Symposium Report: Integration of Computational thinking in Canadian Provinces. In Online Proceedings of the *Computational Thinking in Mathematics Education Symposium*, Scarborough (Canada) *October 2017.* Gannon & Buteau

INTEGRATION OF COMPUTATIONAL THINKING IN CANADIAN PROVINCES

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In recent years, significant attention has been afforded to the addition of computational thinking (CT), programming, and coding into K-12 education. The degree of this integration across Canada varies between provinces, from offering secondary level elective courses in computer science and providing online resources for teachers and students, to the inclusion of computational thinking as a mandatory component of the curriculum. Figure 1 shows a map illustrating the extent of CT integration in each Canadian province as of early 2018.

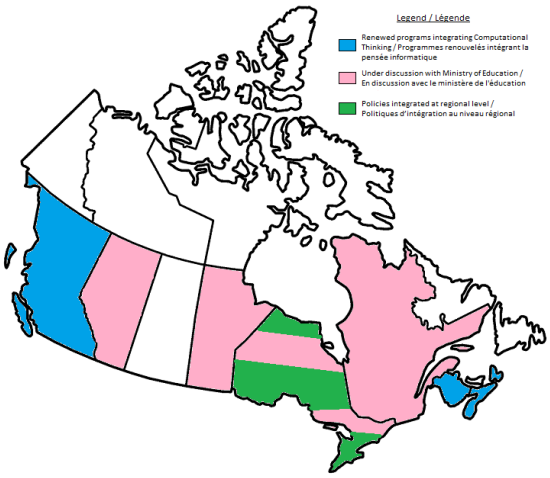

Figure 1. Integration of CT in school curricula in Canada (January 2018)

The colouring of this map began at the 2017 *Computational Thinking in Mathematics Education Symposium* (Scarborough, Canada) based on participants' knowledge, modelled after a European Union map highlighting compulsory CT integration (see Figure 2). It was later finalized after verifying each province's ministry responsible for education.

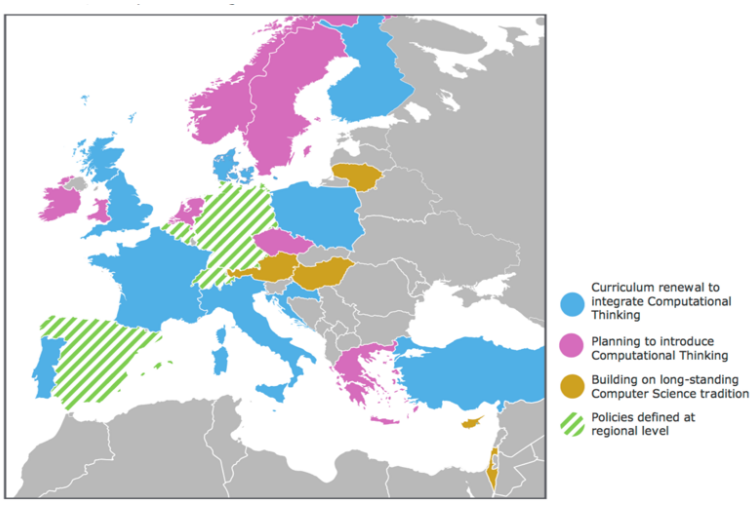

Figure 4. Prevailing approaches in integrating CT in compulsory education

Figure 2. Integration of CT in school curricula in Europe (Bocconi et al., 2016)

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The purpose of this article is to elaborate on this Canadian map, detailing the present integration of CT into the curriculum of each province and discuss where further implementation can be expected in the coming years.

British Columbia

British Columbia is one of the leading provinces in terms of CT and coding integration in education. A curriculum overhaul was announced in early 2016 under then-Premier Christy Clark, stating that the planned changes would eventually teach students the basics of coding by the end of grade 9, with the opportunity to specialize further in high school (Silcoff, 2016). The expansion of British Columbia's Applied Design, Skills, and Technologies (ADST) curriculum for the 2016-2017 school year was a component of these changes, where coding and CT became a focus in grades 6-9 (British Columbia Ministry of Education, 2016a). The curriculum is designed such that schools can structure ADST content by choosing from several content modules, one of which is Computational Thinking. The focus in grades 6 and 7 is on algorithms and programming languages, building to sequential instructions and in grade 8, students focus on debugging. The content modules are slightly altered in grade 9, with coding and CT included within the modules of both Drafting, Electronics & Robotics and Information and Communications Technology. In earlier grades (K-5), there is no specific ADST content, but teachers are encouraged to integrate these skills into other subjects with an emphasis on design thinking (British Columbia Ministry of Education, 2016b). For grades K-3, this involves concepts such as ideating, making, and sharing, while in grades 4-5 more emphasis is placed on prototyping and testing. These recent changes to British Columbia's curriculum demonstrates a significant focus on the integration of CT, programming, and coding to students throughout the province.

Alberta

Another province at the forefront of incorporating CT into schools is Alberta, evident through forthcoming changes to their mathematics curriculum. A 2017 draft of the province's new scope and sequence for K-12 mathematics highlights five overarching essential understandings, with subsequent guiding questions tailored to each grade and possible concepts and procedures to address these questions (Alberta Education, 2017). CT supporting coding is prevalent throughout the entire document via a concept or procedure, incorporated (at least once) under all essential understandings, and across all levels (except for grade 10). This new focus on CT and coding comes as part of a $64 million K-12 curriculum overhaul addressing six major subjects, including mathematics, aiming to update Alberta's curriculum to incorporate coding as one of several new topics of focus (Bennett, 2016). These changes were announced by Education Minister David Eggen in June of 2016, and are being implemented in three phases, from the lowest to highest grades, over a six-year period aiming for completion in 2022. These updates to Alberta's curriculum illustrate a new focus on providing students with foundations for coding and CT within mathematics.

Saskatchewan

Presently, Saskatchewan has no formal integration of CT within its curriculum, but there has been some discussion surrounding teaching coding in the province's schools. Similar to Manitoba (and Alberta before recent curriculum reforms), Saskatchewan's K-9 mathematics curriculum places emphasis on the use of technology in mathematics (Saskatchewan Learning, 2007). Technology, including the use of computers, is included as one of the province's seven mathematical processes, and it is stated that "Technology contributes to the learning of a wide range of mathematical outcomes, and enables students to explore and create patterns, examine relationships, test conjectures, and solve problems" (Saskatchewan Learning, 2007, p. 19). Programming and its use in problem solving are otherwise evident in secondary level elective computer science courses (Saskatchewan Education, 1999). In

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November 2017, Education Minister Bronwyn Eyre pledged to incorporate coding into both elementary and secondary level education (Macpherson, 2017). At the present, there is no official news release from the ministry regarding a concrete plan for implementation, but Eyre's announcement suggests potential changes in coming years.

Manitoba

Manitoba, like Saskatchewan, has limited integration of CT within the province's curriculum, but some programs are being explored to teach coding to elementary students. The K-8 mathematics curriculum in Manitoba resembles that of Saskatchewan by including technology as a mathematical process, also including the use of computers (Manitoba Education, 2013). Computer science courses are also offered in the province's secondary level programming at the Senior 2, 3, and 4 levels (grades 10, 11, and 12), including problem solving and the learning of programming languages as part of their curriculum (Manitoba Education, Citizenship and Youth, 2004). Several boards throughout the province (and boards in other provinces such as Ontario, New Brunswick, and Prince Edward Island) 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.

Ontario

There is no mandatory instruction of coding in Ontario, however, the Ministry of Education has undertaken numerous initiatives in recent years to promote CT education throughout the province. Broader support for learning with technology is being provided through a $150 million, three-year investment towards the province's Technology and Learning Fund, starting in the 2014-15 school year (Ontario Ministry of Education, 2016). Initiatives to promote coding education, including the development of resources for teachers, greater board-level supports, and increased hands-on learning opportunities, were announced by then-Minister of Education Mitzie Hunter in December 2016 during the province's annual celebration of Computer Science Education Week (Ontario Ministry of Education, 2016). Much of the Ministry's support for teachers is in the form of online resources, such as Teach Ontario's *Coding & Computational Thinking in the Classroom* (Teach Ontario, n.d.), developed in partnership with the Ontario Teachers' Federation, and Technology Enabled Learning Ontario's (TELO) *Coding in Elementary* (Technology Enabled Learning Ontario, n.d.). These websites provide supports for educators to integrate CT and coding within their classrooms, including resources such as webinars, discussion boards, and innovative lesson plans.

While instruction of computer programming skills is only evident in the curriculum for secondary-level elective computer studies courses (Ontario Ministry of Education, 2008), many of Ontario's initiatives to develop students' CT emphasize its integration with mathematics education. The Mathematics Knowledge Network (MKN), funded by the Ontario Ministry of Education and hosted by the Fields Institute for Research in the Mathematical Sciences (Mathematics Knowledge Network, n.d.), is one such initiative. The MKN hosts a community of practice focused on computational thinking, with one of its goals aiming to explore the integration of coding in K-12 school math education. The April 2017 edition of *What Works? Research into Practice*, a resource developed jointly by the Ontario Association of Deans of Education and the Ministry's Student Achievement Division, focuses on the combination of coding and mathematics at the K-8 level (Gadanidis, Brodie, Minniti & Silver, 2017). This

publication provides information for educators, based in scholarly research, on how CT can enhance students' conceptual development in mathematics, with a listing of related online resources. Many of the coding-based lesson plans found on the Teach Ontario and TELO sites are also based on Ontario's mathematics curriculum. Finally, Ontario has some regional programs emphasizing coding education, such as the Wellington Catholic District School Board's integrated Grade 10 Math+CS project. As part of this initiative, students are offered a two-credit package focused on promoting computer science and its connections with mathematics (Cummings, n.d.). The Toronto District School Board's (TDSB) K-12 STEM Strategy (Toronto District School Board, n.d.) is another such program which, among other aims, supports using technological innovation to build solution prototypes and solve problems based in the real world. Many Ontario students also participate in provincial coding programs, such as Hour of Code (Ontario Ministry of Education, 2017) and The Learning Partnership's Coding Quest (The Learning Partnership, n.d.).

Quebec

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. Initiatives to integrate coding into Quebec's secondary level programming has been discussed amongst some politicians, specifically as part of a set of resolutions proposed at an August 2017 conference on education (Authier, 2017). Despite this, no official Ministry announcements or initiatives to formalize coding within Quebec's curriculum have been put in place to date.

Newfoundland and Labrador

No mandatory coding programs are currently evident in Newfoundland and Labrador. Like other Canadian provinces, programming is included within elective courses at the secondary level in the subject of Technology Education, specifically within a robotics course (Newfoundland Labrador Education and Early Childhood Development, 2017). The Newfoundland and Labrador English School District's website provides a listing of online resources where students can learn to code (Newfoundland & Labrador English School District, n.d.). These include popular programs such as Hour of Code and Code Academy. No discussion of upcoming plans to incorporate CT or coding within the province's curriculum was found on the Ministry's website or in local news sources.

Prince Edward Island

In Prince Edward Island, there has been some discussion surrounding the addition of coding to the curriculum in recent years. Some schools are currently participating in coding programs with external organizations. Thirty-five teachers of grades 4-6 began participating in Coding Quest during the 2016-2017 school year, along with other schools in Manitoba, New Brunswick, and Ontario, and the province aimed to expand this program for 2017-2018 (MacMillan, 2017). As described above, the program emphasizes CT through teaching coding skills and video game development, incorporating cross-curricular approaches with science and mathematics. The only formal inclusion of programming and coding within the province's curriculum is seen in secondary level elective computer science courses (Prince Edward Island Department of Education and Early Childhood Development, 2009). In 2015,

Education Minister Hal Perry announced that the Ministry would be discussing the addition of coding to the province's curriculum with advisory councils (CBC News, 2015), but no formal plans have been evident since.

Nova Scotia

As one of the earliest provinces to focus on the teaching of CT, Nova Scotia has made significant advances in the integration of coding within their education system. Coding was first announced as a priority in 2015 for the province's Education Action Plan, as Education and Early Childhood Development Minister Karen Casey cited the role of coding in promoting students' innovation, problem solving, and critical thinking, and its connection to the skills taught in Nova Scotia's mathematics curriculum (Nova Scotia Education and Early Childhood Development, 2015). 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). In earlier grades, ICT is not taught as its own subject, but is integrated throughout a variety of other curriculum areas (Province of Nova Scotia, 2015a). 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.). Finally, the province places an emphasis on technological fluency more broadly as one of six graduation competencies for grades 1-8, including applications of technology and its use in the creation of knowledge (Province of Nova Scotia, 2016a). Nova Scotia is evidently a leader in the integration of coding and CT within their education programming, as seen in recent developments to their provincial curriculum.

New Brunswick

New Brunswick is another province that has made recent changes supporting the integration of coding education for students in junior and intermediate grades. In 2016, New Brunswick's Ministry of Education released an announcement of new funding for a variety of educational opportunities, including coding, as part of a ten-year education plan (Government of New Brunswick, 2016). The new Middle School Technology Education (MSTE) curriculum 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). Furthermore, the curriculum emphasizes that a minimum of 10% of each year of technology education must be spent teaching coding (New Brunswick Department of Education and Early Childhood Development, 2016). The MSTE document also provides resources to assist teachers in this endeavour, including lists of teaching strategies, global resources, and affirmative statements to encourage students in their learning (New Brunswick Department of Education and Early Childhood Development, 2016). As described

above, New Brunswick is also involved with the CT-focused program Coding Quest that teaches coding skills to many of the province's grade 4 to 6 students.

Conclusion

There is significant discrepancy amongst Canadian provinces in terms of integrating CT and coding into provincial education. British Columbia, Nova Scotia, and New Brunswick are leaders in this regard, having recently integrated coding and CT education in late elementary and middle school programming. Another leader in this field is Alberta, whose six-year education plan will soon incorporate coding into the provincial curriculum for all grades. Teaching programming as part of the curriculum has been discussed to varying degrees in Saskatchewan, Quebec, and Prince Edward Island, although concrete plans to achieve these aims have yet to be formally developed. Though Ontario has not formally integrated coding as a mandatory component of its K-12 curriculum, its Ministry of Education has contributed significant funding towards the creation of resources for educators and the implementation of coding-based initiatives throughout the province. Multiple provinces are participating in extracurricular coding initiatives, with one of the largest being the grade 4-6 program Coding Quest, in place in several boards throughout Manitoba, Prince Edward Island, Ontario and New Brunswick. As of early 2018, there is no evidence to suggest an emphasis on CT within education in Newfoundland and Labrador.

The connection of CT and coding with mathematics also varies significantly across provinces. While most provincial math curricula broadly discuss the use of technology for mathematical purposes, Alberta's recent curriculum changes explicitly emphasize this connection by highlighting the need to develop students' CT and coding skills within K-12 math programming. The connection between CT, coding, and mathematics is also prevalent in many of Ontario's Ministry-funded initiatives for researchers and educators, as well as some board-level programming. Furthermore, extracurricular initiatives such as Coding Quest may employ a cross-curricular approach to integrate mathematics with computer sciences. Canadian provinces thus demonstrate a wide variety of stances on the integration of CT and coding into school programming and their connections with mathematics, with significant reforms started in many provinces in recent years.

Acknowledgements

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