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A Comparative Review of Mathematics Educational Strategies in Ontario and Finland

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Abstract

Finland's education system has become the subject of much interest recently due to their students' continued success on international tests such as PISA (Programme for International Student Assessment) where they have excelled in language, science, and mathematics over the last decade. This article compares the mathematics education provided to senior students (17–18 years old) in Ontario and Finland by examining (a) the methods used to prepare prospective teachers to teach at the senior level, and (b) the curricula of both jurisdictions. The following points of comparison are covered: teacher education, official goals of mathematics education, course content, and assessment. Although the content taught to students in this age group did not differ significantly between Ontario and Finland, there were important differences in the areas of teacher-training and student assessment. The article concludes with some feasible suggestions for improving mathematics education in Ontario.

Keywords: mathematics education, Finland, Ontario, teacher education, formative assessment, inquiry-based learning, mathematics reading comprehension, senior mathematics

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Education in Finland has become the subject of much interest in recent years because of the country's outstanding performance on the Programme for International Student Assessment (PISA) tests. According to the Organization for Economic Cooperation and Development (OECD), Finland ranked in the top five in all three tested subjects and was ranked first in at least one subject in each of the 2006, 2003, and 2000 PISA tests (OECD, 2007; 2004; 2003). Finnish students' success on the PISA test is of particular interest because Finnish teachers make use of innovative teaching techniques rather than rote memorization and other traditional strategies, which distinguishes them from many other countries that were also highly ranked by the PISA tests (Partanen, 2011).

PISA is a test administered by the OECD, an organization of countries and economies around the world that works to "help governments foster prosperity and fight poverty" through the gathering and analysis of studies and information (OECD, 2013a). PISA is a two-hour written test given every three years to 15-year-old students attending school in OECD countries and other partnership countries (OECD, 2012a). Since PISA's inception in 2000, 70 countries have administered the test.

The test covers reading, mathematics, and science, one of which is emphasized more on the test on a rotating basis (science in 2006, literacy in 2009, mathematics in 2012). The test is intended to assess not only content knowledge (as is the case with other international tests such as the Trends in International Mathematics and Science Study), but also competency in learning skills required by the particular subject emphasized that year (use of information and communication technologies in 2006, learning strategies and interests in 2009, problem-solving in 2012). PISA also includes a questionnaire designed to evaluate the school's ability to weaken the correlation between the student's social background and success in school.

The Finnish education system underwent extensive revision in the 1970s, and this revision is credited as the main cause of Finland entering the information age (Lavonen, Meisalo, Sormunen, & Vesisenaho, 2010). Prior to 1970, Finland was a society based largely in agriculture and with deep class divides (Aho, Pitkänen, & Sahlberg, 2006). To modernize the country, immense changes had to be made. The medium for these changes was the education system (Kaiser, 2005), which accordingly was rebuilt with careful attention given to every detail "from curriculum and textbooks to salaries and administration" (Aho et al., 2006, p. 1), with a particular focus on both teacher education and providing an equally high quality education to all students across the country.

Now, because of the immense amount of planning and attention paid to the education system and because enough time has passed to allow these changes to take effect, education in Finland has become a subject of interest for researchers around the world (Burridge, 2010).

In Finland, compulsory education ends at age 16, at which point students can apply to attend either upper secondary education or a vocational school (Finnish National Board of Education [FNBE], 2012a). Upper secondary school is a three-year program intended as a preparatory school for university; students in the 17- to 18-year-old age group are typically in their second year of this program. Of the subjects taught in upper secondary school, mathematics and languages are the only ones that are divided into two streams: the Advanced stream and the Basic stream. To complete the Advanced mathematics program, ten Advanced-level mathematics courses are required; to complete the Basic mathematics program, six Basic-level mathematics courses are required (FNBE, 2012b).

At the conclusion of upper secondary school, students may choose to write a matriculation exam, which was at one time the entrance exam for the University of Helsinki but has since become the entrance exam for most Finnish universities (Matriculation Examination Board, n.d.). The exam must consist of at least four tests, with one test in the student's first language being compulsory; the student selects which subjects will comprise the remaining three tests in his or her exam, choosing from a second national language, a foreign language, mathematics, or general studies covering both sciences and social sciences. In addition to these four mandatory tests, students may elect to write optional tests in other subjects as part of their examination. The mathematics and the language tests are offered at both Advanced and Basic levels, and the student may choose either level regardless of which level he or she studied in school

(Matriculation Examination Board, n.d.).

The high taxes in Finland are an earmark of the commitment to the egalitarian philosophy that pervades all aspects of Finnish culture, including education (Kaiser, 2005). Providing all students with an equal opportunity to succeed was a central goal of the Finnish education reforms of the 1970s. No school of any level in Finland, including university, graduate school, medical school, and law school, is permitted to charge tuition (Partanen, 2011). Thus, although upper secondary school is not mandatory, students who choose to attend are not required to pay. PISA test results have consistently demonstrated that the relationship between a Finnish student's score on the test and his or her socioeconomic background is weaker than the OECD average (OECD, 2013b; 2010; 2007). This commitment to equity has been credited as a major contributor to Finland's success on international tests such as PISA (Kaiser, 2005).

According to the Education Quality and Accountability Office (EQAO), an independent agency funded by the Ontario provincial government, Ontario has performed well on all five PISA tests, although the results have been consistently lower than Finland's in reading, mathematics, and science (EQAO, 2013). In terms of achievement in mathematics, Ontario's results have been statistically the same as the Canadian average and have exceeded the OECD average for each of the five years of the PISA tests (EQAO, 2013; 2010; 2007; 2004; 2001). Until the most recent test in 2012, the mathematics results in Ontario had been stable, while other Canadian provinces had seen declines in their mathematics scores and Finland's scores had consistently increased. In 2012, however, the mathematics scores for all participating Canadian provinces as well as Finland declined, although Finland's results remained higher than both Ontario's and Canada's (Council of Ministers of Education, Canada, 2013). Thus, the PISA results indicate that while mathematics education in Ontario is succeeding on the Canadian front, Ontario is still being outperformed by Finland.

In contrast to Finland, public school in Ontario is mandatory until the age of 18, at which age students are usually in grade 12: the final year of the four-year high school program and of publicly funded education (Ontario Ministry of Education [OME], 2012). Students are required to take three courses in mathematics in high school, but no grade 12 math courses are mandatory. Throughout high school, mathematics courses (in addition to most other subjects) are divided into three streams – university, college, and workplace – with each stream being designed to prepare students for the named destination.

High school is the final stage of public education in Ontario, and education at this level is free for all students. Students may choose to continue their studies at a postsecondary institution, such as university or college, for which tuition is charged. There is no standardized admission test for postsecondary schools in Ontario.

Taxes in Canada are lower than they are in Finland. According to OECD Statistics (2013), total tax revenue (as a percentage of GDP) has been lower in Canada than in Finland since at least 1965. The difference was narrow before the 1970s and the aforementioned reforms in Finnish society, but in the 1970s, Finland began to increase taxes while taxes in Canada remained largely stable at 30–35% of GDP. Recently, the difference has become more pronounced, reaching over 12% in 2011 (OECD Statistics, 2013).

Moreover, although equity has been named as a core principle of mathematics education in the Ontario curriculum, this reference to equity speaks to employing a variety of teaching strategies to reach students with differing learning methods rather than considering the needs of students from different socioeconomic backgrounds (OME, 2007). Although the correlation between a student's socioeconomic background and his or her mathematics test score in Ontario was lower than the OECD average for the 2012 PISA test, it was higher than both the Canadian average and the Finnish results (OECD, 2013c).

Methods and Data Sources

The main goal of this study was to examine existing resources and research to analyze the differing approaches to mathematics education in Ontario and Finland. To do so, I compared the education provided to 17- and 18-year-old students in each jurisdiction: that is, students in grade 12 in Ontario and students in their second year of upper secondary education in Finland. I excluded Finnish vocational schools from the analysis, as Finnish upper secondary schools more closely resemble Ontario high schools because of their focus on academic subjects.

This paper first covers teacher-training programs, followed by an in-depth analysis of the Ontario and Finnish mathematics curriculum documents for these school levels. For each topic, the analysis first discusses each jurisdiction separately, followed by a comparison where important differences between the Ontario and Finnish approaches are noted.

For the section on teacher training, I examined the teacher-training programs themselves, as well as consulting scholarly articles that aggregate information on these programs. The curriculum content for both Ontario and Finland is presented in three distinct categories: (a) the purposes of the curriculum, (b) assessment, and (c) courses. Scholarly articles and government statements serve to supplement the information provided in the curriculum documents, thus providing a more complete picture of the reality of education in each jurisdiction. These additional resources are particularly important for the topic of assessment, which is not fully detailed in the Finnish curriculum document but which has garnered much attention in both the news media and the scholarly world.

Many scholarly articles separately critiquing Finland's and Ontario's education systems with references to pedagogical research already exist and provide excellent insight. These are referenced in the Discussion section, where I draw some key lessons from the comparisons in each topic.

Finally, the Conclusions section provides specific suggestions for Ontario. Finnish practices should not be adopted wholesale because of certain fundamental differences that exist between Ontario and Finland, such as demographics and economics. In particular, Finland's population is culturally and religiously homogeneous, and their taxes are much higher than in Canada due to consensus among the population that social services and education should be provided by the state (Kaiser, 2005). However, their practices can nonetheless be studied and used to improve mathematics teaching methods in Ontario; other countries ranked highly by the PISA tests, including Finland, are similarly studying other successful countries to improve their own practices (Kajander, Kotsopoulos, Martinovic, & Whiteley, 2013).

Results

Teacher Training

One of the key differences between the education systems of Ontario and Finland is how each jurisdiction trains its teachers. Teacher-training programs were one of the major components scrutinized in the education reforms in Finland in the 1970s and are often cited as an important factor in successful student performance on PISA (Lavonen et al., 2010).

The case of Ontario. To become a teacher in a secondary school in Ontario, pre-service teachers must currently complete (at minimum) a three-year postsecondary degree and an eight-month teacher-training program to obtain a Bachelor of Education degree. This will change in the near future because the Ontario Ministry of Education is set to extend the eight-month teacher-training program to two years in September 2015 (OME, 2013). Usually the postsecondary degree and teacher-training program occur consecutively, with teacher training taking place after subject training. However, programs exist that offer some teacher training concurrently with the postsecondary degree, such as the Concurrent Programs in Education at Lakehead University (Lakehead University, n.d.). In these cases, students take education courses and gain teaching practice throughout their postsecondary program; they then complete a two-term teacher-training program devoted both to furthering their classroom experience and to a study of pedagogical practices.

In both consecutive and concurrent programs, the length of time spent in education courses is about the same. Thus, pre-service teachers can apply to a teacher education program (a) after high school, (b) during their postsecondary degree (i.e., concurrent education program), or (c) after completing their postsecondary degree (i.e., consecutive education program).

The requirements for pre-service teacher education vary depending on the grade level that the teacher will be teaching. The twelve years of public education are divided into three levels for this purpose: Primary/Junior (grades 1–6), Junior/Intermediate (grades 4–10), and Intermediate/Senior (grades 7–12). Intermediate/Senior (I/S) teachers must be qualified to teach at least two subjects (Ontario College of Teachers, n.d.); the first teachable subject usually requires more study than the second teachable subject. To obtain a first teachable qualification in mathematics, I/S pre-service teachers entering a consecutive education program must have completed a certain number of credits in their postsecondary studies in mathematics; this number varies between three and six, depending on the teacher-training program (Kajander et al., 2012).

To obtain mathematics as a second teachable subject, I/S pre-service teachers must complete two or three mathematics credits, the number again depending on the teacher-training program (Kajander et al., 2013). While in the Bachelor of Education program, prospective I/S mathematics teachers take between 24 and 73 hours of mathematics-focussed pedagogy, with most institutions requiring 72 hours (Kajander et al., 2013).

Teacher-training programs are very competitive at some universities: Faculties of education in Ontario receive between 1000 and 2000 applications and accept between 100 and 400 applicants. Depending on the institution, between 6% and 25% of applications to faculties of education are accepted (Council of Ontario Universities, 2012).

With the minimum required training described above, secondary school teachers in Ontario earn a starting salary of $41,206 per year (USD); this increases to a maximum salary of $69,575 (USD) after 10 years of experience (see Table 1).

The case of Finland. All Finnish school teachers, at both primary and secondary school level, must have completed a five-year Master's program, including a mandatory research thesis (Lavonen et al., 2010). A primary school teacher will have a Master's degree in pedagogy, and a secondary school teacher will have a Master's degree in his or her subject specialty (Bjorkqvist, 2005). The training of teachers occurs within universities, which have departments both of education (which focus on research in education and educational planning) and of teacher training (which focus on teacher education and research in teacher education; Kansanen, 2003). Students who wish to become teachers will usually apply to the education program of the university where they are completing a Master's program after their second year of subject studies; if accepted, they will complete their subject studies concurrently with their pedagogical studies and teaching practice (Kansanen, 2003).

Upper secondary school teachers in Finland study two different subjects to teach and must acquire 55 credits in their first teachable, 35 credits in their second teachable, and 35 credits in education and pedagogy throughout their five-year program (for perspective, a five-year program contains a total of 160 credits) (Kansanen, 2003).

Teachers study research methods throughout their program. The core goal of the teacher-training program is "to impart the ability to make educational decisions based on rational argumentation in addition to everyday or intuitional argumentation" (Kansanen, 2003, p. 90). Research-based thinking is seen as actualizing this goal, and while both theory and practice are studied during the program, bridging the two is viewed as equally vital (Kansanen, 2003). In fact, although the pre-service secondary teachers will have experience with research methods in their own fields through their Master's thesis, each is also introduced to research methods that are more applicable to pedagogy and educational research as this is seen as vital to the profession (Kansanen, 2003).

Teaching is viewed as a very honourable profession in Finland and is held in very high regard (Frysh, 2011). Teachers are granted a great deal of autonomy in the education system, in that the national government does very little prescribing in the curriculum (Bjorkqvist, 2005). In fact, individual curricula usually differ from school to school because teachers and subject departments, not government, are in charge of the direction their classroom pursues, including details such as the choice of textbooks to be used (Bjorkqvist, 2005). This in-school curriculum planning is seen as an excellent method of encouraging teacher collaboration, serving as in-service professional development for teachers (Kansanen, 2003). Teachers, moreover, play a further role in curriculum planning even outside of their schools because "teacher's unions have a strong voice in shaping education policy" (Frysh, 2011).

Becoming a teacher in Finland is a competitive process, with only about 15% of applicants being accepted into teacher-training programs (Kansanen, 2003).

The annual salary for upper secondary school teachers in Finland with the minimum required training is $32,276 (USD) for new teachers; this reaches a maximum of $45,377 (USD) after 20 years of experience (see Table 1).

Table 1

Annual Teacher Salaries, Minimum Training, 2010 (USD)

	Starting Salary	Salary after 15 Years' Experience	Maximum Salary	Years to Maximum Salary
Ontario	41,206	69,575	69,575	10
Finland	32,276	42,809	45,377	20

Source: Statistics Canada, 2012; OECD 2012b.

Comparison. The major difference between teacher-training programs in Ontario and Finland is that Finnish teachers are required to have a Master's degree in pedagogy or in the subject they will teach, which is not the case in Ontario. In Ontario, there is currently only one program that combines a Master's graduate degree with a teaching certification; this is the Master of Teaching program at the Ontario Institute for Studies in Education (OISE, 2013). Secondary school Finnish teachers must have a degree in their field, and all Finnish teachers must conduct their own research to complete their Master's thesis. In Ontario, a mathematics teacher must have a postsecondary degree, but not necessarily a degree in mathematics; the qualifications to teach mathematics come from completing a certain number of postsecondary mathematics courses, not necessarily from fulfilling the requirements of any mathematics program. In the absence of a mathematics degree, there is little assurance that a teacher has a well-rounded experience in mathematics; they have demonstrated specific knowledge in only a few mathematical niches. Additionally, there is no universal requirement in Ontario for pre-service teachers to conduct any research of their own (either in their teaching subject or in education), although there are some teacher-training programs that do have compulsory research components (Kotsopoulos, Mueller, & Buzza, 2012).

Another difference between Ontario and Finland is that subject studies are carried out concurrently with pedagogical studies and research methods in Finland. Although pedagogy and subject studies do occur concurrently in some education programs in Ontario (such as the Concurrent Programs in Education at Lakehead University), this is not the case in general.

Officially Stated Goals of the Ontario and Finnish Mathematics Education Curricula

Ontario

The goal of mathematics education as outlined in the Ontario curriculum is presented as a combination of what students should get out of an education in mathematics and how teachers can effectively fulfill that objective (OME, 2007). The reasons cited for why students should have a mathematics education vary, depending on whether the student is preparing for college, university, or the workforce, and address not only the mathematical tools students will be introduced to during their high school career, but also the learning and thinking skills that mathematical training provides. The curriculum names reasoning, logical thinking, problem-solving, critical thinking, communication, and the ability to learn independently as skills that Ontario mathematics education can provide for students: all skills that will be essential for their success whether or not they proceed to university or college (OME, 2007). The OME document notes that our technologically advanced society requires productive members who are able to use technology for processing large amounts of information and to adapt and interpret or present that information in many different ways (OME, 2007). In short, the Ontario curriculum sees mathematics as necessary for all students to learn because of its ability to train people to think and learn in the divergent and logical ways that are necessary in our current culture, regardless of where that student goes after high school.

To achieve these goals, the curriculum suggests that teachers provide students with the opportunity (a) to investigate problems independently, and (b) to learn through inquiry, asking their own questions as well as seeking out their own answers (OME, 2007). The document goes on to state that the curriculum be presented as a continuous program (rather than a sequence of modules) to allow students to link ideas together and to "see the 'big pictures,' or underlying principles, of mathematics" (OME, 2007, p. 4). The importance of making connections between strands and types of learning is emphasized, as this will help students not only to connect their prior knowledge with the new concepts they are being taught but also to "develop an understanding of the abstract mathematics involved" (OME, 2007, p. 4).

The Ontario curriculum also addresses the role of technology in school, stating that technology should be used to allow students to bypass tedious calculations and procedures in favour of having them solve more complex problems (OME, 2007). However, the curriculum provides a limited view on technology integration as it does not present technology as a vehicle for facilitating "students' creativity and imagination in making their own mathematics" (Martinovic, Muller, & Buteau, 2013, p. 96).

Finland

Mathematics education in Finland has essentially two types of goals: improving student skills and changing student perspectives on mathematics (FNBE, 2003). The skills that Finland wants its students to acquire include (a) communication (both oral and written) of mathematical ideas, (b) the ability to solve application-type problems by making connections between mathematics and other topics, and (c) improvement of their calculation and problem-solving skills (FNBE, 2003). The Finnish curriculum also addresses the student’s ability to explore mathematics through inquiry, to make predictions and conjectures and support them logically, and to find creative solutions to their problems; in short, the curriculum is designed to acclimatize students to a mathematical way of thinking (FNBE, 2003).

The goals of the Advanced and the Basic curriculum in schools differ somewhat in their focus, but both curricula aim at instilling a confidence with mathematics in the students so that they are able to be creative with the subject and can explore it themselves through inquiry-based approaches. Both curricula also propose a certain perspective on mathematics itself as a goal, each stating that students should be able to understand the nature of mathematical knowledge as a logical structure. Both curricula also want to give their students a sense that mathematics is useful for something: the Advanced curriculum wanting its students to find mathematics as being critical for the development of science and technology, and the Basic curriculum wanting its students to see mathematics as playing a role in the development of culture, as well as being an essential tool for describing and modelling real-world phenomena. The Advanced curriculum is designed to prepare students for university or vocational school. Unlike the Basic curriculum, it alludes to getting students to see mathematics as its own subject with its own conventions and syntax, rather than being simply a tool for studying other subjects in applications. The Advanced curriculum wants students to be able to “understand and be able to use mathematical language, so as to be capable of following mathematical presentations, reading mathematical texts and discussing mathematics, and learn to appreciate precision of presentation and clarity of argumentation” (FNBE, 2003, p. 123). It emphasizes this point by stating that students should develop their ability to make and assess assumptions and generalizations, both of which are key components in pure mathematical studies.

In contrast, the Basic curriculum is concerned with preparing its students for everyday life. Rather than stressing mathematics as its own subject, the Basic curriculum aims to prepare its students to critically assess the use of mathematics in the media and to be able to make their own arguments supported by statistics and models.

Comparison

Both the Ontario and the Finnish mathematics curricula emphasize the effectiveness of inquiry-based methods to teach mathematics, thereby encouraging students to conjecture, experiment, and learn independently. It is prudent of the Finnish curriculum to note that this goal requires students to have mathematical confidence, as an increased level of confidence will make students more willing to experiment with ideas, thus increasing the effectiveness of inquiry-based learning methods.

Both the Ontario and Finnish documents also maintain that mathematics is useful for students, regardless of whether or not they continue to study it or a related field in an academic setting. Additionally, both curricula cite creative and logical thinking as benefits to be gained from a mathematics education.

The Finnish mathematics curriculum makes no specific mention of the role of technology in the classroom as a tool for learning, while the Ontario curriculum encourages, but does not require its use to enable students to attempt more intricate problems. On the other hand, Finland specifically mentions the importance of teaching students how to follow written and oral mathematical arguments, while Ontario does not.

Courses

Ontario

Appendix A provides a complete list of the mathematics courses available to Ontario students aged 17–18. It is important to note that mathematics courses at this level are not compulsory, so a single student would not take all of these courses and, indeed, may not take any. Each mathematics course in an Ontario secondary school requires at least 110 hours of in-class time (OME, 2012).

The courses offered in the university stream focus largely on functions, with one course (Data Management) focussing instead on probability, statistics, and discrete mathematics. The college stream contains a functions course with an emphasis on technology, as well as a course that includes finance and data management.

Finland

Finland does not assign courses to specific years of upper secondary school as explicitly as Ontario does for high school. Because the Finnish government grants more power to individual schools, each school is given the opportunity to distribute its mathematics courses among the years in a way that they feel will best benefit their students. Judging, however, from typical student timetables made available by some Finnish upper secondary schools, it appears that there is some consistency between schools.

Appendix B provides a list of the mathematics courses usually taken by 17- to 18-year-old students attending upper secondary school in Finland. Note that some are not compulsory and thus are not taken by all students and that each course requires at least 38 hours of in-class time

(FNBE, 2012b). The Basic courses introduce functions (including the concept of a derivative), statistics, probability, and discrete mathematics. The Advanced courses provide a more in-depth investigation of functions and probability, and then progress to integration.

Comparison

The specific topics included in each jurisdiction are largely the same, as both cover functions, introductory calculus, probability, statistics, and discrete mathematics. One difference in the topics studied at this level is that the majority of the courses offered in Ontario are focussed on functions, with less attention given to probability, statistics, and sequences and series. In Finland, on the other hand, both the Advanced and the Basic curricula require students to take at least one course on probability and statistics, and both curricula have a compulsory course that addresses sequences and series.

The way that functions are handled relative to calculus is also different. In Ontario, students learn about functions and their properties first in Advanced Functions, followed by the Calculus and Vectors course where they learn differentiation and the applications of calculus. In Finland, however, functions and calculus are taught alongside each other rather than in sequence. For example, students first learn the concept of a derivative and how to differentiate polynomials in MAA7, then cover logarithmic, radical, and trigonometric functions and their derivatives in MAA8 and MAA9; in these courses, the function is taught alongside its derivative and applications within calculus. Additionally, students must take some calculus to graduate from Finnish upper secondary school, regardless of which program (Advanced or Basic) is taken; in Ontario, calculus is not mandatory for any student.

Although this information is not illustrated in Appendix B, the fact that the Finnish curriculum is decentralized and placed largely in the hands of individual schools has led to the creation of many optional courses with atypical subject matter. For example, Maunulan Mathematics High School in Helsinki offers 17 mathematics courses in addition to those prescribed by the curriculum, thus giving their students an opportunity to take elective courses in enrichment subjects (such as complex analysis, game theory, the history of mathematics, and differential equations) that are not offered in Ontario (see Appendix A).

In Ontario, there is the option for schools or school boards to create "locally developed courses," which are intended to "accommodate the educational or career preparation needs of students…or the needs of exceptional students" (OME, 2000, p. 8). However, it appears that the only locally developed courses in mathematics are the locally developed compulsory courses, which are grades 9 and 10 courses created to prepare students for (a) the workplace-level math course in grade 11, or (b) grades 9 and 10 applied level math courses (OME, 2004); we know of no enrichment courses per se.

Because Finland's upper secondary school ends with a matriculation exam, many schools offer an overview course in mathematics at the end of upper secondary education to allow students to revisit topics and prepare for the exam. This could certainly serve as an excellent place to explore some of the 'big ideas' of mathematics that are spoken of in the stated goals of the Ontario and Finnish curricula, as it would tie together all courses taken throughout upper secondary education.

Assessment

Ontario

The Ontario curriculum states that main function of assessment is to "improve student learning" (OME, 2007, p. 23) by allowing teachers not only to establish the extent to which a student has met curriculum expectations, but also to use this information to provide feedback to the student as well as change the classroom experience in response to student needs. Assessments also serve to improve students' ability to assess their own work, thus enabling them to become better independent learners.

The curriculum states that assessment should come from various sources, including presentations, projects, and assignments, as well as written tests. It specifies that 70% of the student's grade will come from assessments occurring during the course and 30% will come from a final evaluation at the end of the course. Of particular note is the Data Management course, which is unique in that it is the only course that is required by the curriculum to have an inquiry-based culminating activity.

In 2010, the Ministry of Education released a supplementary document on assessment and evaluation entitled *Growing Success*, which updated and added detail to the information provided in the curriculum documents for grades 1 to 12 (OME, 2010). One of the key elements in the document is its exploration of three functions of assessment: (a) assessment for learning (AfL), (b) assessment as learning (AaL), and (c) assessment of learning (AoL). AfL provides students with constructive criticism that will aid their learning. AaL is an assessment that is itself a learning activity; it is meant to develop a student's independent learning and metacognitive skills, as well as improve their ability to self-assess. Finally, AoL is the teacher's evaluation of what the student has learned about the subject and is the typical way that assessment is viewed.

The document outlines additional methods for AfL and AaL, including conversations, discussions, observations, projects, and peer- and self-assessments. In particular, AfL and AaL are differentiated from AoL by when they occur in the learning process: AfL and AaL take place during the learning process itself and give both the student and the teacher information about how to best proceed, whereas AoL takes place at the end of the learning process.

Finland

The assessment section of the Finnish math curriculum is much shorter than the assessment section in the Ontario math curriculum and states which skills and knowledge need to be assessed rather than how a teacher might go about making the assessment. However, the curriculum does single out formative assessment as having an important role in mathematics instruction and assessment, and adds that assessment should “develop students’ ability to present solutions” (FNBE, 2003, p. 122). Emphasis is placed on continual assessments that are “encouraging and supportive by nature” (FNBE, 2012a) and that often come from the teacher’s observation of the student’s progress (FNBE, 2003). Student self-assessment also plays an important role in Finland (FNBE, 2003).

Comparison

While the assessment guidelines for both jurisdictions are very similar, it is difficult to ascertain which aspects of them are actually followed in classrooms. Finland is well known for not subjecting its students to many high-stakes tests as happens in North America (Hendrickson, 2012). In fact, “national testing, school ranking lists, and inspection systems do not exist” (FNBE, 2012a), and teacher observation is specified as an important source of assessment. This is due to the commitment to formative assessment, as tests are seen as undermining the purpose of assessment, which is to “produce information that supports both schools and students to develop” (FNBE, 2012a).

Ontario’s curriculum also emphasizes the utility of formative assessment for mathematics education, and the *Growing Success* document provides teachers with much detail on what AfL and AaL are and how to implement them. However, the 30% final assessment that is required in all courses undermines these efforts by mandating AoL assessments only. In addition, province-wide mathematics tests are administered each year by EQAO; they are intended to facilitate improvements to the education system, but are also used by some to rank schools by EQAO test scores (Fraser Institute, 2013).

Discussion

The most significant difference between the education systems of Finland and Ontario is the education of their teachers – most notably, the Master’s thesis that all pre-service teachers in Finland are required to complete. Teachers who have completed their own research in any field will have been exposed to the method of learning through inquiry, where students are encouraged to formulate their own questions and find their own answers. The fact that Finland requires its teachers to have a Master’s degree and to have completed original research as part of their training ensures that teachers have themselves experienced a teaching style that encourages questioning, experimentation, and independent learning.

The curricula of both Ontario and Finland state that this method of teaching is particularly effective for teaching mathematics. Requiring teachers to have completed their own research encourages the use of this style of teaching by giving teachers an appreciation for its effectiveness as well as the confidence to implement it. It is difficult for pre-service teachers to envision inquiry-based mathematics education when they have never experienced it; by requiring all pre-service teachers to engage in scholarly research, the Finnish teacher-training program is leading its pre-service teachers by example. Teachers' use of an inquiry model for education can in turn help students attain the creative thinking and independent learning skills that the Ontario and Finnish curricula put forward as a major goal of mathematics education.

Requiring teachers to conduct research also cultivates an appreciation for research itself and its role in education. LaFerrière, Sheehan, and Russell (2003) note the importance of training teachers to value research as a means of facilitating innovations in teaching. They found that "research is not valued intrinsically by either new teachers or by experienced teachers until they participate in a graduate programme in education" (p. 42) and that "innovations are being attempted, but it is not clear that they are being welcomed or understood against the invisible theory of tradition" (p. 42). Thus, if teachers have conducted research themselves as an essential part of their training, they are more likely to value it and turn to it throughout their career to implement new practices as the field of education evolves. This understanding of the value of research can ease the implementation of new developments in education in Ontario as they become necessary.

Including research in teacher-training programs will not only encourage the inquiry-based teaching that is called for in both the Finnish and Ontario mathematics curricula, but will also empower individual teachers and schools to challenge tradition and to improve their teaching practices throughout their career based on their research and their own observations.

All prospective teachers in Finland receive their subject training concurrently with their subject studies. This is the case with some, but not all programs in Ontario. Concurrent studies would strengthen the relationship between the teaching of the subject and the subject itself for prospective teachers, thereby cultivating their awareness of the connection between theory and practice that is cited as being vital in the education of Finnish teachers but is sorely missing in the education of Ontario teachers (Kansanen, 2003; LaFerrière et al., 2003).

It is also an important observation of the Finnish National Board of Education that education in reading comprehension beyond basic language comprehension is necessary to enable students to learn independently. Bain (2004) observed that reading comprehension is taught in schools in the United States (the case in Canada is similar) only when students are very young and is not revisited in later years when students are expected to read much more complex texts at more advanced levels of various subjects. In the Ontario curriculum, this is not noted, but it is likely that addressing this problem will not only increase the ability of students to learn independently from textbooks and other sources, but will also give them the confidence to do so. The ability to read about mathematics effectively can enable students to seek out learning opportunities outside of their textbooks and can enrich their education by encouraging them to explore different topics as they desire. This is perhaps the simplest change that could make a significant difference in the mathematical experience of students in Ontario's high schools.

The true role of formative assessment in each jurisdiction is very important. Although the curriculum documents of both Ontario and Finland note that formative assessment should be heavily used in mathematics classrooms, only Finland seems to take the implications of this to heart. The move from formal to formative assessment is, in many ways, a philosophical one; it is a change in perspective on the purpose of assessment: from quantifying to facilitating student learning. This philosophy is wholly accepted in Finland where its principles have infused many areas of education, one example being the rarity of high-stakes tests and the absence of national tests.

By contrast, formative assessment has been adopted only at the surface level in Ontario. Ministry documents speak in depth about AfL and AaL, but the curriculum also mandates a 30% final assessment for every course, and province-wide tests for achievement in mathematics are administered annually. Because of this emphasis on testing, students do not feel the benefit of a student-centred learning environment, even though such an environment is encouraged in the curriculum document. A more thorough commitment to implementing the formative-assessment style of educating and assessing is necessary to reap its rewards.

The prevalence of observational assessment in Finland helps to further that country's commitment to inquiry-based learning. Assessment based on teacher observation allows teachers to give students feedback and suggestions for improvement earlier and more frequently, rather than simply assigning grades. This would allow teachers to identify at-risk students faster than having to wait for test results at the end of a unit. Continuous feedback is more helpful for student improvement because it can take place while the class is studying a particular subject rather than after the fact, which is when the more traditional AoL takes place. Moreover, an emphasis on student self-assessment can increase student self-efficacy and self-regulation, allowing for more effective independent learning as well as an increased feeling in the students of control over and responsibility for their own performance (Hendrickson, 2012).

In reference to teaching calculus in particular, the difference between the approach to teaching functions and derivatives is an interesting one. However, it is not clear which approach will better allow students to make connections and to see the underlying mathematical structures and processes of functions and calculus. This is an opportunity for further studies in mathematics education.

Conclusions

A Plan for Ontario

As discussed at the beginning of this paper, Finnish educational practices cannot be adopted indiscriminately by Ontario; there are significant differences between Ontario and Finnish societies that would make such a move untenable. However, there are key lessons that can be distilled from the Finnish system and applied to Ontario to improve mathematics education.

The Finnish requirement for all high school teachers to have a Master's degree in their primary teaching subject is a large jump from the current Ontario requirements and could put strain on the government, which funds most graduate students. However, the value of research can be instilled within the education that pre-service teachers are already required to have in Ontario. For example, a research project in education could be made a requirement of all teacher-training programs in Ontario. This would not increase the amount of schooling that teachers need, but would help produce teachers who are more confident with inquiry-based instruction, more receptive to reading and conducting research, and more willing to change and improve their craft over the duration of their teaching career.

In addition, more should be done to encourage in-service teachers to conduct research. Recently, many initiatives have been implemented in Ontario to close the gap between researchers and teachers, including initiatives to have teachers conduct their own research (Martinovic et al., 2012); however, more consideration must be given both to minimizing the obstacles preventing teachers from participating in such initiatives and to changing non-participant teachers' perceptions of education research (Martinovic et al., 2012). In particular, involvement in education research would give teachers an appreciation for both inquiry-based learning and formative assessment, which can ultimately improve the independent-learning skills of Ontario's students.

Independent student learning can also be aided by the introduction of mathematics reading comprehension in the classroom. In order to learn independently, students must possess the skills necessary to utilize the resources available to them outside of school; almost all of these resources will require a student to be able to read mathematics. Reading mathematics involves different practices than other types of reading and should be explicitly discussed with students. The main obstacle to teaching students to read mathematical texts seems to be simply a lack of acknowledgement that such teachings are necessary. In Ontario, resources that provide teachers with the knowledge and activities to develop their students' math reading skills already exist (OME, 2005), but they are not widely used. An increased appreciation of the necessity of math-specific reading skills will help improve students' ability to learn independently.

An effort to educate teachers about the benefits of subject-specific reading strategies would likely be very helpful. Teachers do not teach mathematics reading comprehension because it is not seen as a topic that needs attention, nor are its rewards well-known. Including mathematics reading comprehension in the curriculum as one aim of mathematics education would be an important first step in increasing awareness of its value.

Teacher-training programs and professional development sessions should address the importance of developing subject-specific reading skills and should provide prospective and practising teachers with strategies or activities for their classrooms. One strategy could simply be to introduce teachers to the resources already available to them, given that the problem is not the effectiveness of the resources themselves, but the fact that they are not or are rarely used. Material covering mathematics reading strategies should also be included in future textbooks from major educational publishers.

Finally, inquiry-based learning must be more readily accepted and used by teachers, but its assessment practices must also be more thoroughly implemented. This means fewer high-stakes tests and a greater emphasis on other forms of assessment, such as in-class observation on the part of teachers and self- and peer-evaluation on the part of students. Many excellent resources exist that offer specific strategies for giving students numerous and varied opportunities to demonstrate what they have learned (GAINS, 2013; OME, 2010; OME, 2009).

However, few resources exist that provide suggestions for integrating these philosophies in a mathematics classroom specifically, so it would be beneficial to have resources particular to mathematics available for professional development sessions. Tradition is a powerful force to overcome in education. When attending professional development sessions to facilitate innovative techniques, mathematics teachers may succumb to the idea that certain techniques are applicable to other disciplines, but not to mathematics. In this case, subject-specific suggestions can help to prevent teachers from thinking that mathematics is somehow exempt from these new approaches to education.

It should be noted that the suggestions listed above offer a means by which Ontario teachers and students can better achieve the goals already articulated in the mathematics curriculum: (a) teachers will be better able to lead an inquiry-based classroom as the curriculum suggests they do if they themselves have been students in an inquiry-based classroom; (b) students will be better able to learn independently if they are able to engage with mathematics texts on their own; and (c) students will also be able to produce conjectures, experiment, and become more skilled problem-solvers if their evaluations encourage them to do so, as would be the case in a truly inquiry-based classroom. Accordingly, these suggestions would be useful for any mathematics education culture that has initiated a change in mathematics classrooms away from rote memorization and examinations and towards a more student-centered approach. These are the goals of the Ontario curriculum that are served by the propositions discussed in this study.

Just as it is important for teachers to be able to examine new research and adopt successful tactics of other teachers to improve their craft, it is also important for the bodies that oversee education to critically assess the practices and policies of other successful jurisdictions. Finland's success in education (as measured by its performance on PISA tests) should draw Ontario's attention to (a) the demands of 21st-century teacher education, (b) the value of reflective teachers, and (c) the importance of confidence, reading comprehension, and commitment to inquiry-based learning in improving students' experiences in the classroom.

Mathematics education in Ontario can be enhanced by engaging with these observations, and the changes this paper proposes can help Ontario to continue to implement innovative and modern techniques to improve both the quality of education and the attitude of its students towards mathematics.

Appendix A
Grade 12 mathematics courses in Ontario

Ontario secondary schools offer five grade 12 mathematics courses that are geared towards preparing students for further studies, either in university or college. All information on course expectations is from the Ontario Mathematics Curriculum (Ontario Ministry of Education [OME], 2007).

Advanced Functions (MHF4U) is designed to prepare students for a university program in business, social sciences, or health sciences. It covers exponential, logarithmic, trigonometric, polynomial, and rational functions, and requires students to study the characteristics of each of these families of functions, including concepts such as rates of change (without calculus) and how combining functions through composition can affect certain properties of functions.

Calculus and Vectors (MCV4U) is an extension of MHF4U and is designed to prepare students for more mathematically oriented university programs such as engineering, science, and economics. It covers differentiation of the functions addressed in MHF4U as well as some basic linear algebra concepts, such as the geometry and algebra of vectors.

Data Management (MDM4U) prepares students for university programs with a statistics component, such as social sciences and the humanities. It covers topics like probability and probability distributions, combinatorics, and the organization and statistical analysis of data. It includes a final project where students prepare a data management investigation using all the topics covered in the course.

Mathematics for College Technology (MCT4C) is designed to prepare students for a college program involving technology. It covers the study of a variety of functions, such as polynomial, exponential, and trigonometric. Although these are the same types of functions covered in MHF4U, here the focus is less on the properties of the functions and more on how to solve equations involving these functions (both algebraically and via graphing). MCT4C also covers geometry with a focus on problem-solving, including using vectors and circle geometry to solve problems.

Foundations for College Mathematics (MAP4C) is designed to prepare students for college programs with less of a mathematics emphasis, such as business, human services, and hospitality. It covers mathematical modelling (both algebraic and graphic), personal finance, geometry and trigonometry with a focus on problem-solving, and data management (focussing on interpreting and analysing data).

There is also one workplace preparation course called *Mathematics for Work and Everyday Life (MEL4E)*, which is designed to give students the mathematical abilities they need for the workplace rather than for a postsecondary education program. This course covers topics such as using data for reasoning, personal finance, and applications of measurement.

Appendix B
Grade 12 mathematics courses in Finland

In Finland, there are two streams of mathematics courses available to upper secondary students: Advanced and Basic. For the three years of upper secondary school, the Advanced mathematics stream has 13 courses available in total, with 10 being required for graduation, and the Basic steam has 8 courses available, with 6 being compulsory.

The following is a list of mathematics courses that students are likely to take in their second year of upper secondary school (*Helsingin Matematiikkalukio*, 2012; *The English School*, 2013). Most of these courses are compulsory. The third year of upper secondary school is typically reserved for students to take elective mathematics courses as well as review courses for the matriculation exam (course descriptions not shown). Those courses that are not compulsory are specified as such in the descriptions below. All information on course expectations is from the Curriculum for Upper Secondary Schools (FNBE, 2003).

Advanced Courses

Probability and Statistics (MAA6) covers probability, discrete and continuous probability distributions, mathematical and statistical probability, expected value, normal distributions, and combinatorics.

The Derivative (MAA7) examines such topics as limits, continuity, and the derivative of polynomials and products and the quotients thereof. Students also learn how to (a) solve equations and inequalities involving rational functions, (b) apply their knowledge of the products and quotients of polynomials to describe the effect these operations have on the behaviour and critical values of a function, and (c) use these skills to solve application problems.

Radical and Logarithmic Functions (MAA8) teaches students how to (a) solve equations involving these types of functions, (b) extend their differentiation knowledge to this class and to the compositions of functions, and (c) invert functions that are increasing monotonically.

Trigonometric Functions and Number Sequences (MAA9) introduces students to trigonometric functions and their symmetry and periodicity through the unit circle and radian measures. Students learn to solve simple trigonometric equations and identities, and to differentiate trigonometric functions. Number sequences are introduced, and students learn to solve such sequences using recursion formulae and to solve application problems regarding arithmetic and geometric sums.

Integral Calculus (MAA10) provides students with an introduction to definite integrals and the applications they have to calculations of area and volume.

Numerical and Algebraic Methods (MAA12) covers topics such as absolute and relative error, Newton’s method, factoring polynomials, and using mathematical equipment to complete numerical calculations of area and rates of change. MAA12 is an optional course.

Advanced Differential and Integral Calculus (MAA13) is a course intended to combine and enhance the skills gained by students in their various other functions courses involving differentiation and integration. It builds upon concepts of continuity and differentiability, introduces the indefinite integral and its applications to probability, and addresses the limits of number sequences, series, and sums.

Basic Courses

Mathematical Analysis (MAB4) is a calculus course that examines rates of change of functions initially without calculus, and then introduces the notion of the derivative. The derivative is used to describe the behaviour of a function and to solve optimizations problems.

Statistics and Probability (MAB5) is an introductory course that addresses basic concepts in statistics and probability. Topics covered include normal and standardization of distributions, continuous and discrete statistical distributions, and combinatorics.

Mathematical Models 2 (MAB6) is a course that covers many topics in linear algebra. Students learn to solve systems of linear equations, solve equations and inequalities with two variables, and use linear programming in certain applications, as well as learning arithmetic and geometric sequences and series.

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