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A 21st Century Economic, Educational and Ethical Mathematics Curriculum Policy

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Abstract

Reformulating a mathematics curriculum is a political act, contextualized by economic, educational and ethical considerations, among others. This article represents a political rendition of a rationale to update the Saskatchewan, Canada, curriculum so it harmonizes with a cultural understanding of school mathematics (Ernest, 1988). By revisiting the 19th century definition of school mathematics that we generally follow today, its economic, educational and ethical consequences seem contrary to the expectations of 21st century Saskatchewan.The article's point form organization, uninterrupted by the appearance of references, conforms to the genre of submissions to government committees. However, footnotes will clarify information for readers unfamiliar with current Canadian events. A lengthy detailed document written for the academy is easily accessible (Aikenhead, 2016). This TME article is a very short synopsis of that document.

Key Words: school mathematics, Indigenous, cultural, economic, reconciliation, transformational

A. Issue:

High school mathematics directly influences Saskatchewan's economic sustainability.

B. Preamble:

Saskatchewan's economic sustainability depends in part on having a government reliant on employed Indigenous taxpayers compared to an Indigenous population reliant on social welfare. Graduation from high school is therefore critical. A major hurdle for many Indigenous students is mathematics (e.g., linear and quadratic functions, radicals, and geometric sequences), which often depresses Indigenous students' graduation rates more than other high school subjects do.

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C. What Do We Need to Know about Mathematics?

1. Mathematics is a human invention that has developed from its origins in ancient civilizations. Every major culture has developed its own mathematics system in tandem with their everyday cultural activities, such as: counting, locating, measuring, designing, playing, and explaining. For instance, the mathematical process of designing is found in Indigenous embroidering and in Western (Euro-American) civilization's mathematics modelling, which forecasts the weather, for example. Mathematics' symbolism is a very powerful human tool.
2. Mathematics in any culture can be thought of as a *symbolic technology for building a relationship between humans and their social, economic and physical environments*.
3. What we teach as school mathematics today is one of many mathematics systems currently existing worldwide.
4. If we don't know the history of our own Euro-American mathematics, how can we move forward in a rational transformative[2] way?

D. What Do We Need to Know about the History of School Mathematics?

1. After the Dark Ages ended, ancient mathematical ideas found their way into Europe. Academic thinkers appropriated these ideas in a way that made sense to them. This was before universities existed.
2. When these early mathematicians appropriated an ancient mathematics idea, they ignored the culture-rich connotations associated with ancient numbers, symbols, and shapes. In their place, European mathematicians unconsciously attached their own culture's connotative meanings. European mathematics went on to invent other clever mathematical ideas, for example, geometry systems different from Euclidean geometry.
3. The Renaissance period of history brought about universities. The Renaissance version of mathematics slowly found a home in *elite* British universities, such as Cambridge and Oxford during 17th -18th century England[3]. Mathematics had to compete with the classics, history, ancient languages, etc. that were purposefully made very difficult. To be

[2] At the moment, the Saskatchewan Government has initiated a major project, TransformSK, for citizens to suggest, in specific detail, how some aspect of what occurs in the Provence (business, resources, agriculture, health, education etc.) can be transformed to bring about better results.
[3] This occurred about a century later in the New England Colonies, for example, at Harvard University.

accepted and survive in these elite universities, mathematicians taught their most abstract ideas without any context to help students think about mathematics' everyday use. They followed Plato's way of thinking: The world is made up of only two things: either ideas in our head or everyday concrete things and phenomena. These Platonist[4] mathematicians promoted Plato's "World of Ideas" and ignored anything that gave mathematics a human dimension or an everyday context.

4. The elite British Grammar Schools at the time prepared the aristocracy for elite universities. So their mathematics curriculum was the elite Platonist version of mathematics.
5. The Industrial Revolution (18th-19th centuries) brought about the British public education system in the mid-19th century, quickly adopted in Canada and the U.S.A. Mathematics became a core subject. At the time, however, educators debated over which version of mathematics should be taught: academic elite that had no context? or practical relevance that would connect students with their real world around them?
6. The Platonist educators won the battle over their utilitarian colleagues by using a rhetorical trick. They invented a dichotomy that divided mathematics education into: ***formal*** and ***informal***[5]. Formal mathematics was defined in a way that conformed to Plato's philosophy that the universe is made up of mathematical abstract concepts. The informal mathematics dealt with everything that made mathematics a human endeavour. Simply put, the formal surreal version of school mathematics became the school subject; the informal humanistic version was suppressed. Formal mathematics is the curriculum we have today, except for the advances in the primary grades.
7. Very few mathematics educators today know about informal mathematics. This fact is very important because today we need to revisit the Platonists' 19th century decision, informed by its history and by the historical context of Canada's 21st century era of reconciliation[6].

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[4] A Platonist belief about mathematics is a "doctrine that mathematical entities have real existence and the mathematical truth is independent of human thought" (Collins English Dictionary, 3rd ed., 1994, p. 1193).

[5] See Ernest (1991).

[6] In 2008, Canada's Federal Government apologized in Parliament for having kidnapped Indigenous children over many generations and for often holding them in faraway residential schools in a cruel attempt to rid them of their Indigenous self-identities. In 2008 the Government also established a Truth and Reconciliation Commission whose final report was released in January 2016. That report issued Calls for Action, which include: "improving education attainment levels and success rates" and "developing culturally appropriate curricula." Ministries of Education

E. What Has Sustained Platonist Mathematics All These Years?

1. Elite mathematics students who do well and go on to STEM (science, technology, engineering, and mathematics) careers (such as myself) serve the economy and nation well. But this group is a small minority, about 24% according to the 2016 OECD report on the latest PISA mathematics assessment. As explained in section F.2 below, this is a rather stable proportion of students over the years.
2. Efforts to attract more students into STEM since World War II have been largely counterproductive, except for traditionally marginalized groups such as Indigenous students and girls. In spite of efforts to increase enrolment in STEM programs, high school and university enrolment tend to decrease. The purported problem is that there are not enough high school STEM graduates going into post-secondary STEM programs, who will then graduate to fill business and industry job vacancies, which in turn will sharpen a country's competitive edge in globalized markets. However, the STEM enrollment issue is:
    a. actually the fault of university STEM departments, not schools. The rate at which university STEM students leave the STEM pipeline is *twice* that of high schools. The problem to be fixed is how students are treated in university STEM programs.
    b. moot in most cases. Research studies[7] that tract graduates of STEM report that many are unemployed. Business and industry wanting specific STEM expertise need to train potential employees themselves and/or attract such employees by paying them much more than they are paid now. It is the cost of competing internationally. It is not a high school problem.
    c. irrelevant according to economic research. The major factors that influence a country's competitive edge are beyond the influence of school STEM programs. Factors are, for example: emerging technologies, industrial restructuring, poor management decisions, and government policies that affect military development, monetary exchange rates, wages, and licensing agreements.

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across Canada are taking this Call to Action very seriously. All curriculum will be renewed accordingly, over the next few years.

[7] Charette (2013) reviewed a wide range of government and industry studies related to STEM employment.

Simply put, there is no STEM crisis except for those wishing to have a large employee pool that will keep wages low and profits high. Continuous warnings of a STEM crisis sustains the Platonist version of mathematics.

3. Political-social-economic influence, rather than evidence-based practice, has successfully maintained an elite Platonist curriculum because:
   a. it provides mathematics teachers with the highest status among school subject teachers.
   b. it is about prestige, control, authority, and power in our society.
   c. as mentioned above, it supplies society with highly capable elite workers, albeit a small proportion (24%), while it leaves the majority (76%) to fend for themselves, by memorizing algorithmic content to achieve high school credentials. People who only have credentials but no meaningful understanding to apply what was taught, will not contribute to a nation's STEM-based sector. This suggests to me that the current school mathematics system is not as efficient as it should be.
   d. it allows post-secondary institutions and employers to use student assessment in mathematics as an unquestioned objective screening device,
      i. whether or not the student assessment is really that objective; just as long as the numbers have an aura of objectivity, and
      ii. whether or not the actual mathematics content is relevant to the post-secondary program or to a particular occupation under consideration.

F. <u>What Has Happened in the Meantime</u>?

1. Anthropologists discovered what is described in section C above. Mathematics has the cultural imprint of the culture of those who developed or appropriated it. So the school mathematics we teach in North America has a European cultural imprint. If this does not sound familiar, remember that the Platonists in the 19^{th} century suppressed this "informal" mathematics cultural content in favour of "formal" elitist mathematics content. Given its history described in section D, what we teach today is really *Euro-American mathematics*.
2. Education researchers have found that:

a. a student's home culture and their self-identity may harmonize with, or may be very different from, the culture of school mathematics (Euro-American mathematics). Thus, ***culture clashes*** to varying degrees between the two cultures help explain how students get along with mathematics.

b. a large majority of students find school mathematics "uninteresting, obsolete, and useless." Their sentiments are echoed by a few famous mathematicians.

3. Acknowledging a lot of variation within every culture group, we can indicate an Indigenous collective worldview as being:

   contextualized, subjective, holistic, highly cultural, etc.

   Such a view will likely cause a strong culture clash for many, but not all, Indigenous students in a Platonist mathematics class that presents itself as being:

   decontextualized, objective, analytical, purely acultural, etc.

   No wonder Platonist mathematics discourages, marginalizes, or alienates most, but not all, Indigenous students.

4. Thus, Platonist mathematics significantly lowers student graduation rates, especially for Indigenous students.

5. Back in the mid-19th century, the Canadian Federal Government initiated the policy to kill the Indian and save the child. It was severely enacted by church-run residential schools, from about 1834 to 1996. Thousands perished. Those who did survive to reach high school were usually offered courses in manual or domestic labour, which prevented students from graduating from high school.

6. The residential schools interrupted the normal parenting cycle, in which children learn how to become good loving parents by modelling their parents, rather than modelling austere abusive residential school workers as the children were forced to do. The consequence is an abundance of family dysfunction. It continues today for Indigenous people who suffer degrees of deprivation in education, social assistance, housing, health care, employment, and criminal justice. This is the context of teaching mathematics in classrooms that include Indigenous students.

7. The consequences of residential schools are a significant cause of low graduation rates.

8. A Platonist curriculum and Canadian residential schools have had similar effects on Indigenous high school graduation rates; albeit different degrees of racism, but systemic racism nonetheless. Both are unethical.

G. <u>What Is a Rational Alternative</u>?

1. Canada's 21st century era of reconciliation, which emerged in direct response to Indigenous people having endured residential schools, necessitates some type of transformative action regarding Saskatchewan education generally, and our mathematics curriculum and instruction specifically.
2. Some innovative mathematics education R&D[8] projects in Canada, the U.S.A., Aotearoa New Zealand, and Norway have:
    a. recognized that Indigenous cultures have their own mathematics systems
    b. discovered that some cultural artifacts and processes (e.g. beading or canoe construction) express Indigenous mathematics. These concrete events were analyzed from a Euro-American mathematics point of view in order to point out Indigenous mathematizing concepts that have analogues in Platonist mathematics.
    c. developed teaching lessons or units for students to learn about Indigenous mathematics content, and then to learn specific Euro-American mathematics concepts.
    d. used this strategy from time to time whenever a relationship between the two cultures is observed. A few occasions per month makes a great impact in a non-tokenistic way.

H. <u>What Effect Did It Have on Students</u>?

1. ***Indigenous students'*** mathematics ***scores rose dramatically***, sometimes becoming on par with the state's average score. Indigenous students strengthen their cultural self-identities that helps immeasurably to increase academic achievement. These results strengthen the high school STEM pipeline.

[8] Research and development.

2. ***Non-Indigenous students' average achievement increased noticeably as well***. These students learned about the local Indigenous culture, in the spirit of reconciliation, but not at the expense of learning essential Platonist mathematics.
3. It is a win-win situation.
4. This success happened because:
   a. school mathematics became relevant, interesting, current, concrete, and useful for learning about Indigenous cultures usually through experiential teaching methods.
   b. the culture gap between students' home culture and the culture of Euro-American mathematics had decreased significantly.

I. Can the Culture Clash Be Reduced Even Further?

1. Yes. In addition to section G, innovative mathematics R&D projects in Canada and Norway have revisited the 19th century decision that promoted only an elitist "formal" school mathematics and that suppressed the highly relevant "informal" mathematics with its local cultural content (see section D.6). The R&D projects amalgamated the formal and informal categories and taught Platonist mathematics content ***in the context of*** cultural artifacts and processes found in their mainstream society.
   a. For example, students created a spreadsheet for an activity of high personal interest related to their mainstream society. This taught them to think algebraically while their computer did the tedious arithmetic. Then their thinking was transferred to abstract symbols and equations of Platonist mathematics. The transfer was made easier by explicitly teaching some of the human features hidden within Platonist mathematics, such as its values (e.g., logical consistency) and assumptions (e.g., quantification always makes things more objective). Simply put, students learn Platonist mathematics' *internal* human dimensions.
   b. A completely different type of example is ***mathematics-in-action***[9] in the everyday world. The ideology of quantification can raise ethical issues related to the use of mathematics, for instance:
      i. when is it appropriate or not to represent something with numbers?

[9] D'Ambrosio's (2016) and Skovsmose's (2016) work offers many examples.

ii. math modelling used by airline companies to figure out how many seats should be overbooked on a particular flight in order to maximize profits. If the mathematics modelling equations bump you off the airplane, you have a personal issue.

Simply put, students learn Platonist mathematics' *external* human dimensions.

2. These examples demonstrate ways in which mathematics is a human endeavour. The more that school mathematics is experienced this way, the more its culture seems closer to students' everyday culture. Thus, culture clashes are reduced even further. By doing school mathematics this way, both Indigenous and non-Indigenous students are more engaged because it feels more familiar due to it having human dimensions.
3. If we combine all four approaches:
   a. bringing Indigenous mathematizing into school mathematics occasionally in a non-tokenistic way,
   b. teaching the internal human dimensions of Platonist mathematics in an age-appropriate way
   c. teaching the external human dimensions of Platonist mathematics (mathematics-in-action) in the everyday world, in an age-appropriate way
   d. and in these contexts, teaching *essential* Platonist mathematics content on a need-to-know basis, rather than on the basis of a supremacist's feeling that Platonist mathematics is the crowning achievement of humanity and no other type of mathematics really counts;

   then we'll call it ***cross-cultural Euro-American mathematics***.
4. It maximizes academic engagement and achievement for most students, especially the 76% whose worldviews do not closely harmonize with a Platonist mathematics worldview.

J. <u>For the Minority Who Do Not Experience a Culture Clash</u>?

1. The 24% minority of high school students whose worldviews harmonize with Platonist mathematics will have interests and plans related to the STEM pipeline. Thus, their need-to-know criteria reflect an International Baccalaureate type of high school mathematics

by placing greater emphasis on Platonist content within a cross-cultural Euro-American mathematics program.

2. Two academic pathways will accommodate almost all students: pathway α for the large majority of students, and the Platonist enriched pathway β for the small minority of students.
3. Schools must take steps to ensure that flexible movement can occur between the two pathways.

K. Conclusion:

Saskatchewan's economic future will be directly enhanced by transforming our Platonist school mathematics into a cross-cultural Euro-American school mathematics. This is currently happening in Saskatchewan on a small scale by a few innovative consultants and teachers, and no doubt in other jurisdictions. The way forward is now clear:

- transform ***the curriculum*** from its 19th century version to a 21st century version that engages teachers and all students in reconciliation (as Saskatchewan school science did when it was enhanced with Indigenous knowledge and transformed into a cross-cultural Eurocentric school science, during 2008-2012[10]), for both α and β pathways.
- develop ***teaching materials*** collaboratively with Indigenous Elders and knowledge holders so the materials convey valid Indigenous knowledge and reflect the curriculum's reconciliation goal (as Saskatchewan's Ministry of Education did for school science[11]).
- produce an ***academic reader*** for teachers, which provides detailed background information about the curriculum and teaching materials; that is, ideas summarized in the sections above[12]. (Pearson Education published such a book for the science education transformation[13].)
- slightly modify the ***professional development*** program produced for science education by the Saskatoon Public School Division[14], which always begins with teachers having a significant cultural immersion experience.

[10] See Aikenhead and Elliott (2010).
[11] See footnote 6.
[12] See Aikenhead (2016).
[13] See Aikenhead and Michell (2011).
[14] See Aikenhead and 14 colleagues (2014).

- challenge the Ministry's ***assessment*** branch to either design appropriate 21st century strategies that promotes the curriculum, or hand those responsibilities over to school divisions and teachers. Too often, assessment branches tend to restrict an innovative curriculum by using very narrow and culturally invalid assessment practices.
- Saskatchewan's cross-cultural Euro-American school mathematics innovation requires ***culturally valid transformative thinking*** by all groups involved.

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