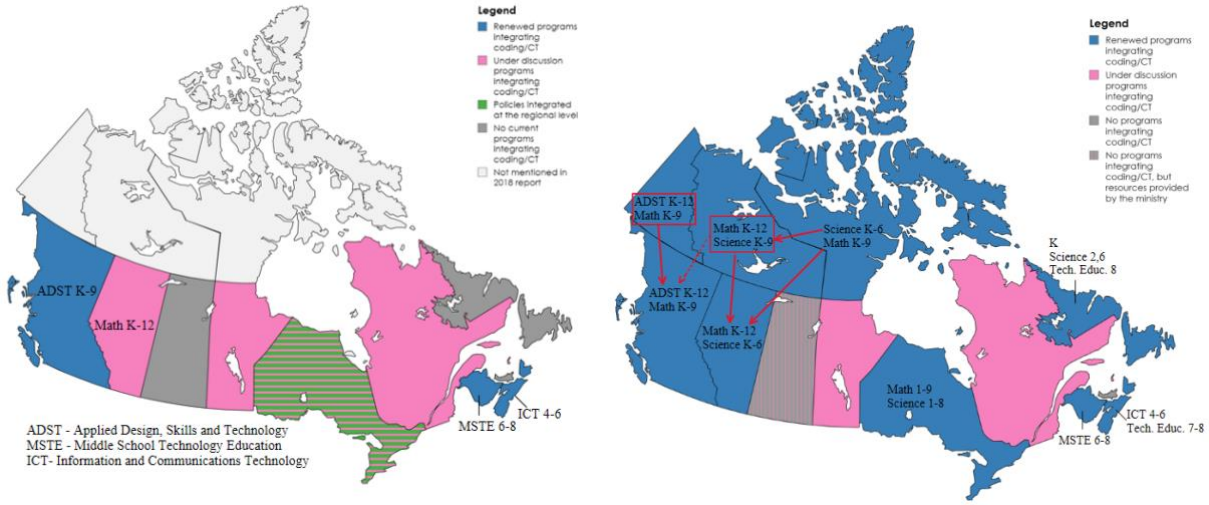

Figure 1. Integration of coding and/or computational thinking in school curricula across Canadian provinces/territories in 2018 (left) and 2024 (right). Solid red arrows indicate that the province/territory uses the same curriculum as the province/territory it is pointing to. Dashed red arrows indicate that the province/territory is switching to the same curriculum as the province/territory it is pointing to.

Canada is not the only country that has been working towards the integration of computational thinking in their school curriculum. For instance, the European Union published a report in 2016 and an updated report in 2022 outlining the status of the integration of computational thinking skills in multiple European countries school curriculums. Figure 2 shows two maps comparing the integration in the 2016 report versus the 2022 report.

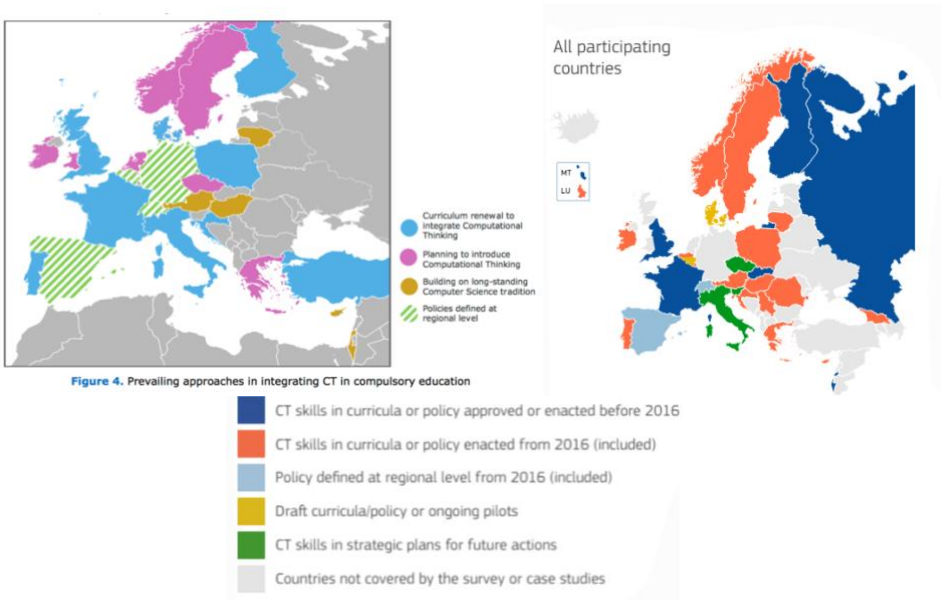

Figure 4. Prevailing approaches in integrating CT in compulsory education

Figure 2. Integration of computational thinking (CT) skills in school curricula in Europe in 2016 (left) (Bocconi et al., 2016) versus 2022 (right) (Bocconi et al., 2022)

In addition to the European countries shown in the Figure 2, Australia, South Africa, and the United States of America, are only a few examples of other countries who have worked towards integrating computational thinking into their curriculum (Stephens et al., 2021).

British Columbia

British Columbia has been, and continues to be at the forefront of integrating coding and computational thinking into their province wide curriculum. Since the 2016-2017 school year, a redesigned curriculum called Applied Design, Skills and Technology (ADST) was being integrated in kindergarten to grade 9, including a focus on coding in grades 6 to 9 (British Columbia News, 2016). As of the current year, 2024, this redesigned curriculum has been implemented in all grades from kindergarten to grade 12 (British Columbia Ministry of Education, n.d.). Starting with kindergarten to grade 5, the goal of the ADST curriculum is to provide exploratory and purposeful play opportunities for students to begin developing the foundational skills in design thinking and making. Then, in grades 6 and 7, students explore more specific areas of the ADST curriculum through the selection of a minimum of three modules, including computational thinking, computers and communication devices, digital literacy, and more. The courses for grades 8 and 9 are more flexible in how they are offered, as schools are required to provide a 'full year course', but this could be offered as one or more modules of various lengths. Lastly, in grades 10 to 12, students can choose to follow a specialized path in a specific area, such as Business Education, Information and Communications Technology, etc., or move forward following broader interests (British Columbia Ministry of Education, 2018).

In addition to the ADST curriculum, the use of technology and coding has also been integrated into the kindergarten to grade 9 mathematics curriculums in British Columbia. For example, from as early as Kindergarten, one of the Curricular Competencies under reasoning and analyzing is to use technology to explore mathematics. From kindergarten to grade 5, this technology is mainly calculators, virtual manipulatives, and concept-based apps. However, from

grade 6 and onward, coding and programming are introduced under the Curricular Competencies' logic and patterns, and modelling, respectively (British Columbia Ministry of Education, 2016).

Yukon Territory

"Yukon schools follow the British Columbia (B.C.) curriculum, with adaptations to include: Yukon content; and Yukon First Nations' ways of knowing and doing" (Government of Yukon, 2023, Para. 1). Thus, coding and computational thinking are integrated throughout the whole territory.

Alberta

Alberta is another province that has been an innovator in the integration of computational thinking and coding into their curriculum. In the 2018 Gannon & Buteau report, the 2017 draft of Alberta's new scope and sequence for kindergarten to grade 12 mathematics was explored. This draft illustrated the inclusion of computational thinking and/or coding throughout majority of the grade levels under every Essential Understanding (Alberta Education, 2017). Since then, Alberta has continued to incorporate coding and computational thinking into other curriculums, such as the science curriculum as computer science has become a topic implemented as a unit of study from kindergarten to grade 6 (new LearnAlberta, 2023). In the subject introduction, it is stated that "The study of computer science allows students to apply creativity, design, and computational thinking and to develop scientific inquiry and problem-solving skills" (new LearnAlberta, 2023, p.1). The descriptions of the science curriculum at each grade level are then broken down into three main sections; Organizing Idea, Guiding Question, and Learning Outcome. From kindergarten to grade 6, the Computer Science Organizing Idea is "Problem solving and scientific inquiry are developed through the knowledgeable application of creativity, design, and computational thinking" (p. 15). Then, for grades 3-6 we see computational thinking being more integrated in the Guiding Questions and Learning Outcomes. For instance, in grade 3 there are multiple mentions of computational thinking, as the Learning Outcome for this grade level is "Students investigate creativity and its relationship to computational thinking" (p.37). Thus, under the Learning Outcome subcategories (Knowledge, Understanding, and Skills & Procedures) computational thinking is divided into explorable aspects, such as what it includes (e.g., breaking down a task, designing instructions, etc.), how it is a process that requires the use of creativity, and more. In grades 5 and 6, computational thinking and coding are then brought together. For instances, the use of computational thinking in the design process of computational artifacts (new LearnAlberta, 2023, p. 59).

Northwest Territories

In a recent CBC News article, it was discussed how Northwest Territories has followed Alberta's education curriculum since the 1950s, but is now beginning shift toward British Columbia's curriculum (Lachacz, 2023). Although some changes have begun, NWT currently still follows Alberta's mathematics curriculum (Government of the Northwest Territories, n.d.-a) and Alberta's grade 7 to 9 science curriculums. Although NWT does not follow Alberta's kindergarten to grade 6 science curriculums, they have their own science and technology curriculum that has been implemented since 2004 (Government of the Northwest Territories, 2004). In this curriculum, the ability to use computer programs to enhance and deepen student learning and understanding is emphasized. Additionally, "students can use computer programs to compile, organize, and store data gathered through investigations; to write reports and papers in

which they present their findings...; and to work with simulations in areas of study in which hands-on activities are not feasible (e.g., in astronomy) or in which there is too great a safety risk" (Government of the Northwest Territories, 2004, p. 15). Therefore, there is a significant amount of coding integration in the NWT curriculum, and as they transition into using British Columbia's curriculum, there will be even more.

Nunavut

Nunavut's curriculum is divided into four strands, one being Iqqaqqaukkaringniq which is an "integrated core curriculum that focuses on ways in which we describe and improve our world. Concepts in mathematics, analytical and critical thinking, solution-seeking, innovation, technology and practical arts will be explored" (Department of Education Ilinniaqtuliqiyikkut, n.d., p. 11). The approved curriculum falling under this strand is either unique to Nunavut or draws on the curriculums from other provinces/territories. For instance, Nunavut follows Alberta's kindergarten to grade 9 mathematics curriculum and NWT kindergarten to grade 6 science and technology curriculum (Department of Education Ilinniaqtuliqiyikkut, 2019). With the inclusion of these two curriculums, Nunavut has therefore integrated coding and computational thinking into their education.

Saskatchewan

Since the 2018 Gannon & Buteau report there has been no updates to the mathematics or science curriculum at any grade level in Saskatchewan. Thus, Saskatchewan currently has no formal integration of coding or computational thinking in their curriculum (Saskatoon Industry Education Council, 2024b). However, something that is being adopted and integrated in the kindergarten to grade 12 classrooms, at the teacher's discretion, is "SaskCode" activities. SaskCode is not required to be introduced into the classroom, but it is an option that is available to all teachers in Saskatchewan which has been growing in popularity over the last few years with it being used in over 4,200 classrooms (Saskatoon Industry Education Council, 2024a). The main goal of SaskCode is to "equip teachers throughout Saskatchewan with the pedagogy, technological skills, and physical tools they need to embed computational thinking and coding into their classrooms" (Saskatoon Industry Education Council, 2024a, para. 3). It does so by providing appropriate grade-level, hands-on activities, such as beginner block-based language coding for grades 6 to 9. Moreover, SaskCode emphasizes the need to integrate technology effectively in the classroom to help students build digital fluency, which is defined as "the ability to use digital technologies readily and strategically to learn, to work and to play" (Saskatoon Industry Education Council, 2024b, p. 2). In addition to SaskCode, there are other coding and computational thinking related resources available on the Government of Saskatchewan Curriculum website. For example, "Opportunities to Address Computational Thinking in the Grades 1 to 6 Mathematics and Science Curricula" is a free resource which outlines ways that teachers can integrate computational thinking in their classroom, including how it relates to curriculum expectations in that subject/grade (Saskatchewan Ministry of Education, 2021).

Manitoba

Similar to Saskatchewan, there has been no updates to Manitoba's curriculum to include coding or computational thinking in recent years, but there is and has been an emphasis on the inclusion of technology in the mathematics curriculum. For instances, one of the mathematical

processes included from kindergarten to grade 12 is technology visualization (Government of Manitoba, n.d.). Moreover, in the 2018 report, it was discussed that:

> Several boards throughout the province ... are participating in Coding Quest in collaboration with The Learning Partnership, a program that teaches coding and video game development to students in grades 4-6 over a period of 25 sessions (The Learning Partnership, n.d.). The CT-focused program also utilizes a cross-curricular approach by incorporating various subjects, including science and mathematics. Though there are no present ministry initiatives in place to include CT as part of the provincial curriculum, Manitoba's participation in Coding Quest illustrates some focus on teaching coding skills to the province's students (Gannon & Buteau, 2018, p. 3).

There have been no new updates on the utilization of Coding Quest or any future plans to integrate coding and/or compactional thinking more directly into the Manitoba curriculum.

Ontario

At the time of the 2018 Gannon & Buteau report, there was no mandatory, province-wide, inclusion of coding or computational thinking in Ontario, but there was the start of many initiatives aiming to change that. It is safe to say that these initiatives were successful because since 2020/2021, coding and computational thinking have been integrated into the grades 1 to 9 mathematics curriculum (Broley et al., 2023). Broley et al.'s chapter summarizes how the use of coding is integrated into the algebra strand- "[t]he overall expectation is that students in Grades 1 to 8 ... will learn to solve problems and create computational representations of mathematical situations using coding concepts and skills" (Broley et al., 2023, p. 11). These skills and coding concepts are learned in a progression, beginning with sequential events, then nested events, followed by sub-programs and other control structures, and lastly, by the end of grade 9 "students are expected to be able to apply coding skills to represent mathematical concepts and relationships dynamically, and to solve problems, in algebra and across the other strands (e.g., number, data, spatial sense, and financial literacy)" (Broley et al., 2023, p. 11). Moreover, computational thinking "is presented as part of the transferable skills that 'are in high demand in today's globally connected world, with its unprecedented advancements in technology'" (Broley et al., 2023, p. 11).

In addition to the revised mathematics curriculum, the science curriculum was also updated in 2022 to include coding and computational thinking in grades 1 to 8 (Government of Ontario, 2022). Similar to computational thinking being a transferable skill in mathematics,

> Skills developed through STEM education include computational thinking, coding, innovation, and scientific and engineering design. These skills are in high demand in today's globally connected world, as advancements in science and technology continue to impact all areas of our lives, and they form a critical component of the science and technology curriculum. Students use an engineering design process and associated skills to design, build, and test devices, models, structures, and systems, and they write and execute code in investigations and when modelling concepts (Government of Ontario, 2022, The Importance of STEM Education, para. 3).

Coding is mainly integrated in Strand A – STEM Skills and Connections where students evaluate the impact of technology and coding on everyday life and in STEM fields, as well as use coding in their investigations to model science concepts (Government of Ontario, 2022).

Québec

Since the 2018 Gannon and Buteau report, there has been no changes to the Québec curriculum to integrate coding or computational thinking compulsorily. Thus,

> Presently, Quebec has no formal integration of CT or coding within its curriculum. The Quebec Education Plan for mathematics, science, and technology suggests ways in which computers can be utilized in elementary mathematics and science, where the use of ICT is required, but how this is accomplished is at the teacher's discretion (Québec Ministère de l'Éducation et de l'Enseignement Supérieur, 2001). Listed suggestions have a basis in CT, including activities such as "learning to do a computer simulation of a random experiment" (Québec Ministère de l'Éducation et de l'Enseignement Supérieur, 2001, p. 21). Quebec's English school system offers online coding lessons, called Kids Code Jeunesse, for students between the ages of 7-12 (Learn Quebec, n.d.). The courses offered as part of this program emphasize CT through the teaching of programming languages and website building (Gannon & Buteau, p. 4).

However, there has been some local initiatives discussed in the "plan d'action numérique" (digital action plan) which aims to integrate programming in the classroom. For instance, at Alexander-Wolff primary school, students in grade 6 spend about an hour a week learning/exploring computer programming (Gouvernemernt du Québec, 2018). Moreover, "The action plan's 33 measures are intended to give new impetus to the shift to digital in the education system and to contribute actively to the development of Quebecers' digital skills" (Gouvernemernt du Québec, 2018, p. 9). In the second measure specifically, it is stated that "The Ministère will encourage and support the use of coding for educational and didactic purposes in order to help students acquire the learning and competencies prescribed in the Québec Education Program (QEP)" (Gouvernemernt du Québec, 2018, p. 27). According to the Action Plan, the use of coding in the classroom was hoped to be in most elementary and private schools by the 2020-2021 school year, but the "integration of coding will be driven by schools" (Gouvernemernt du Québec, 2018, p. 27). Thus, although coding is not officially required in Québec's curriculum, there are many local initiatives/ projects that have been and continue to be implemented at the school level.

Newfoundland and Labrador

In earlier years, Newfoundland and Labradors integration of coding and computational thinking has been limited; one of the only mentions of coding their curriculum appears in the 2016 grade 2 Science Curriculum. This curriculum introduces the idea of kinaesthetic coding, such as creating a step pattern of moving up, down, left, or right, to solve a problem (i.e., getting a car from point A to point B). Moreover, it is stated that as an extension students could be introduced to programmable robotics, computer programs or mobile device applications as a way to expose them to technology-based coding (Department of Education for Newfoundland and Labrador, 2016). However, there were no other cross-curricular mentions of coding until 2018. Starting in 2018, the grade 6 science curriculum "What Causes Eclipses?" unit was updated to now include the minor requirement to "Use coding (e.g., Scratch programming) to create a digital model of solar and lunar eclipses" (Department of Education for Newfoundland and Labrador, 2018, p. 87). It has since been a steady incline of coding integration into the curriculum. In 2021, a new Technology Education course, "Computer Science", was added into the grade 8 curriculum (Newfoundland and Labrador Education, 2023). This course begins to introduce students to the fundamental concepts of programming, including the planning,

designing, and creation of block-based programs for a given task (Department of Education for Newfoundland and Labrador, 2021). Then, in 2022, the kindergarten curriculum was updated to include more mentions of coding in other school subjects, such as science, stating "students may play with coding-related toys and technologies that develop their problem-solving abilities." (Department of Education for Newfoundland and Labrador, 2022, p. 31) and "students may Identify problems to be solved when using coding-related toys and technologies" (p. 33).

Prince Edward Island

In 2015, a news article was released pertaining to the discussion of integrating computer coding into Prince Edwars Island's curriculum. The main advocate, Maureen Kerr, wanted to follow in Nova Scotia's footsteps and make computer coding a required course of the elementary curriculum (Russell, 2015). However, there were no further updates on the status of this integration since, and as seen in the current curriculum, computer coding is still not a required course. Although, in 2018, CBC news published an article on P.E.I.'s participation in the international coding program Hour of Code, this appears to be the extent of coding that has been introduced in the P.E.I. classrooms.

Nova Scotia

Nova Scotia is one of the provinces with the earliest integration of coding and computational thinking in its curriculum. More details can be found in the 2018 report, but in short,

> Coding was first announced as a priority in 2015 for the province's Education Action Plan... The Education Action Plan included a three-year goal, from 2016-2019, where all students would be introduced to coding, technology, and design (Province of Nova Scotia, 2015b). With the implementation of the ICT/Coding 4-6 Integration beginning August 2016, coding became mandatory for grade 4-6 students as one of eight of the program's desired outcomes (Province of Nova Scotia, 2016b). The new curriculum for coding emphasizes the basics of computer science, including computational thinking and the use of algorithms, the sequencing of steps in a program, and debugging code (Province of Nova Scotia, 2016b). Writing programs to model real-world situations is also a component of programming education throughout these elementary grades (Province of Nova Scotia, 2016b). ... Beyond elective computer science courses offered in secondary school, Nova Scotia's Ministry of Education and Early Childhood Development website provides a variety of resources to introduce and develop coding skills in grade 6-12 students (Nova Scotia Education and Early Childhood Development, n.d.) (Gannon & Buteau, p. 5).

Additionally, as part of Nova Scotia's renewed grade 7 and 8 curriculum, Technology Education has been fully implemented province-wide (Nova Scotia Department of Education and Early Childhood Development, 2022). By the end of this course, the goal is that learner will be able to use a variety of "technological tools, processes, and applications; integrate technology education with other academic disciplines; design and create devices and objects that solve technological problems; and explain the consequences of technology and how it affects society" (Nova Scotia Department of Education and Early Childhood Development, 2022, para. 1).

New Brunswick

This report, like the 2018 Gannon & Buteau report, focuses solely on New Brunswick's Anglophone curriculum. As discussed in the 2018 report, New Brunswick is another province

that has dedicated time to integrating coding and computational thinking into their curriculum (Gannon & Buteau, 2018). Since 2016, the Middle School Technology Education (MSTE) curriculum has been implemented, which

> ... has made coding and programming mandatory for students in grades 6 to 8 as part of its conceptual framework on Digital Technology Skills Exposure (New Brunswick Department of Education and Early Childhood Development, 2016). These skills are taught as components of the MSTE's general curriculum outcome (GCO) focusing on critical thinking and problem solving, highlighted in specific curriculum outcome (SCO) 2.5 that students in these grades should "understand and demonstrate computer coding/programming concepts and terminology" (New Brunswick Department of Education and Early Childhood Development, 2016, p. 19) (Gannon & Buteau, 2018, p. 5).

Moreover, it is required that a minimum of 10% of MSTE classes (per year) must be dedicated to coding. There have been no changes or updates to this curriculum since its implementation (Government of New Brunswick, 2024).

Conclusion

Overall, there has been an increase in the (compulsory) integration of coding and computational thinking into the curriculum across the different provinces/territories. As of the current year (2024), nine provinces/territories have renewed programs integrating coding and/or computational thinking. These nine provinces/territories are comprised of; British Columbia, Nova Scotia, and New Brunswick, which had renewed programs as of the 2018 (Gannon & Buteau) report; as well as Alberta and Ontario which had programs still under discussion with the Ministry of Education/ had policies at the regional level as of 2018; and Newfoundland and Labrador which had very little integration in the 2018 report but has since added more; in addition to Yukon Territory, Northwest Territories, and Nunavut which were not previously explored in the 2018 report, but have been found to have programs with integrated coding/computational thinking. Québec and Manitoba still remain with mentions of future integration, but with no further updates at this time; and Prince Edward Island and Saskatchewan are still without mention of possible compulsory integration into their curriculum. Nevertheless, we are seeing an upward trend of integrating coding, computational thinking, or simply the use of technology in the classroom. Additionally, there are more and more available online and in-person resources for teachers or students to explore coding, such as the CanCode 3.0 Projects which includes Canada Learning Code, The Learning Partnership, and more (Government of Canada, 2023).

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