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[1] Lesson plans are found in separate files, each paged as an independent document.

Acknowledgements

The research team is indebted to Nakawē (Saulteaux) Elder Albert Scott for his extensive Medicine Wheel teachings, his wise counselling, and his generous sharing of sacred Nakawē ceremonies that launched our research project with an authenticity that energized each and everyone.

The research team is most thankful for the professionalism of the teacher participants, Kevin Duchscherer, Serena Palmer, Krysta Shemrock, and Danielle Vankoughnett; for the leadership of principal Sari Carson and for the cooperation of their students. The majority of the content of this project report comes directly and indirectly from the school participants, which is the reason they are listed first in the authorship on the cover page.

The research team would also like to acknowledge the encouragement and support of the North East School Division's Director, Don Rempel.

This research project would never have occurred had it not been for the financial support of the McDowell Foundation and for the patient guidance of its manager, Ellen Whiteman. Thank you ever so much.

Project Report Summary

Background

In Canada's era of reconciliation, cross-cultural respect through mutual understanding was emphasized by the Truth and Reconciliation Commission (TRC, 2015a) in its description of reconciliation. It matters how we do things, such as *how* we teach mathematics.

The project *Culture-Based School Mathematics for Reconciliation and Professional Development* responds to the TRC's calls to action by exploring *how* mathematics can be taught in a culture-based way thereby enhancing Western mathematics pedagogy with Indigenous mathematizing[2]. These two cultural mathematical systems have similarities and differences that create interest among most students. By learning examples of local Indigenous mathematizing, teachers and students develop an understanding of their Indigenous neighbours. Therein lies a tangible act of reconciliation.

This project was inspired by the successes of culture-based mathematics research in Alaska, Hawai'i, Aotearoa New Zealand, Norway, Sweden, and Canada's Maritimes. In these studies, Indigenous students' interest and achievement increased dramatically while the non-Indigenous students generally responded favourably (Aikenhead, 2017a, p. 75). It is a win-win situation that is also evidenced by Serena's assessment data.

Research Question 1

> What supports do teachers need to enhance their teaching of Western mathematics in a sustainable way by bringing some examples of local Indigenous mathematizing into their classrooms?

[2] Indigenous languages are verb-based, whereas Western languages are noun-based. This fundamental difference in cultural worldviews is respected by the use of the term "mathematizing" (verb) exemplified by activities in which counting, measuring, locating, designing, playing, or explaining occur within an Indigenous culture.

The Process

Sharon Meyer (project leader) and Glen Aikenhead (project contact person) mentored and collaborated with four rural mathematics teachers of Grades 5 to 12, Serena, Danielle, Kevin, and Krysta (who went on maternity leave part way through the project) and principal Sari Carson at the Carrot River School. These participants took part in a two-day Indigenous culture immersion; a mandatory experience that initiates teachers into culture-based teaching.

Currently, a key missing support for teachers is the availability of any culture-based lessons applicable to Saskatchewan's Indigenous peoples and its mathematics curriculum. Thus, the development of some lesson plans was a prerequisite process to identifying the support teachers need to implement such culture-based lessons.

Therefore, a half-day personal lesson-planning session with Sharon was held for each teacher. This provided teachers with concrete ideas about outcomes, resources, and classroom activities (i.e., usually Indigenous mathematizing). It boosted the confidence required of developers of culture-based lesson plans. The teachers were left entirely on their own to design their draft lesson plan.

The draft received feedback from Sharon and Glen before the lesson was taught. The feedback became critical to what teachers learned in their journey into culture-based school mathematics.

Then Glen observed the lessons preceded by an audio-taped discussion about how it was developed and what was intended. A post-lesson discussion was held to learn: the teacher's reaction, the students' engagement, the teacher's insights into culture-based school mathematics, Glen's feedback, and their ideas for polishing the lesson plan further. Developing a different second lesson plan after Christmas provided more evidence regarding the type of support required by various teachers. A mentored third lesson plan is unnecessary when in-school teacher network support is in place.

The Product

Each lesson plan development revealed a need for explicit and implicit supports for all teachers who teach lessons similar to the ones developed in this project or for the teachers employed in the future to develop more culture-based lessons for the province.

On the one hand, these supports included: (a) finding authentic Indigenous sources of information, (b) *learning* some features of local Indigenous cultures, and (c) locating examples of Indigenous mathematizing.

On the other hand, we discovered the need for teachers to *unlearn* certain Euro-Canadian ways of understanding Western mathematics and perceiving the world; ways that interfere with cross-cultural understandings found in culture-based school mathematics. Of course, this was only if teachers had not already unlearned them. Unlearning included such ideas as:

- Including an Indigenous topic in a mathematics lesson is not enough to meet a culture-based standard for implementation.

- The popular yet erroneous assumption that mathematics itself is free from human values and any cultural features. This assumption *suppresses* a goal of Saskatchewan's mathematics curriculum: understanding mathematics as a human endeavour. The mistaken assumption either undermines or negates culture-based school mathematics.
- An unconscious cultural ethos of Eurocentric superiority that suppresses humility and marginalizes most Indigenous students.
- The unquestioned appropriation from non-Eurocentric cultures in very subtle yet disrespectful ways. It is so subtle that it seems like common sense to those who do it.
- The habit of dichotomous (i.e., either/or) thinking only. This habit suppresses holistic thinking: "degrees of both." Holistic thinking lets us see the world with two or more different, yet coexisting, fundamental ways of thinking.

Unlearning can be as fruitful as learning, because unlearning broadens one's openness to what can be learned. Yet unlearning is the more challenging process as it is at first invisible to most people in Canadian mainstream culture. In Antoine de Saint-Exupéry's book *The Little Prince*, we learn, "What is essential is invisible to the eye" (1943, p. 70). The teacher participants talked about the importance of approaching Indigenous ways of knowing with an open mind and carrying out open-minded dialogues with fellow teachers, administrators, and parents. In contrast, B.C.'s provincial Auditor-General reported, "Our 2015 report highlighted the impact of the *racism of low expectations* [for Indigenous students]" (Bellringer, 2019, p. 13).

Habits of reasoning are taught to us informally during our family upbringing and formally in our schools and universities. One example is the habit of identifying differences between Indigenous and non-Indigenous students' mathematics test scores as an achievement gap rather than as Canada's accumulated educational debt to Indigenous students that today falls on the shoulders of schools and teachers. It becomes an ethical financial issue for Saskatchewan's legislature, Ministry of Education, and school divisions responsible for supporting schools and teachers.

What is required in part, therefore, is continuous support for teachers to unlearn the habits that inhibit cross-cultural understanding. These were identified and discussed with the project's teachers as the issues arose. This often led to a revision of the original lesson plan in a few ways. Thus, the participating teachers had the immediate opportunity to put their new learning/unlearning into revising their lesson plan. In the future, teachers who implement these lessons will be introduced to the learning/unlearning of information, perspectives, protocols, and advice. Seven culture-based lesson plans were produced.

The four participating teachers learned to feel comfortable with pluralistic thinking by constantly going back and forth between two ways of interacting with the world mathematically (Western and Indigenous), an achievement called two-eyed seeing. It is a matter of taking the best from each way of knowing and drawing on both (to some degree) as needed to solve a problem or issue at hand.

This predilection for two-eyed seeing will always encourage new ways for teachers to engage Indigenous perspectives and mathematizing in their teaching. A sustained impetus to innovate this way comes from students' positive reactions to culture-based mathematics.

At the same time, according to the principal, an even stronger impetus was established by the teachers when they developed an informal professional learning community among themselves. Sari cited that achievement as a major support for the project's sustainability.

Lesson planning accompanied with feedback is a particularly rich context for advancing a teacher's journey into school mathematics for reconciliation.

The participating teachers demonstrated a capacity for continuing their journey into culture-based teaching into the future. Some have already made plans to continue this project informally. During the project, two teachers expanded their culture-based teaching into a *cross-curriculum* approach for selected topics.

The teachers noted a major impediment to their innovation that pervasively discouraged them from doing more than we asked for – the over-crowded and often out-dated mathematics curriculum.

Research Question 2

> What are the identifiable effects on non-Indigenous and Indigenous students as a result of their engagement with Indigenous mathematizing?

It is unreasonable to expect that a short intervention of just one or two culture-based lessons would impact on students' *understanding of mathematics.* Any noticeable change would be remarkable. The sample size (about N = 16 per class) is too small for a meaningful statistical analysis. However, some consequences related to gaining *Indigenous knowledge* were identified in a student questionnaire and in a focus group. The school has very few students of an Indigenous ancestry. For those who participated in a focus group at the end of the project, a unanimous appreciation was expressed for an alternative way of learning mathematics.

Observations

Classroom observations of students learning Indigenous mathematizing pointed to students' physical, emotional, and intellectual engagement, especially students who were not normally engaged in class. A public showing of pride in their mathematizing invariably ensued.

Two comments are relevant here. First, the greater engagement of students reflects the fact that Indigenous mathematizing is naturally action oriented due to the verb-based nature of Indigenous languages and worldviews. Most students naturally responded favourably to action-oriented events.

Secondly, along with greater engagement comes stronger student motivation to learn. When a teacher makes a clear connection between the Indigenous mathematizing and an analogous idea in the Western mathematics curriculum, this Western content is generally introduced to students who are already motivated to learn. This helps explain the international research results, mentioned above, that Indigenous students' scores on standardized tests rise dramatically while non-Indigenous students' scores improve favourably. Time taken for learning Indigenous mathematizing seems to be more than compensated by its greater motivational effect on students.

Student Questionnaires

Data from pre- and post-questionnaire responses showed dramatic increases in Grade 5 students' interest in enhancing their mathematics class with Indigenous mathematizing. In addition, there was an obvious trend toward gaining an understanding of Indigenous cultural knowledge. The former result substantiates the motivational value of culture-based school mathematics, while the latter result indicates participation in reconciliation.

In contrast, the Grade 12 pre- and post-questionnaire results showed little difference. Their open-ended responses suggest: (a) students had become rather set in their views that mathematics is unrelated to anything including Indigenous mathematizing; and (b) students tended to oppose a change in the routine of their mathematics classes to which they had become accustomed.

Overall, however, a majority of all participating students (Grades 5, 6, 10, and 12) expressed an openness to learning Indigenous mathematizing as part of their mathematics class. Within the remaining minority, some continued to be opposed to change, while others became more predisposed to learning Indigenous mathematizing once they were introduced to it.

Project's Objectives

1. To collaborate with four non-Indigenous teachers to help them develop a pedagogy that increases students' understanding of Indigenous perspectives by an occasional engagement with Indigenous mathematizing.

2. To mentor the four teachers as they develop a capacity to independently expand this innovation in the future, as well as transfer their knowledge and wisdom to other teachers as best practice when given sufficient support from school administrators, division administrators, and the Ministry of Education.

3. To reduce Indigenous students' feelings of marginalization by including instances of Indigenous mathematizing. Indigenous students should not devalue their own culture's worldview in order to succeed in the school's Western mathematics.

These objectives address *reconciliation, sustainability,* and *social justice respectively*. The evidence in this project report suggests that all three were met to a reasonable degree given the one-year project.

Conclusions

Learning to teach Saskatchewan Indigenous mathematizing and Indigenous perspectives was experienced by the teachers as a journey upon which to embark. It was accelerated each time a culture-based mathematics lesson was taught along with mentoring support.

It was not so much a professional development exercise as it was a personal life journey with far-reaching rewards.

The teachers discovered that the current mathematics curriculum works against the sustainability of culture-based school mathematics. The Ministry of Education has the authority to cull the current obsolete or inappropriate content taught to most students. This would make room for 21st century innovations such as Indigenous culture-based school mathematics. It would also decrease the negative consequences that accrue for a large minority of high school students who are led to believe they are academically inadequate and who have learned to hate mathematics (Simeonov, 2016). When they become parents, this negativity tends to be passed on to their children who then become a challenge for elementary teachers teaching mathematics.

Continuous support for teachers must come from the school administration, school divisions, and the Ministry of Education. Three key supports for the teachers are a revised mathematics curriculum, Saskatchewan authentic teaching materials, and a professional development experience for Indigenous culture-based instruction. A culture immersion is an effective way to begin the journey.

A revised curriculum for the 21st century, plus administrative *support* from all administrative levels, could enhance mathematics teachers' efforts:

1. to bring Canada's era of reconciliation into their classrooms.

2. to address effectively the diversity of learners from the math-phobic, math-shy, and math-disinterested to the math-curious and math-oriented.

3. to contextualize learning in the general public's actual experiences in *their everyday* worlds rather than in the much narrower experiences of a mathematician's everyday world.

4. to foster two-eyed seeing in all students.

5. to teach at least six to eight Indigenous culture-based lessons a year, similar to those found in Appendix E, for each grade level to Grade 9; and then for Grades 10-12, the same number each year for each mathematics program (some programs might share a lesson plan or more).

6. to motivate all students to reach their potential in reasoning arithmetically, algebraically, and/or spatially given their mathematical preferences, aspirations, aptitudes, and self-identities.

7. to increase the average mathematics achievement of both Indigenous and non-Indigenous students. A plethora of research demonstrates this outcome.

8. to identify math-curious and math-oriented students and encourage:
   - ✓ their preparation for future mathematics-related employment.
   - ✓ their future contribution to creating cutting-edge algorithms for artificial intelligence.

- ✓ their dedication to ensuring best ethical and social practices of artificial intelligence for the good of humanity.

The province's school divisions have a pivotal role to play in the implementation and professional development of culture-based school mathematics.

Our project illuminates a way forward; a method for developing Indigenous culture-based teaching materials on a province-wide basis to match a revised curriculum. Scaling up requires more personnel and greater efficiency, of course. We provide a detailed recommendation in the last section of this project report.

Introduction

Our project[3] was developed in direct response to the Truth and Reconciliation Commission's (TRC) 10th Call to Action that includes: "developing culturally appropriate curricula" (TRC, 2015b, p. 2). Their 63rd Call to Action includes: "Building student capacity for intercultural understanding, empathy, and mutual respect" (p. 7), and "Identifying teacher-training needs relating to the above" (p. 7).

The TRC's description of reconciliation emphasized establishing and maintaining respectful relations and mutual understanding between non-Indigenous and Indigenous Canadians. We adopted this meaning.

Our project also responded to the Saskatchewan Chamber of Commerce's 22nd Call to Action (2017, p. 13, emphasis added), "Ensure cross-cultural learning opportunities are embedded or offered in *all* primary, secondary, and post-secondary institutions."

Mathematics taught in schools today has a long and evolving history. Here is a thumbnail sketch. Early inventions of rudimentary mathematics occurred independently in four isolated diverse cultures (ancient Babylonia, Egypt, China, and India) between 3100 and 2100 BCE. As time went on, there were interactions between these and other cultures such as the ancient Greek, Japanese, and Islamic cultures. As a result, appropriation and further mathematical inventions took place. This evolution of mathematical knowledge only became known to Europeans mainly between 1300 to 1400 CE. This was the era when European mathematicians appropriated the Latin translations of Islamic texts stored in pre-Renaissance monasteries in southern Spain. Plato's philosophy of mathematics was welcomed by a few scholars, while the commercial promise of mathematics was principally realized in a Renaissance economy (Ernest, 2016a). Then over centuries, mathematicians in Europe and its colonies created their own improvements thus putting their unique cultural fingerprints on what is generally called modern or Western mathematics.

Every major culture has devised their own system of mathematics (Ernest, 2016c) with its unique cultural imprint. Therefore, what we teach today is actually *Western* mathematics; that is, European mathematics that evolved with the participation of mathematicians in European nations and all its colonies. Due to colonization and globalization since the 17th century, Western mathematics is used almost worldwide. Some older mathematical systems, such as Islamic and Indigenous mathematics, continue to be used in coexistent ways with Western mathematics.

[3] Appendix A is a short summary of the research project written for the general public.

Our project embraces Western mathematics, and to some extent, the local Indigenous mathematics found across Saskatchewan. Both mathematical systems coexist in non-competitive ways. In the context of students learning both systems, we call this school mathematics culture-based.

Our project's specific purpose was to better understand how four rural teachers (Grades 5-12) can promote cross-cultural experiences for non-Indigenous and Indigenous students by embedding some Indigenous mathematics – Indigenous mathematizing – in their classrooms. By learning some local Indigenous mathematizing, explicitly related to local Indigenous worldviews, non-Indigenous teachers and students generally increased their understanding of their Indigenous neighbours' worldviews. Therein lies authentic reconciliation because from mutual understanding comes cross-cultural respect.

Objectives

As described in several sections in this project report, we achieved our principal objectives to a reasonable degree given the project's one school-year limitation.

Objective 1: To collaborate with four non-Indigenous teachers to help them develop pedagogy that increases students' understanding of Indigenous perspectives by an occasional engagement with Indigenous mathematizing.

Objective 2: To mentor the four teachers as they develop a capacity to repeat the complex process described in Objective 1, so they can independently expand this innovation in the future. Also to transfer their knowledge and wisdom to other teachers as best practice, all in a sustainable trajectory, when given sufficient support from school administrators, division administrators, and the Ministry of Education.

Objective 3: To reduce Indigenous students' feelings of marginalization by including instances of Indigenous mathematizing that can be seen as analogous to Western mathematics curriculum content. In short, Indigenous students should not have to devalue their own culture's worldview in order to succeed in the school's Western mathematics.

Western school mathematics, more than any school subject, has a social issues problem. It tends to undermine First Nations students' graduation rates from high school by marginalizing students in mathematics classes (Abrams, Taylor & Guo, 2013; Anderson & Richards, 2016; Perso, 2012). Our research project's *aim* is to inspire changes to school mathematics in order to ameliorate, and hopefully eliminate, this systemic historical discrimination pervasive in mathematics classes.

Our aim is not ethereal. In the Nova Scotia school division "Mi'kmaw Kina'matnewey" where most Mi'kmaw students attend, the high school graduation rate has risen from about 40% in 1997 to 88% in 2013 (CBC News, 2013; Simon, 2014) and has reached 90% for the 2017-2018 school year (Lunney Borden, 2018). The average graduation rate for First Nations students across Canada was 35% in 2013.

Paying Off Canada's Educational Debt

When describing these different graduation rates, some speak of an achievement gap between non-Indigenous and Indigenous students; for instance, the TRC's 7th Call to Action:

> We call upon the federal government to develop with Aboriginal groups a joint strategy to eliminate educational and employment *gaps* between Aboriginal and non-Aboriginal Canadians. (TRC, 2015b, pp. 1-2, emphasis added)

Unfortunately, this term "gap" implicitly blames Indigenous students for not being adequately prepared to achieve in school mathematics. The term conveys a student's deficiency. Of course, this was not the intent of the TRC.[4]

The blame irrefutably lies elsewhere. The gap is actually *an educational debt* accumulated by Canada's past and present governments, and approved by a large portion of Canadians who continually looked the other way, when racism occurred, when brutal colonial genocide was enacted, and when residential schools tried to kill the Indian in every child. In many ways, Indigenous peoples were officially denied a place in Canada's economic growth.

Today economic participation tends to be allowed only reluctantly forced by rulings from Canada's Supreme Court. In short this educational debt accrued with every instance of colonial genocide:

> Colonial genocide is "the destruction of those structures and practices that allow the group to continue as a group" (TRC, 2016, p. 3).

Government action took the form of violence, starvation, sexual exploitation, cultural erosion, racism, oppression, and marginalization (Daschuk, 2013). As a direct result, with a few notable exceptions, Indigenous peoples currently suffer degrees of deprivation in social assistance, housing, health care, *education*, employment, and criminal justice.

Non-Indigenous citizens of Canada have *financially profited from* this deprivation by either not caring or not knowing that their increasing privileges accrued at the expense of most Indigenous citizens. Little did they know their privileges would accumulate an enormous educational debt. To close the educational achievement gap, financial payments literally must be made by the provinces to finance the human resource payments to be made through innovations and increased efforts by mathematics educators today and in the future. Given their worst inequity record of all subjects, mathematics educators have a larger share of the educational debt.

Mathematics educators in Canada and elsewhere are beginning to do their part toward such reconciliation efforts to help pay off our educational debt by committing themselves to taking a professional development journey into enhancing their school subject with Indigenous perspectives. What can mathematics educators do?

Our research project, *Culture-Based School Mathematics for Reconciliation and Professional Development*, inspires educators to transform school mathematics so it becomes an

[4] This situation exemplifies how English words and expressions can act like a Trojan horse by surreptitiously assimilating Indigenous people into thinking in a Euro-Canadian way, simply by the English words and expressions they pick up habitually, thereby continuing Canada's ongoing agenda of colonization. Battiste (1986, p. 23) identified this process as "cognitive imperialism."

equitable (not equal) learning environment. It shows how one small town school can take the time and energy to learn to modify what and how they teach in order for Indigenous students to achieve on par with their non-Indigenous counter parts.

In doing so, we are helping to pay off a modest amount of our country's educational debt. At the same time, non-Indigenous students tend to become more engaged and understand Indigenous perspectives in greater depth. This is one conclusion to the section Background and Relevance of the Research, and the conclusion is supported by data in the subsection Analyses of Student Questionnaires.

How do we know when the debt has been paid off? When people no longer speak of an educational gap. It took our country a few centuries to accumulate today's enormous educational debt. It will take many years to pay it off. Our Supreme Court has already begun to call in the social services' debt. Education (the new buffalo) may likely be next including school mathematics.

Initiating a professional transformation offers a secure way to begin paying off our debt, step by step, and reaping the same satisfaction that other mathematics teachers have enjoyed when they began to put in the effort (Aikenhead, 2017b, section 8).

Background and Relevance of the Research Project

One of the four goals of the Saskatchewan curriculum is learning "mathematics as a human endeavour." This expresses a humanistic perspective that recognizes the Western cultural identity of mathematics (Sriraman, 2017). It also acknowledges the mathematical systems that Indigenous cultures possess – Indigenous mathematizing.

Aikenhead (2017a) refers to a respectful, non-tokenistic, coexistent combination of the two systems taught in schools as culture-based school mathematics. The idea was developed in: Aotearoa New Zealand (Barton, 1995), Australia (Maths in Aboriginal Communities Project, 2007), the U.S. (Furuto, 2014; Lipka & Adams, 2004), Norway (Fyhn, 2009, 2013), Sweden (Jannok Nutti, 2013), and Canada (Beatty & Blair, 2015; Fettes, 2007; Lunney Borden, 2013). The successes and limitations of these and other similar projects were reviewed by Aikenhead (2017a, pp. 104-118; & 2017b, sections 8 & 9). Of note is the consistent dramatic increase in academic achievement by Indigenous students and the noticeable increase by non-Indigenous students. This is why our project matters.

Because Indigenous knowledges are place-based rather than universal like Western mathematics, specific culture-based school mathematics *outside* of Saskatchewan cannot be directly applied here, but it can certainly inspire a parallel development and improvement in Saskatchewan.

Missing in this research literature are investigations into the experience of mathematics teachers who implement culture-based school mathematics for the first time, with one exception being Sámi mathematizing taught by Sámi teachers in Norway (Fyhn, 2009, 2013) and Sweden (Jannok Nutti, 2013). Even in the case studies published by the substantial Alaskan Yup'ik *Math in a Cultural Context* project, teachers' voices were all but missing.

In contrast, the experiences of science teachers implementing Saskatchewan's Indigenized science curriculum have been explored (Aikenhead et al., 2014). There are some transferable results for mathematics teachers such as: (a) the necessity of holding a culture immersion at the beginning of implementation; and (b) "the brain needs the heart" (p. 107). But because school mathematics is unique, mathematics teachers' experiences will certainly differ on other issues.

The assessment of students in culture-based school mathematics projects has largely been limited to quantitative measures. As stated above and well worth repeating, these research findings consistently show that *mathematics achievement on standardized tests increases dramatically for Indigenous students, and noticeably for non-Indigenous students.*

More specifically, culture-based school mathematics projects have "increased student mastery of science and math concepts, deeper levels of student engagement in science and math and increased student achievement in math and science" (U.S. Congress House of Representatives Subcommittee on Early Childhood, Elementary and Secondary Education, 2008, p. 13), (see also: Meaney et al., 2012; Nichol & Robinson, 2000; Perso, 2012; Richards, Hove & Afolabi, 2008; Sakiestewa-Gilbert, 2011).

Greater achievement was also found for *non-Indigenous* students in those same classrooms (Adams, Shehenaz Adam & Opbroek, 2005; Beatty & Blair, 2015; Davison, 2002; Lipka, Wong, & Andrew-Irhke, 2013; Nelson-Barber & Lipka, 2008; Richards et al., 2008; Rickard, 2005). Simply put, teaching culture-based school mathematics is a win-win situation in terms of student engagement and achievement.

Qualitative assessments in culture-based school mathematics have largely gone unreported. Saskatchewan school divisions, wishing to implement culture-based school mathematics programs in keeping with possible future developments in Saskatchewan's mathematics curriculum, will be assisted by the answers to our qualitative research questions (stated next).

Research Questions

1. **What supports must be in place for teachers to enhance their mathematics classes with Indigenous mathematics in a sustainable way? (i.e., culture-based school mathematics).**

   In other words, we want to better understand how four rural teachers (Grades 5-12) can promote culturally responsive experiences for non-Indigenous and Indigenous students by embedding some Indigenous mathematizing in their classrooms. These experiences lead to mutual cultural respect.

2. **What are the identifiable effects on non-Indigenous and Indigenous students as a result of their engagement with Indigenous mathematics?**

These two questions determined the data that the research team sought throughout the project.

Research Team

1. Sharon Meyer – Team Leader
    - Plains Cree ancestry.
    - Cree knowledge holder.
    - Total of 28 years' teaching/administration/consultant including one semester teaching at the Carrot River School where she was a colleague with participating teachers Krysta and Kevin.
    - Greater Saskatoon Catholic Schools, Muskoday First Nation Community School, and North East School Division.
    - Received numerous awards of excellence throughout her career such as the University of Saskatchewan Alumni Excellence in Aboriginal Initiatives Award.
2. Dr. Glen Aikenhead – Team Contact Person
    - A white, middle-class male.
    - Total 5 years' teaching high school and lower secondary mathematics and science (Calgary, Germany, and Switzerland) and 33 years at the University of Saskatchewan (retired in 2006, Professor Emeritus, Aboriginal Education Research Centre).
    - Involved in research and development with Indigenous cross-cultural science over the past 26 years and cross-cultural mathematics for three years.
    - Contributor to Indigenizing *Pearson Saskatchewan Science* textbook series.
3. Danny Sylvestre – Team Member
    - Dené ancestry.
    - Total of 13 years' teaching.
    - Presently at La Loche, Grade 5; earlier a Math Catalyst, Chief Little Pine First Nations School.
4. Kelley Cardinal – Team Member
    - Cree Ancestry.
    - Total of 5 years' teacher/consultant.
    - Greater Saskatoon Catholic Schools.
5. Ted View – Team Member
    - Vietnamese ancestry.
    - Total of 17 years' teacher/administrator.
    - Greater Saskatoon Catholic Schools and earlier at Osk'yak High School.
    - Contributor to Indigenizing *Pearson Saskatchewan Science* textbook series.

Carrot River Collaborating Teachers:

1. Mrs. Sari Carson – Administrator
   - 25 years' teaching experience, B.Ed. Elementary.
   - Eight years in administration (five years K-4 and three years 5-12).

2. Mr. Kevin Duchscherer – Grades 7-12
   - 19 years' teaching experience, B.Sc. (Math), B.Ed. (Secondary Math and English/History).

3. Mrs. Serena Palmer – Grade 5
   - 12 years' teaching experience, B.Ed. (Reading, Math).

4. Mrs. Krysta Shemrock – Grades 11-12
   - 10 years' teaching experience, B.Sc. (Math), B.Ed. (Math, Biol.).

5. Miss Danielle Vankoughnett – Grade 6
   - First year of teaching, B.Ed. (Middle Years).

These teachers represent a diverse group, and they are located in the typical, rural, small town school of Carrot River. These conditions are favourable to transferring this research project's findings to many schools across Saskatchewan.

Entry to Research Site

In November 2017, while preparing our Letter of Intent to submit to the McDowell Foundation, Sharon Meyer contacted Mr. Don Rempel, Director of the North East School Division (NESD), to express our intent to develop a research proposal. His response was very encouraging. Before we submitted our April final proposal for the Foundation's adjudication, we received immediate and enthusiastic support from director Don Rempel and the school's principal, Sari Carson.

During an interview at the end of the research project, Sari explained, "I felt honoured to be worthy of Sharon's invitation to carry out the project. She must have felt that our teachers are open-minded enough to take on something that was beyond their comfort zone."

When we learned in June that our proposal had be accepted by the Foundation, Sari reacted by offering us August 31 as a full professional development day to begin our collaboration with the four mathematics teachers who volunteered to participate. At the Carrot River School, the morning of August 31 was dedicated to the four teachers and principal while all of the staff attended the afternoon portion of the professional development day.

August 31, 2018 Meeting

The day's agenda is found in Appendix B. The following people attended:

- Project teachers Krysta, Kevin, Danielle, and Serena.
- Project team leader Sharon Meyer, project contact member Glen Aikenhead, and team member Danny Sylvestre.
- Project Elder Albert Scott (Saulteaux) and principal Sari.

To describe the project to the teachers, its title was partitioned into four parts:

A. Culture-Based School Math

B. Reconciliation

C. Professional Development

D. Initiating Collaboration

A. Culture-Based School Math

1. All major cultures past and present have invented their culture's way of doing mathematics often borrowing from other cultures (Aikenhead, 2017b, section 4.4).
2. Our culture's mathematics was appropriated from past empires and civilizations and has been improved upon in some ways. Thus, it became Western mathematics – the mathematics of Western nations – that is the mathematics we teach in Saskatchewan schools. This mathematics content can be taught in the context of Saskatchewan's major cultures. We call this approach culture-based mathematics.
3. Besides Western mathematics, Saskatchewan has Indigenous mathematical systems defined by how a First Nations community traditionally counts, measures, locates, designs, plays, and explains. In Saskatchewan, consequently, there are two major culture-based mathematics systems – Western and the local Indigenous.
4. Through hands-on activities, Sharon demonstrated:
   a. features of Indigenous mathematic systems – Indigenous mathematizing.
   b. how some of the six fundamental processes of mathematics in an Indigenous culture are analogous to some of the content in Saskatchewan's mathematics curriculum.

B. Reconciliation

As mentioned above, the TRC's description of reconciliation emphasizes establishing and maintaining respectful relations and mutual understanding between non-Indigenous and Indigenous Canadians (TRC, Summary Report, 2015a, p. 27).

We adopted this general meaning of reconciliation. Four teachers were mentored to include an example of authentic Indigenous mathematizing in a mathematics lesson. Teachers taught Indigenous concepts or processes analogous to certain Western mathematics concepts or processes. These special lessons connected the Indigenous activity to an Indigenous worldview. Sharon made these connections explicit. This learning process is simply a way of developing an understanding of Indigenous worldviews that contributes directly to respectful relations. In their Indigenous mathematizing lessons, teachers pass these understandings on to their Indigenous and non-Indigenous students; a process in harmony with the TRC's notion of reconciliation.

C. Professional Development (outlined in Table 1)

1. Sharon and Glen will mentor teachers in developing lessons involving Indigenous perspectives. Lessons will be discussed with fellow teachers and with Sharon and/or Glen prior to being observed.

2. After teaching/observing a lesson, valuable feedback was identified with respect to:

   a. what the teacher's goals were for that lesson.

   b. how students reacted to it.

   Based partly on that discussion and guided by the teacher's professional intuition, an updated lesson plan will be written for the purpose of disseminating it. See Appendix E in this project report. During the project, this accumulated feedback will be condensed for this project report (see section Culture Based-Mathematics Lesson Taught and Discussed). The whole process should be transferable to other teachers and school principals for creating their own professional development program for teaching Western mathematics and some Indigenous mathematizing in a way that enhances school mathematics for all students.

3. In the morning session, the teachers read and discussed "Teresa's Story: Benefits of Interacting with Elders and Knowledge Holders;" and "Tina's Story: The Brain Needs the Heart" (Aikenhead et al., 2014). The stories were created by science teachers in a professional development program somewhat similar to this one. The first story offered dramatic evidence for students' increased engagement as a result of their teacher's participation in a culture immersion. As a result, the four teachers had some insight into the consequences of participating in their own culture immersion planned for early October (described in the next section of this project report).

4. Next, relevant details of our McDowell Foundation contract were addressed. Copies of the ethics contract were distributed to the teachers, discussed,

and taken home for scrutiny. They were signed only after every detail was completely understood.

D. Initiating Collaboration

Just before lunch break, the teachers were asked to generate questions they anticipated their colleagues would ask about the research project during the afternoon session. Each teacher and researcher selected one of the questions that they would answer in the session with their peers. Collaboration began that day.

The afternoon session was held for all teachers in the school. Elder Albert Scott presented a detailed description of his Medicine Wheel model for teaching that applies to both educating students and living in a good way. His model's axiom was: "Creator made everything in the sacred number four." Twelve topics are organized into tetrads that Elder Scott described and connected to education.

Examples of tetrads included:

- Sun, sky, moon, stars.
- Fire, rock, water, wind.
- East, south, west, north.
- Tobacco, sweetgrass, cedar, sage.
- Infancy, youth, adult, eldership.
- Body, emotions, mind, spirit.

This Medicine Wheel model can serve as an inclusive holistic framework that offers direction for what to include in mathematics lessons that teach Indigenous mathematizing or perspectives.

The collaborating teachers and researchers then formed a panel to respond to questions posed by the other teachers.

Teachers' Retrospective Comments

In early November when the four teachers were working on their first culture-based lesson, each was interviewed in order for the research team to learn how the teachers viewed their experiences at the August 31 professional development day.

All four experienced mixed feelings. On the one hand, three expressed positive feelings (e.g., very excited, honoured to be involved, invigorated, and felt they were in good hands with Sharon as team leader) because of earlier contact with Sharon as a colleague or as a consultant helping teachers enhance their science program with Indigenous perspectives when the science curriculum was renewed in 2008. Most recognized we are living in an era of reconciliation and that meant the project was highly worthwhile to them.

On the other hand, they began the day feeling:

- overwhelmed by what might lie ahead.
- anxious over feeling inadequate due to not knowing very much about First Nations culture in spite of hearing some previously,
- uncertain about how First Nations knowledge would fit into mathematics lessons and about how the project would unfold.
- worried over how much extra time the project will take.
- very concerned about making a mistake or inadvertently offending the Elder and others.
- unease over the extra pressure from knowing how serious and worthwhile the project is.

Serena and Krysta had moved from teaching science to teaching mathematics recently, which added to their uncertainty. Danielle felt understandably petrified as it was her first year of teaching. She also felt confused as she had assumed the research project would entail learning to teach an experimental unit already developed by others rather than learning how to develop innovative lessons herself. And lastly, Krysta was concerned about how her maternity leave beginning in December would affect her participation.

When the teachers summarized the day, however, we heard: "A lot of my questions were answered." "I felt more comfortable" because we will have "lots of assistance along the way," and "The expectations of the teachers were spelled out." Yet some uncertainties remained: "Can I make the First Nations content relevant to my students?" "Will students become engaged?" "Do I really understand what reconciliation means?"

The Culture Immersion

A culture immersion is a transformative experience organized by a group of Indigenous Elders and knowledge holders that lasts at least two consecutive days and includes an overnight stay if feasible.

It is a *foundational prerequisite* for:

1. a project or teachers who will develop culture-based teaching lessons (Chinn, 2007; Furuto, 2013, 2020; Fyhn, Sara Eira, & Sriraman, 2011; Lunney Borden et al., 2017; Michell et al., 2008).

2. teachers who implement those materials (Aikenhead, 2017b, section 8; Aikenhead et al., 2014).

3. curriculum writers who compose outcomes and indicators for culture-based school mathematics (Aikenhead, 2017b, sections 2.4 & 10.3; Belczewski, 2009).

Culture immersions are filled with superb learning moments including those that help guide us around potential linguistic pitfalls that otherwise may cause confusion or misconceptions.

Team Leader Sharon Meyer and Elder Albert Scott planned and organized a two-day culture immersion experience held on October 2 and 3, 2019. Albert led the first day's activities while Sharon ran the second day. The teachers had collaborated with Sharon on planning by supplying her with ideas and questions they wanted addressed.

The culture immersion was held at the Carrot River School for the participant teachers and principal. Elder Albert Scott was accompanied by Wayne Thomas, his Oskābēhos (Pipe Ceremony helper), and guest Elder Arthur Scott. See Appendix C for each day's agenda.

The event began by Elder Scott presenting an informative talk comparing Indigenous and Western worldviews. The day was highlighted by everyone smudging, followed by a pipe ceremony and a traditional feast. These became memorable events. They surfaced at the conclusion of the research project during the interviews conducted by Team Member Kelley Cardinal and Daniel Sylvestre.

Albert's description of the feast is found in the first half of Appendix C. (For a synopsis of the interviews, see section Independent Final Interviews with the Teachers.)

The ceremonies were introduced by Albert Scott, who explained the connections between what protocols are followed and the Saulteaux (Nakawē) First Nations indicative[5] worldview. This process of connecting an action with an aspect of a worldview was modelled for the teachers. They will be mentored to follow the process when teaching Indigenous mathematizing along with Western mathematics. Making connections is a fundamental process in culture-based school mathematics.

The teachers' and principal's first-hand experience participating in these ceremonies caused them to learn most of the protocols. At the end of the day, teachers had their questions answered. They learned, for instance, that these ceremonies focused on the individual spirituality of each participant. The result for teachers was the feeling that they had joined Elder Scott's circle.

Sharon took responsibility for the second full day of the culture immersion. Her agenda is also found in Appendix C. She demonstrated parts of the Medicine Wheel teachings; for example, the holistic relationships among Grandfather Fire, Grandfather Rock, Grandfather Tree, and Grandfather Wind. Sharon discussed life on a reserve and answered all of the teachers' questions.

The reconciliation part of our research project is:

1. teachers learning Indigenous perspectives from an Elder, from a knowledge holder, or from some other authentic source.

2. teachers passing on those ideas to their mathematics students by way of Indigenous-based activities and classroom discussions. The goal is to pass along as much as teachers can remember and not to worry about forgetting some details.

3. students discussing what they had learned with their friends and family.

Next, the teachers participated in playing a few Indigenous games, making a dream

[5] An indicative worldview indicates what members do, while a prescriptive worldview is what they are expected to do. Sometimes the two legitimate senses are confused. The latter sense risks stereotyping.

catcher, and looming with plastic beads (e.g., free style looming). This was followed by brainstorming the connections between these activities and Western mathematics. This ended the second day.

It became evident that the teachers were establishing their own network to carry on such brainstorming and to help each other with planning ideas for mathematics lessons that made connections to Indigenous mathematizing.

The day can be summarized by Step 2 in Table 1. The teachers were engaged in the same processes that they will engage with their students.

> "Learn: (a) how to do it; and (b) how it is related to the local Indigenous community's indicative worldview." (Quoted from Table 1.)

Teachers' Retrospective Comments

As was the case for the August 31 professional development day, the teachers were interviewed in early November about their culture immersion experiences. The following are quotes and paraphrases expressed by each teacher.

Krysta

We started the first day with teachings from Elder Albert Scott. He presented a First Nations worldview, and he compared it to our traditional worldview. I wondered how we're supposed to incorporate First Nations content into math, because math is very traditional and structured. Learning the worldview of the First Nations allowed me to see that mathematics' rigidity does not need to exist. There is not only one way to teach math, as there is not just one way to view our world. There's much more flexibility and freedom. Albert reinforced that for me.

We also participated in a pipe ceremony and feast. I feel honoured to have been a part of this ceremony and to learn more about Albert's First Nations culture. It reinforced my understanding of their worldview and how we need to honour Mother Earth. I had smudged previously when working with Sharon at teacher conventions.

Albert did a great job of explaining the First Nations worldview. At the end of the day, I still felt like I needed to know more about *connecting* First Nations content to my specific curriculum.

On the second day of our culture immersion, Sharon talked about a First Nations worldview by explaining the importance of earth, wind, fire, and water. In the afternoon, we made dream catchers, made bead looms, and played Indigenous games. Throughout all of these, Sharon asked us to reflect on making connections to our math teachings. For dream catchers, I thought about methods of counting and the fundamental counting principle. In bead looming, I thought about conditional probability and placing all of your beads in one dish and then grabbing them at random to make the loom. The games linked well to probability, logic, and reasoning.

Sharon described the history behind today's annual ritual among First Nations people to collect $5 treaty money. Many times, a person would not show up, or they had decided never to collect their $5 from the federal government. That money goes back to the federal government to spend. It is not treated like a bank account that holds the money for a person. Sharon posed important mathematics questions about financial implications such as compound interest. How much interest would accrue for the federal government after the first year of taking back the unclaimed $5 treaty money? Considering compound interest, how much money would the federal government gain over 25 years if someone never collected any treaty money? Is it ethical to do what the federal government does? Sharon's questions demonstrated how to connect Indigenous knowledge with mathematics.

Sharon never told us what materials would produce a good lesson. Instead, she was a resource who showed us or described an Indigenous activity. Then it was up to us *to think* of connections and *to decide* what materials would work. That was a skillful process we were beginning to learn.

One thing I found beneficial was having the opportunity to work with my colleagues. For example, a phrase Kevin used, "the lines get smaller" clicked "calculus" in my mind. As soon as I said "Kevin," he too made connections to calculus and math limits.

Being familiar with your curriculum is important, but having Sharon guide us through activities was powerful.

Sharon has a wealth of knowledge of First Nations traditional games and activities. She would ask, "How could you incorporate this Indigenous activity"? Then she gave us time to flush out ideas on how to use them in the classroom. She inspired, and we did the follow-up thinking and creating. There were lots of moments when I thought, "I don't know." But the more I thought about it and discussed it with my colleagues, all of a sudden we were able to bounce ideas off of one another.

Kevin

I was blown away by how much I don't know about Indigenous cultures. I'm both overwhelmed and fascinated by the chance of learning more. But I still fear doing something wrong. Albert did a good job of putting me at ease.

My participation in the feast, helping to distribute the food, was an honour. I tried online to understand a Saulteaux word he repeated often, but I didn't know how to spell it. It was amazing. I sat through the pipe ceremony and noticed everything was in fours. The medicine wheel is in fours. So many things are in fours.

The first day laid the foundation for the second day. I felt more at ease the second day, because we discussed pedagogy and materials to incorporate in lessons. That's my business, so I felt more comfortable. But without the first day, the second day would have been mechanical and would not represent the spirit in what we want to accomplish.

The looming activity was personal to me. I really got involved. I look forward to using the items Sharon showed us as part of the mathematics curriculum delivery in my courses. Instead of thinking about two separate things (Indigenous and Western mathematics), I want to mesh the two in an interlocking way. I don't want students to see them as separate. I don't want students to feel the Indigenous culture is just another curriculum outcome. I want it to have *meaning* to the student.

For example, when you ask people, "What is mathematics?" they'll say adding, subtracting, multiplying, and dividing. Why can't this be on the Medicine Wheel for teaching? I described to Sharon how I would set it up. That made me reflect on how important the Medicine Wheel is. It can be a personal thing too.

Danielle

On the first day, I felt a little overwhelmed because too much information was given. A lot overlapped with what I learned recently in my B.Ed. program at the University of Regina. It was a very long day. The next time, day one should focus on bringing First Nations knowledge and math content together. The First Nations knowledge was *great*, but it needed to be connected to math.

In the closing circle that day, guest Elder Arthur Scott said, "We're on a path. We're wobbly at first, but then it gets better." I believe that, because I'm a little bit out of the dark, but not completely out of the dark.

On the second day, we sat and listened in the morning. The afternoon went quickly because we were *doing* activities that had a lot to do with math content. Having thought about what I just said, I see it's important to not always be teaching *to* my students, but have them *do it* as well.

My internship cooperating teacher was big on integrating First Nations knowledge but not in math. I had learned that curriculum treaty outcomes were the only Indigenous knowledge to be taught. The second day of the culture immersion, I learned a lot more about teaching any Indigenous knowledge. It showed me how freeing the teaching profession is, because you can be flexible with the curriculum.

As easy as textbook work is, the session taught me that it is not always the best option. I wrote down everything Sharon went through. As I began planning my first lesson, I used the same symbols on both documents to show when an idea in my lesson plan illustrated or followed what I had written in my notes on Sharon's ideas. Danielle was certainly making connections.

Serena

I had heard my sister-in-law speak of First Nations knowledge based on her university studies and on her personal experiences participating in ceremonies such as a Sweat Lodge. Thus, I was very much looking forward to the first day of our culture immersion to learn.

As we were going through the day, several thoughts came to me:

1. We could learn so much from First Nations cultures about patience, respect, gratitude. Elder Scott's prayers were all about thankfulness.

2. I saw connections between my Christian perspectives and First Nations perspectives. There are so many ideas that cross over between the two, exemplified by Sharon's description of her family. Both perspectives are about living in a good way.

3. Sharon talked about the four dimensions of being human (physical, emotional, mental, and spiritual). Our Western cultures have missed out on the spiritual. We're so focussed on the physical side.

4. I found it very interesting how life lessons were always connected to an experience and how teaching the younger ones is best through experiences. And I thought, *wow*! As teachers, we talk about how students will remember things if we can make it part of their experiences. First Nations people have focused on this for years. For instance, I used to pick berries with my Grandmother. According to First Nations understanding, this taught me self-discipline as it does Indigenous children when they pick berries. And from nature, bees can teach us concepts of form and space, both analogous to concepts in Western math.

5. There is a lesson in *everything* we do. We can go through the day doing what we have to do for living. I focus on getting the job done well. But First Nations people tend to look deeper to find a lesson to be *learned* or a lesson to be *taught*. In my world, life is so busy that I don't think, "What lesson can I learn from this?"

6. And I think *we* have purposes too. But because we're not thinking of them like First Nations people are taught to do, we miss out on identifying an activity's meaning for us.

After the first day was finished, I thought, "My lifestyle is missing so much that is there to discover." For example, rather than express our gratitude by offering tobacco to a tree we're about to take down, we focus on the resulting land we can use for *our* benefit. We don't see the tree as a gift to us from Mother Earth.

I came away from that day feeling very humble and very thankful for having been a participant. Wow!

On our second day, Sharon shared some background information about living in Saskatchewan as an Indigenous person. Then she gave us First Nations games that we can possibly use in our math lessons.

The more I learn about First Nations, the more I think that our understandings of First Nations people are based on *mis*understandings and untruths. The wording in the treaties can lose meaning when translated. For instance, Cree concepts for numbers differ from our concepts. The Cree First Nation gives the number zero much more attention than we do. Cree counting (translated) goes like this: zero, one, two, three, etc. The treaties were written in English, so it counts like this: one, two, three etc. Misunderstandings will likely occur whenever zero is translated.

It was an awesome afternoon. We did so many activities and games. My only complaint was I think we could have done that all day long. In one afternoon, there wasn't time to think about where the activities and games could fit into the curriculum I'm teaching.

When reflecting upon the sequence of events so far in the research project, there were good reasons for the August 31 meeting coming first, and then the first culture-immersion day, followed by what we did the second day. It all worked for me. I felt more prepared and equipped to create my lessons.

Sari

The culture immersion was *powerful* stuff. For example, there was the feast and the sacred ceremonies in which we were allowed to participate. These were first-time experiences for us especially the finer points about *how* the food was handed out and *who* did it.

Conclusions

Krysta's question, "Is it ethical to do what the federal government does?" signifies that mathematics used in everyday life is subject to interrogation *beyond* the narrow concern – Is it mathematically correct? This idea to broaden the scope of mathematics is crucial to living in the 21st century.

Consider how the mathematical algorithms of artificial intelligence influence, and often dominate, society today (O'Neil, 2017a; 2017b). Artificial intelligence's powerful algorithms are mostly kept invisible to all citizens. In some social contexts, these mathematical algorithms make decisions for humans (e.g., airline bumping, using a dating service, target advertising that appears on the internet sites we visit, obtaining a loan, deciding on sentencing for law breakers, etc.). Just because they are data-driven and mathematics-driven does not mean they are objective. Programmer and data biases inhabit the mathematical algorithms of many artificial intelligence devices.

The teachers' comments convey a growing interest in, a growing understanding of, and a growing respect for Indigenous peoples. Reconciliation is obviously an integral feature of culture-based school mathematics. Their comments provide dramatic evidence in favour of drawing on an Indigenous style of pedagogy – personal experiences create engagement for students and teachers followed by reflections on what has been learned.

Dr. Greg Cajete, a Tewa from the Santa Clara Pueblo in New Mexico, described Indigenous pedagogy as "coming to know." Students' coming to know means "to learn in a deep way" (Cajete, 2000, p. 110). How deep? Coming to know engages students in *personal* meaning making. This is achieved when students make connections between what is to be learned on the one hand, and on the other, their culture, their self-identities, and the *purpose* behind what is to be learned.

As described at the beginning of this section, Culture Immersion, culture-based mathematics educators discovered the necessity of holding a culture-immersion session in order to develop a successful professional development program. As mentioned above, a co-author teacher participant in a culture-based school *science* project (Aikenhead et al., 2014), Tina Rioux wrote her story called, "The Brain Needs the Heart" (p. 107).

This theme implicitly underscores the present research project's participant teachers' retrospective descriptions of their culture immersion. Within their unique perspectives, the teachers were moved emotionally from the heart. This led them to contemplate a personal *purpose* for engaging in our project. At this point in their journey of coming to know culture-based school mathematics, their involvement has been ignited. Now they are all keen to put culture-based school mathematics into action.

At the end of the culture immersion, the teachers expressed a wish to have had more time during the culture immersion to work with potential teaching materials and to connect them with their curriculum. We realized their wish could come true if Sharon mentored them *individually* during a half-day of released time; the topic of the next section.

Mentoring the Collaborative Teachers

It was agreed that Sharon would meet with each teacher once during October for a half-day in order to work with them on their lesson planning. She followed the same approach she used in the afternoon of the culture immersion's second day. She inspired, while the teachers did the thinking, chose creative connections to the curriculum, and made the final decisions. The teachers began to develop their Indigenous culture-based lessons in October, during and after Sharon's mentoring sessions. Their lessons were taught in November. The project's sustainability (i.e., its continuation and progression into the future) depends, in part, on the capacity building by the teachers.

To summarize, Sharon coached each teacher on the challenging, cross-cultural, creative process of turning an Indigenous process, activity, or idea into a culture-based mathematics lesson or a series of lessons. She was able to guide their thinking by asking questions and by describing Indigenous processes and content for a teacher to consider. In other words, she encouraged each teacher to play around with it, to explore it in greater depth, or to reject it.

Teachers' Retrospective Comments

At each mentoring session, teachers were focused on coming up with a topic they could expand into their first lesson. The stories of how each teacher developed their lesson are described later in the section Culture-Based Mathematics Lessons Taught and Discussed.

From Sharon's perspective, during their half day with her, each teacher made great strides toward becoming a teacher of Indigenous culture-based school mathematics.

During Glen's audio recorded interviews with each teacher, he asked them to reflect on their mentoring experience with Sharon. On the one hand, the teachers were fairly silent on the *process* of being mentored. But on the other hand, they all profusely expressed their gratitude and appreciation for having the half-day experience with Sharon. Here are some quotations.

- ✓ "Our division is so blessed having you. You brought so much change to our division regarding First Nations and Métis education."
- ✓ "I'm privileged to be part of this project, part of the process, learning about Indigenous knowledge and my math teachings."
- ✓ "I feel validated now."
- ✓ "Sitting with her and learning specifically about the topic I would teach was crucial. There's a lot of information on the web, but having her as a resource was crucial. Working with Sharon was a pivotal moment."

During these one-on-one meetings, teachers tended to ask questions about the research project often wanting information that appeared in handouts distributed and discussed at the August 31 meeting. Such information only makes sense to a person once they become ensconced in the project's activities such as putting a lesson together. As result, every teacher felt more comfortable *at the end of* their private session with Sharon than they did at the August 31 meeting.

An additional interpretation can be drawn from the fact that some of the ideas and expressions in those handouts made little to no sense to the teachers. Those ideas and expressions can only have meaning when a person has gone through the experience to which the words relate. That is to say, the teachers had not lived through the research project to which the vocabulary referred. This idea was expressed above by Danielle when she realized the difference between telling students something and having them experience it.

Through these one-to-one encounters, Sharon forged stronger relationships with all the teachers; relationships that could not have evolved as much in the public context of the culture immersion.

Culture-Based Mathematics Lessons Taught and Discussed

Following Sharon's individual half-day mentoring sessions, the teachers were on their own for exploring ideas for their first lesson and for finding resources. A lesson would take two or three days to teach, as it turned out. Sharon was available to answer questions in her capacity as a North East School Division's consultant until her knee surgery in early November. The teachers began to discuss their progress with each other forming a spontaneous support network. When a good draft had been written, they sent their lesson plans to Glen for him to offer suggestions, if any. He would be with them when the lessons were taught in November.

When he joined them, pre-lesson and post-lesson conversations occurred that were audio taped but not transcribed. Glen composed a synopsis of these conversations for each teacher. The content was checked by each teacher and edited to reflect their understanding and their choice of wording. Thus, each teacher became the author of their synopsis. A table format was adopted in order to emphasize implications for answering the project's two research questions.

Krysta's Lesson

Grade 12 Foundations of Math students engage in the process of designing, which is a fundamental process in any culture's mathematics, Indigenous or Western. In this two-day lesson, Indigenous freestyle looming segues into a probability activity – constructing a probability tree diagram without replacement.

Planning	Elder Albert Scott had provided information and insight into First Nations background knowledge. Sharon pointed out numerous First Nations activities we could use in our class to incorporate math. At the same time, she shared her cultural knowledge. We had permission to pass our understandings onto our students. After my half-day mentoring session with Sharon, I whittled down my ideas to the topic of traditional Indigenous mathematizing in freestyle looming with coloured beads. This whittling process was aided by bouncing ideas off my colleagues participating in this project and by brainstorming over how we could incorporate Indigenous perspectives. I decided that students will loom a bracelet or small keychain. I think this will be an engaging activity. I will connect this activity with some of the curriculum's topics on probability and conditional probability; specifically a probability tree diagram without replacement based on a student's random selection of three beads taken from a jar of a mixture of black and white beads. I learned from Sharon how to gather authentic First Nations materials by using the web. We put a PowerPoint together for my lesson's introduction. I made the decisions on how to use it and how to plan the details of my lesson, which turned into a two-period lesson. An early version of my lesson plan received feedback from Glen.
Teacher's Reaction to Teaching the Lesson	I was impressed by the students' engagement with the Indigenous math activity. One student ran out of string and tied on pieces to lengthen it. He still was not finished by the end of class and asked if he could take some beads home to finish it. He was eager to show me his completed design the next day. Apparently, he actually had to restart the entire loom because his string ended up breaking. What impressed me the most was that this student has shown a lack of dedication to his school work in the past but was engaged in this process and was able to see it through even after he had to restart the activity. He even showed his work to the school principal. I overheard many students showing off their design in the hallway. Those who finished their looming during the first period chose to make another one during the second period while some students completed their first looming. The use of plastic beads in the Indigenous math activity served as a plausible segue into learning probability concepts. This may explain students' continued interest in probability math content. Most students' loom designs told a story associated with a feature of their personal life. Some, for instance, used the colours of their sports team, and some spelled out words such as Jeep and Gemini. Most of the students completed their probability trees in a satisfactory manner. The student who showed his looming to the school principal had zero math mistakes. Overall, students grasped a good introduction to probability. They used the probability tree to solve probability problems.
Teacher's Reflections	Next time I teach this, I would put more emphasis on why they were learning about Indigenous perspectives in math. Students enjoy participating in activities that offer a break from traditional math teachings.

Outsider's Observations	The *investment* of time taken to carry out the Indigenous looming activity was well worth it. The students' engagement and interest with bead looming carried over to their learning curriculum content (i.e., constructing a probability table that represented the chance of randomly selecting three beads in a particular sequence). Moreover, there is a deeper analysis for students to understand. A wampum belt tells an important *story* in some First Nations cultures, and a probability table tells a *story* of interest to mathematicians, scientists, and certain engineers. Thus, a wampum belt and a mathematical table both have a storytelling function, although in two different cultural settings. When Grade 12 students feel safe and comfortable enough to express their personal interests and who they are (their self-identities), their relationship with their teacher and with the course content strengthens. All of the above were demonstrated in this two-period lesson.
Revised Lesson Plan	See Appendix E-A for a slightly revised lesson based on the information here.

Kevin's First Lesson

This two- or three-period Grade 10 lesson for students enrolled in the Mathematics Workplace and Apprenticeship program exemplifies Indigenous mathematizing in the form of a game that becomes an activity for students to explore analytically. Students sequentially make the rules of the board game more challenging and then find patterns in the resulting strategies for winning. Finding hidden *patterns* in players' strategies promotes mathematical spatial reasoning. By creating harder and harder puzzles to solve, students develop puzzle-solving strategies by posing their own problems to solve. This type of in-depth learning is captured by the Pueblo phrase "coming to know" (Cajete, 2000, p. 110).

Planning	In planning my first culture-based math lesson, I was conscious of my own three-step evolution as a math teacher over the years: (1) It's all about me surviving, (2) It's all about knowing the curriculum, and (3) It's all about my students. I was in Stage 1 at our August and October meetings. I feel like I'm at Stage 2 as I am planning my lesson. I want to know more about First Nations cultures (the curriculum). I'm looking forward to reaching Stage 3 someday. During my half-day mentoring session with Sharon in October, I learned more about Medicine Wheel teachings, for instance, the four fundamental substances in the universe: fire, water, wind, and rock. I decided Grandfather Rock would play a role in my lesson plan. I learned about a traditional Indigenous game, Picaria[6], which used small stones that I identified with Grandfather Rock. The game is often played on a piece of hide with intersecting straight lines. Picaria is much more sophisticated than tic-tack-toe and has potential for my Grade 10 apprenticeship math students. Their math program emphasizes *puzzle solving*, *spatial reasoning*, and *pattern analysis*, all of which are found in Picaria.

[6] http://mathcentral.uregina.ca/RR/database/RR.09.00/treptau1/game11.html

	I wanted my lesson to connect students with nature through an Indigenous lens. Weather permitting, we will collect small stones outside and follow a Cree protocol of reciprocity by placing some tobacco on the ground where the stones are *borrowed*, to be returned. Tobacco is a reciprocal sacred gift to Mother Earth. I want to emphasize that First Nations mathematizing and school math could mesh together, and that students could learn this by developing an in-depth understanding by playing the game and finding patterns in the ease by which the first player won when the rules of the game were changed to make the game more difficult. This deeper understanding can be transferred to figuring out real-world problems, thereby avoiding non-authentic word problems found in textbooks. I planned for my three-day lesson to be flexible, for example, adding details during spontaneous teachable moments and letting students' questions or ideas influence how the lesson will unfold. My students respond well if the flow of the lesson reflects their spontaneity and maximizes a variety of teaching methods.
Teacher's Reaction to Teaching the Lesson	Unfortunately, a heavy November snowfall cancelled the first day of the lesson. This was the very first time I had taught First Nations knowledge, which made me anxious. But as I became relaxed, so did the students. I feel that I presented the First Nations information and discussed it with the class rather quickly. When a First Nations student confidently (and with some pride) answered my question about the purpose of such a game, he showed interest in the lesson. This had an immediate effect on all the students. They became engaged enthusiastically. Without exception, they showed interest and respect for First Nations culture. Students began to tap into their personal analytical creativity at finding patterns and at explaining *how* changes to the rules of the game can change which player is favoured to win (e.g., the one who begins or the second player). Students became more concerned with their own ideas rather than conforming to other students' ideas (the norm of many students). My question sheet for students began the second day and served as a review. It helped structure students' in-depth discussions/arguments that ensued. I was impressed with their answers. They creatively initiated their thinking about alternative ways of understanding strategies for winning the game. The two-day lesson went well, I think.
Teacher's Reflections	I feel I could do a better job at teaching this lesson next year when I would be more relaxed and confident. Students pick up on such vibes. It implicitly encourages them to become more *personally* involved in the lesson, which makes them feel connected to the content, which in turn makes the content more understandable for them. Teachers need to feel safe in order to go into an open-ended lesson with some unknown spontaneous results. The rewards are many. Teachers find that they learn from students when students feel they can express themselves (rather than parrot expected answers). I've heard teachers ask, "How do we alter the breadth and depth of topics to meet the needs of diverse students and the teacher?" Include open-ended lessons in a teacher's repertoire of strategies. This tends to be inevitable when Indigenous perspectives are part of the content. Those perspectives are action oriented and require experiential learning (i.e., coming to know, Cajete, 2000, p. 110).

Outsider's Observation	Borrowing from Marshall McLuhan's adage, "the media is the message," Kevin began his lesson in a room with plenty of space for everyone to sit in a circle on the floor, Kevin included. Students spread out easily when it came time to play the game in pairs on the floor. Kevin explained to his students some important features of this Indigenous circle arrangement. For example, everyone is equal including the teacher. He was poised (in spite of being anxious) and spoke knowingly without notes. His voice indicated the importance of what he was speaking. At first, student participation was restricted to a *sequence* of speakers determined by moving clockwise around the circle. Note how easy it is to use a non-Indigenous term (clockwise) when a typical Cree expression is "sun way" (the way the sun goes across the sky). Similarly, many Turtle Island Indigenous groups express respect to Creator by leaving a space in the circle for Spirit to enter the circle, as Spirit flows through everything in the universe. These tidbits are mentioned here to illustrate how mentoring feedback was given to the teachers. When explaining the materials traditionally used to play this game, Kevin detailed important First Nations features such as Grandfather Rock. The significance of the animal skins on which the game is usually played (cloth was substituted for the lesson) led to a short discussion on why animals are referred to as cousins. This fact reinforced the key Indigenous expression, "We are all related." Kevin's introduction provided a holistic-detailed context in which students could experience and understand a First Nations perspective. This speaks to the reconciliation content of the research project. The high student motivation of Day 1 was quickly recaptured in Day 2 by involving students with a question sheet that required students to analyze their earlier experiences in ways described above. In-depth thinking stimulated most of his students for the whole period.
Revised Lesson Plan	See Appendix E-B.1 for a slightly revised lesson based on the information here.

Kevin's Second Lesson

Grade 9 students are introduced to the many and diverse roles that water plays in their everyday world and in First Nations cultures. Students identify some social issues related to clean water. They are assigned a poster-production project to communicate statistical information that sheds light on a social issue chosen by each student. Critical thinking over how to recognize valid sources of statistics ensues. Formats for communicating statistical information are studied. Each student chooses a format amenable to their poster's statistics and defends their choice.

Planning	Kevin aligned this statistics lesson with the Grade 9 curriculum outcome SP9.4 ("Research and present how First Nations and Métis peoples, past and present, envision, represent, and make use of probability and statistics.") as well as aspects of other outcomes such as biases, use of language, and cultural sensitivity. Drawing on resources from his division's FNMI Education Consultant, he excerpted information about water's role in mainstream society and in Indigenous cultures. He would bring this information to his students, so they could think of a relevant issue related to water, with which to develop a poster, thereby

	demonstrating their ability to use the internet for reliable statistics and present them to the class in a clear and convincing way. This small project serves as a formative trial project to prepare students for June's major statistical and probability project: create a survey questionnaire, identify a sample within a population, collect and analyze the responses, and display the results effectively.
Teacher's Reaction to Teaching the Lesson	The brainstorming introduction got students motivated. It set them up to make connections to some of the ideas in my PowerPoint. After I explained what this smaller project entailed, they became highly interested in the posters produced by Grade 9 students in another town near by. The first day's lesson ended earlier than I expected, so we started the second day's plan to go to the computer lab to search for statistical data that addressed an issue related to water of concern to each student.
Teacher's Reflections	I give high priority for students to critique the validity of sources for statistical data. That is a major conversation in the computer lab. "Sometimes the students are in a position to teach me what they have found." In open-ended assignments, students pose their own problem and then solve it as best they can. "You're learning right along with them." Outcome SP9.4 is one of the few outcomes in the mathematics curriculum that attend to Indigenous cultures. The outcome's precise wording is one thing, but its *spirit* is quite another: "To recognize that mathematics is not simply a Western subject. Mathematics is everywhere in all cultures." Outcome SP9.4 "opens up our mindset of our typical everyday textbook." It tells us something important about the nature of mathematics.
Outsider's Observation	Students enthusiastically participated in the brainstorming session on water evidenced by their making both diverse and interesting contributions. A number of important water issues surfaced during the PowerPoint discussions such as the comparison of water advisories between reserve and non-reserve communities. Kevin's emphasis on the spiritual role of water in Indigenous cultures animated the significance of contemporary water advisory statistics. His comments about Indigenous cultures were not isolated in an introduction, but they were sprinkled throughout the lesson. Thoughtful metaphors were expressed such as, "Rivers are the arteries of our planet," which associates an Indigenous perspective on Mother Earth with a Western perspective on Earth. Kevin encourages students to choose an issue that involves Indigenous communities, but students are not required to do so in his open-ended lesson.
Revised Lesson Plan	See Appendix E-B.2 for a slightly revised lesson based on the information here.

Danielle's First Lesson

This three-part lesson for Grade 6 demonstrates the integration of mathematics content (i.e., the number line and integers found along it) and Language Arts. Both emerged from within the school's everyday world and within authentic Indigenous contexts.

Planning	When I was collaborating with Sharon, I couldn't think of doing something in just one lesson, so I thought in terms of several lessons that drew on what was familiar to students such as Language Arts in everyday situations (e.g., describing what happened in a series of downs in a local football game and then translating it to the number line). Indigenous content formed the context for a set of word problems that students translated using the number line: two Cree women fishing, a Pow Wow dancer describing some footwork, keeping track of food at a traditional feast, and an event with two blueberry pickers. For the second lesson, I composed a story of Little Bear on a moose hunt where my students were to pick out all the opposite words it contained. Then groups of students categorized those words on the number line as positive, negative, or depicting zero. For the last lesson, five groups of students each prepared a story containing nine opposite pairs in it. These were read out in class, analyzed by the groups, illustrated by a drawing, and then displayed on the wall.
Teacher's Reaction to Teaching the Lesson	I thought that the use of the number line was very good, because the students could see visually what I was comparing. It really got the students talking about word problems, and they were eager to do the assignment afterwards, which usually never happens. As I walked around the room, I could hear great conversations. A normally disruptive student responded enthusiastically to the contexts of the integer word problems, a response that endured for the whole lesson. He even raised his hand to talk! Most students worked effectively and cooperatively in groups consistently showing respect for their peers. Students mathematically analyzed a moose hunting story about a First Nations father. The story was well-received. It caused a group of boys to spontaneously talk about their families' hunting experiences, and then they became completely engaged in the second lesson. One student spontaneously exclaimed, "This is awesome! Yesterday we got to talk about fishing, and today we get to read a story about hunting!" Most students were very excited when creating their own stories. It was really nice during the lesson to walk around the room and hear the on-task chatter. I did not have to remind them once to get back on task (which happens often in my classroom). It was interesting to see in the third lesson the positive reaction by students when they heard me read out their own compositions with math content about opposites on the number line.

Teacher's Reflections	Don't begin a topic by using formal words (integer) that students will eventually include in their lexicon. Use words familiar to students (number). The context in which students learn math or do math can have a very positive effect on their engagement, especially for reluctant math students. I know that when I was in high school, I struggled with math. But I love teaching it this way that makes sense to many students. My mindset on incorporating First Nations content into math has changed since our meeting on August 31. I did not realize that you could just fit in normal First Nations content. It was easy to incorporate different worldviews into math. I did not hear one student complain because it was math class (they do this more often than a person would think).
Outsider's Observation	Principal Sari happened to walk into Danielle's first lesson and was amazed to see every student energetically on task, which illustrated the noise of learning experientially. Sari commented on how well the reluctant student was doing. Math was implicitly introduced as another language that could be translated back and forth with everyday English. This seems advantageous to math-shy students who usually prefer to learn in the context of everyday language. Learning through translating from familiar experiences into math worked well. The Indigenous contexts for word problems and stories can be judged on the basis of how much detail students learn about Indigenous perspectives from the cultural significance of those details. Simply including Indigenous people or artifacts without including some worthwhile cultural learning does not address the major issue of students understanding an Indigenous cultural perspective, which is a basis of reconciliation. The cooperative engagement of students in groups was pervasive. One key aspect of motivation occurred as the lessons were planned so that the materials students dealt with were in fact made personal by students' participation in creating some of those materials in the first place.
Revised Lesson Plan	See Appendix E-C.1 for a slightly revised lesson based on the information here.

Danielle's Second Lesson

Based on patterns observed on Saskatchewan First Nations Pow Wow regalia, students decorated six identical popsicle sticks on one side in order to investigate the theoretical and experimental probabilities that underscore a popsicle stick drop activity. Then by playing the more challenging Blackfoot Confederacy Stick Game with four authentically decorated popsicle sticks, students solve probability problems and develop combinatory logic capabilities in order to solve a mystery surrounding the traditional Blackfoot game's scoring system. Greater in-depth learning about theoretical probability resulted from the game's follow-up analyses.

The complexity of the Blackfoot Stick Game's scoring system in relation to the ultimate problem solving with combinatory logic by Grade 6 students necessitated several iterative lesson trials and rewrites before the simplicity and sequence of scaffolding activities could lead students to a satisfying solution to an otherwise difficult probability puzzle.

Revised Lesson Plan: See Appendix E-C.2.

Serena's First Lesson

Grade 5 students had memorized multiplication facts up to the product of 81. Immersed in the videos and first-hand experiences of First Nations drumming, students come to a deep understanding of what mathematical multiplication actually means, and some students spontaneously taught their peers what division actually means. An Indigenous hand drummer joins the first and third of three consecutive lessons.

Planning	During the last afternoon of our culture immersion event, I thought of ways to incorporate Indigenous games into a math lesson. But then I challenged myself to find some other way to enrich my students' understanding of multiplication. Sharon suggested I look into drumming. The more resources I found, the more enthusiastic I became. Then a breakthrough occurred. Someone knew of an Indigenous drummer, Brad, who agreed to help me teach my students about First Nations drumming. I had to figure out how we could engage them physically, emotionally, and intellectually in our math curriculum content while at the same time involving them in reconciliation by their learning about First Nations cultures. (Our school has a half-dozen hand drums.) Brad first challenged my students to recognize that an Indigenous drumming *rhythm* was created out of a certain number of beats. Then part of an Indigenous song could be understood as being made up of a number of *repeated rhythms.* The question is, "What are the total number of beats played altogether"? Students can count how many beats are drummed. Then in groups, one student could create their own rhythm and repeat it a chosen number of times while the others count the total number of beats. Everyone took a turn.
Teacher's Reaction to Teaching the Lesson	I was really impressed by the way Brad interacted with my students and how openly they responded. When he joined a group, they saw him work out a multiplication equation just like they did. "He's a drummer, and he's doing our math." It didn't take too long before some students realized what was going on. A simple short cut to knowing the total number of beats without counting them is to multiple the number of beats per rhythm by the number of rhythm repetitions counted. This was called a multiplication equation. Don't be surprised when a student announces that they can also do division this way – calculate the *number of repetitions* in a piece when you know the *total number* of beats and how many *beats in a rhythm.* Brad came back two days later with his five-year-old son. They joined each group to hear the variety of rhythms and repetitions that students created. These personal interactions between my students and Brad and his son had a phenomenal impact on students. Most became unusually focused on all parts of the activities, and their deep engagement was reflected in their sustained cooperation within their groups. I can see how slight changes in the sequence of events would have made my expectations clearer for some students. Having a room with more open space than a regular classroom would have made life a little easier for me, but it didn't seem to bother Brad or the students.

	At one point, Brad demonstrated an Indigenous teaching/learning technique. He had the students observe him drumming a certain rhythm, and then he invited them to join him when they felt like it. They practiced gaining competency at drumming that later spilled over to a competency at understanding multiplication. A small number of students needed my help to identify the number of beats per rhythm and to count them accurately. To finish the class, Brad spontaneously drummed so students could figure out the rhythm and the total number of beats in each rhythm and then state the multiplication equation. Students responded attentively to such spontaneity from a class visitor. Expect that some students will wish to perform their drumming for the whole class without an invitation to do so.
Teacher's Reflections	These lessons resonate with what my students learn in their Music and Social Studies classes. This has cross-curricular teaching potential. A key competency developed by students *before* the second visit by Brad was being able to count the number of beats in a rhythm. We practised with drumming videos.
Outsider's Observation	As evidenced by the strong attentiveness students gave to their group work, mature cooperative group work appeared to result from the students' deep engagement with drumming activities and from the discussions that in turn led to learning key ideas planned for the lesson. These were emphasized by the teacher and by students in their groups. One student thought he'd blow everyone's minds for entertainment by drumming out 10 x 10! Many communities in Saskatchewan have Indigenous drumming groups who could be an excellent resource for teachers, especially in cities. This lesson is discussed in the videotaped conversation between Serena and Sharon (see Appendix F).
Revised Lesson Plan	See Appendix E-D.1 for a slightly revised lesson based on the information here.

Serena's Second Lesson

This lesson follows the lesson that introduced polygons and their attributes. Grade 5 students create a multi-coloured pattern that incorporates a quadrilateral in order to make a beading artifact. They draw their pattern on graph paper using coloured pencils. From there, the design is transferred to an 11-strand loom constructed with coloured beads. After the students have made their beading artifact, they describe the attributes of their quadrilateral as well as analyze other students' bead work for quadrilaterals.

Planning	Indigenous mathematizing inherent in loom beading had been successful in a fellow teacher's Grade 12 class when associated with probability. I thought it could also work for Grade 5 students' understanding of polygons and specifically common quadrilaterals. Deeper understandings could be achieved by students if they produced such patterns in simple loom beading and identified such patterns in traditional and contemporary First Nations regalia. I researched some of the history of First Nations loom beading to learn about its significance to First Nations cultures and worldviews.
Teacher's Reaction to Teaching the Lesson	Throughout all facets of the lesson, students were highly engaged and constantly on task. It was a delight to see. Many students' loom-beaded artifacts conveyed a personal meaning such as a student's family initials, a hockey jersey number, or a word that expressed a value. Students responded to the handout assignment very well, especially the attributes of the quadrilateral in their own beading artifact. Interestingly, some students found multiple quadrilaterals in other students' artifacts that had otherwise gone unnoticed. The important expression "right of passage celebration" has meaning for Grade 5 students if relevant examples are provided such as getting their driver's licence. I was amazed to observe three boys whose fine motor skills are very weak when they print. They do struggle. But they loved this activity. Their looming was tight. Their artifacts were awesome. It was really encouraging to see them succeed. They spontaneously showed off their work to some of their classmates. This was a huge plus.
Teacher's Reflections	I had an epiphany about the inclusion of Indigenous perspectives in math classes when my class participated in a video production of a culture-based lesson on birch bark biting. It was taught by our school division's Indigenous science and math consultant. I now see *how* she draws First Nations knowledge into a lesson. She introduces some of that information fairly quickly at the beginning of the lesson. But then she weaves in more information as she goes along. In our lesson plans, the Outcomes sections are separate entries – the curriculum math (e.g., quadrilaterals) and First Nations mathematizing (e.g., beading). This seems to encourage teachers to deal with each type of knowledge separately. But weaving in a little bit of First Nations perspectives at a time, over a longer period of time, in the lesson is much more effective. For example, the next time I teach this lesson, I would go through the PowerPoint in my loom-beading lesson more quickly by using fewer examples at first but dealing with the other examples throughout the lesson. This would make the lesson feel more coherent and less bifurcated.

	[Later, Serena expressed her idea in a diagram, A Braiding Model of Instructing Culture-Based School Mathematics. See section Independent Final Interviews with the Teachers.]
Outsider's Observation	Visual patterns observed on a regalia have meaning to a First Nations dancer (e.g., representing a family's strength), and those patterns likely have a different meaning to a mathematician (e.g., a quadrilateral or rhombus). This is an important distinction to make, because otherwise we could easily appropriate the First Nations pattern by ignoring its personal meaning for the dancer and simply identifying it as being a mathematical pattern. See section Further Observations and Insights and subsection Avoiding Subtle Appropriation. Serena conveyed this distinction to her students by the directions she gave them. "You are going to find patterns that have First Nations meaning, but we see them as quadrilaterals." When a student did recognize a regalia pattern as a quadrilateral, a diamond, a kite shape, or an irregular quadrilateral, Serena first acknowledged the discovery but then pointed out that the pattern had a different purpose for the dancer than for a math class. This distinction is re-enforced by Questions 9 and 10 in the lesson's Student Assessment Handout. The questions address the personal and mathematical meaning, respectively. They mirror a First Nations meaning of a pattern compared to a mathematical meaning of the pattern. Loom-beaded *artifacts* shown to students garnered more attention from students than photos of artifacts, unless the students felt a purpose to engage with the photos. An object held by a student seems to speak to that student in unique ways. Such real-world objects have teaching power in themselves for most students.
Revised Lesson Plan	See Appendix E-D.2 for a slightly revised lesson based on the information here.

A Principal's Perspective

"I've been watching the evolution of the teachers from the beginning of the project," Sari recalled. "At first, they were nervous, anxious, and worried. Within the last five months, however, culture-based math teaching is something they have come to *embrace*. Their comfort level is higher, and their confidence level in what they are doing is higher. This is really good for an administrator to see!"

"They have formed an informal professional learning community right inside the school. They support each other. They talk about successes and challenges. Together, they revisit lessons to revise for next year. This is fantastic! I sense that the project has taken on an independent feeling to continue on its own next year. That's great! That independence serves as evidence that the teachers are feeling confident. I am very proud of them. Their work has sustainability."

"Succeeding is really not about the lessons. It's the permission to teach what you remember from an Elder or knowledge holder. It's feeling confident to develop one's own lessons in which the Indigenous content is sprinkled throughout and not posted at one time in order for a box to be checked off. It's a matter of including it in a math lesson whenever it makes sense to do so. For example, 'Here is a Western math explanation, why not include a relevant piece of Indigenous knowledge where it could belong?'"

Consequences for Students

Teachers' Observations

Students participated in game playing, drumming, explaining, and looming, all examples of Indigenous mathematizing. According to their teachers, the most engaged students tended to be the ones least dedicated to learning Western mathematics. One example was Krysta's student who became focused on constructing a probability tree because of his initial engagement with a looming activity. Another example is some of Danielle's normally disruptive non-Indigenous students who had mathematics problems to solve, contextualized in these boy's local culture of hunting. The students became unusually engaged in their lesson. Such contrast in student behaviour attracted attention from teachers and the principal. This illustrated that culture-based school mathematics can embrace both an Indigenous culture and the local mainstream community culture.

Students' positive reactions to Indigenous mathematizing should not be surprising. Indigenous languages are mostly verb-based, which corresponds to a dynamic view of a chaotic universe. For example, what mathematicians call a circumference (a noun), some Cree people use an expression that when literally translated means running around a small stone (an action).

An action-based Indigenous language contrasts with noun-based European languages that correspond to a predictable more static universe. Irrespective of ancestry, most students[7] enjoy an active class over a static class. Thus, they respond well to Indigenous mathematizing.

Culture-based mathematics lessons tend to be open-ended and somewhat unpredictable compared to static lessons where action rarely occurs. Open-ended lessons, in which a teacher also becomes a learner to a degree[8], demands intellectual, emotional, and physical engagement on the part of students. Simply put, more students become engaged, and the role of a teacher is changed in a way that encourages closer relationships with students and between students. The classroom environment becomes more conducive to coming to know (Cajete, 2000, p. 110).

Analyses of Student Questionnaires

Students responded to a short simple questionnaire prior to being engaged in their first culture-based lesson and again about three weeks later. The secondary and elementary questionnaires are located in Appendix D. The student response data are organized in Tables 2-14.

Most items were formatted with both a Likert-type response (i.e., disagree, disagree somewhat, agree somewhat, or agree) and an open-ended response for students to explain their choice. The secondary and elementary items were almost identical except the secondary version included an item (Question 4 – Q4) about students' interest in post-graduation employment related to mathematics; an item understandably absent in the elementary version. Thus, the secondary version has eight items; the elementary seven items.

[7] Exceptions were certainly present as documented in a few students' responses to the questionnaire, Your Ideas about Your Math Class Analyzed in the next subsection Analyses of Student Questionnaires.

[8] The Māori people of Aotearoa New Zealand see this as common sense. In their language, there is no equivalent to the English teacher or student. The closest is tuakana (a teacher who learns from students) and teina (a student who teaches their teacher) (Bishop & Glynn, 1999).

Otherwise, both versions addressed the same topics:

1. Mathematics as a student's favourite subject (Q1). Students' answers helped clarify their open-ended responses to the final question in the questionnaire.

2. Students' attraction to contextualized mathematics learning (secondary Q2 and Q8, elementary Q2 and Q7).

3. Students' interest to see Indigenous mathematics and Indigenous cultural perspectives in their mathematics class (secondary Q4 and Q5, elementary Q3 and Q4).

4. A self-report on the degree to which a student understands an Indigenous culture (secondary Q7, elementary Q6).

5. One question asks students to identify the specific Indigenous understandings they learned this year in mathematics class (secondary Q6, elementary Q5).

Unfortunately, Kevin's teaching assignments changed radically during the first term due to Krysta's maternity leave. As a result, he was unable to obtain post-questionnaire results. And due to a misunderstanding, Danielle's class accidently wrote the pre-questionnaire *after* the first period into her two-period culture-based lesson. Therefore, two data sets are not available, Kevin's post-data and Danielle's pre-data. There are, however, pre-post comparisons for Grades 5 and 12.

Overall, student responses changed very little between their pre- and post-answers. This seems normal as a short intervention can rarely make much of an impact on students' beliefs about school mathematics. The sample size (about N = 16) is too small for a meaningful statistical analysis.

Any sizable shift between the pre- and post-responses would therefore be noteworthy. For example, in the Grade 5 class results (Table 14), Q3 and Q4 deal with students liking Indigenous mathematics in their study of mathematics. An *increase* in students' "agreeing somewhat" and "agreeing" with such an inclusion was 64% and 46% respectively. The two-period intervention of culture-based mathematics made an impact on many students. Their reasons are found in Table 13. For Q6 (concerning the statement, "I understand an Indigenous people's culture."), there is a consistent shift from the "not at all" side of the scale to understanding more about an Indigenous culture.

However, in the Grade 12 results (Table 5), exactly the same topic (the inclusion of Indigenous mathematics, Q4 and Q5) showed virtually no difference between the pre- and post-responses. Students' explanations are found in Table 3 (e.g., "I am used to what I have been taught throughout all the years of my schooling." and "Math is math."). It would seem that about 60% of the students tend to be rather set in their views of, and their routine in, mathematics classes. At the same time, however, about 40% were open to seeing Indigenous mathematics and ideas in their study of mathematics. Their reasons for holding their views are recorded in Table 3 (e.g., "It is something new and interesting to learn.").

Approximately 60% to 80% of Grade 10 students (Table 6) were interested in learning Indigenous mathematics along with their Western mathematics. Their reasons are noted in Table 7. The Grade 6 class' interest was somewhat lower at about 50% to 60% (Table 8).

Grades 10 and 6 students' explanations (Tables 7 and 9 respectively) are certainly diverse. No generalizations or patterns seem noticeable. On the pre-questionnaire for Grade 5, interest was even lower (Table 10, Q3 and Q4) probably due to the fact that they had never experienced First Nations mathematizing. But as described above, once they did experience it, the effect on their interest was dramatic.

Greater scrutiny of the Grade 12 class's results indicated that eight of 17 students appeared to be open to learning something new. In their post-questionnaire comments, they mentioned their culture-based mathematics experience in the following terms: "It was kind of cool." "It was interesting, but I like more advanced math concepts which the Indigenous people were not aware of." "It made math easier." "I like logic; however, it is still good to learn about First Nations cultures." "It is interesting to learn new things." "I like small projects to help enhance my learning."

On the other hand, the same two-day culture-based mathematics lesson had no impact on the other nine Grade 12 students. Expressed on their post-questionnaire, their reasons included: "Math is math." "I like straight out of the textbook math." "I hate math." "Math is useless in my everyday world." "Indigenous math didn't help me with my math assignment." "I don't see what beading has to do with my math."

A deeper analysis of the Grade 5 qualitative results shed light on the existence of three groups of students comprised of four, nine, and four students respectively. The analysis compared the pre- and post-questionnaire's open-ended answers for each individual student. In other words, it explored what the quantitative data in Table 14 mean according to the viewpoints of the students who provided the quantitative data.

But first, a closer look at the context in which the students responded to the pre-questionnaire. Unlike the Grade 6 students, the Grade 5 students were somewhat challenged by having to write or print their reasons for choosing their Likert-type answers. Evidence for this came from the large number of "I don't understand" choices on the Likert-like scale and the appearance of many blank responses. For instance, some students were unfamiliar with the word "Indigenous."

However, their post-questionnaire responses were generally plentiful and articulate for Grade 5 students. Apparently they became familiar with Indigenous topics made explicit in their culture-based lesson on drumming and multiplication.

As mentioned above, the data indicated that there were three groups of students within the Grade 5 class. In the first group's pre-questionnaire responses, four students expressed a positive orientation to having some Indigenous mathematics in their learning mathematics. They apparently strengthened their interest evidenced by their post-questionnaire answers: "I never knew you could mix the drumbeat with multiplying." "It is more fun to learn the Indigenous ways." "It's easier." "I can learn in fun ways."

The nine students in the second group appeared to have a neutral orientation to Indigenous mathematics on their pre-questionnaire, but they became very open to learning Indigenous mathematics, as expressed on their post-questionnaire answers: "It is easier to do." "It helps me better." "I like my way of math and their way of math, now." "It is fun to count beats." "I like learning new things." "I want to learn about others."

And finally, the group of four students began the culture-based lesson closed-minded to the idea of having Indigenous knowledge taught in the mathematics class, and they did not change their view on the post-questionnaire: "I just do not understand all the questions [on the questionnaire]." "It is boring."

It would be reasonable to expect that just two culture-based mathematics lessons would have the similar responses from most classes. This may change, however, if a series of such lessons were experienced over several months.

Of the written responses by all students who participated in culture-based lessons during the year, only 3% of the students expressed a negative view toward First Nations people. There were other reasons expressed for not including Indigenous mathematizing and perspectives in mathematics classes. In Tables 3, 7, 9, 11, and 13, a number of students affirmed the view that school mathematics cannot be related to *anything* outside of its academic existence. This generalization excludes there being a relationship between Western mathematics and Indigenous mathematizing. The abstract nature of decontextualized, conventional, school mathematics may have given such students this impression of mathematics' isolation from other mathematical systems. (See section Further Observations and Insights, and subsection The Nature of Mathematics for a short discussion about what was discovered in classes that compared the two mathematical systems.)

Indigenous Students' Focus Group

Out of a small proportion of Indigenous students attending Carrot River School, several volunteered to join a focus group conducted by Team Members Daniel and Kelley. The number dwindled to three students due to other commitments that arose and un-returned permission slips. The two girls and one boy came from elementary and high school grades.

The following information documents their voices, but it does not necessarily represent the Indigenous students at Carrot River School.

All three students were pleased to see mathematics taught in a different way, that is:

1. without textbooks.
2. with First Nations cultural knowledge – "It was cool." "It was relevant."
3. with teachers looking more animated as they made it happen.

Even though the various Indigenous games (a.k.a. mathematizing) played in lessons were not familiar locally, students applauded their appearance in their mathematics class.

All three felt good about becoming aware of the connections between Cree culture and their school mathematics. Two students were surprised by another outcome they experienced. Each became aware of Indigenous art and artifacts in the school and around the community; things they had not noticed previously. An awareness had been awakened. Another student began to talk with their mother about her beadwork as a result of the student beading in their mathematics class.

The drumming made one student feel calm in their mathematics class. By making connections between what was learned at school and what happens at home, their school work had purpose for them. But some of their classmates saw no purpose to including Indigenous ways of mathematizing in their mathematics class. The focus group students were able to transfer what they learned in school to their home experience. For example, one played an Indigenous game learned at school with their parents.

They all agreed that they understood school mathematics better (e.g., ratios and proportions) when they learned it along with Indigenous mathematizing. The students concluded that all their subjects at school should include Indigenous ways of knowing and not just mathematics and social studies classes.

When asked, “What would you like to say to non-Indigenous students?”, the focus group responded, “It’s good to learn about different cultures and ways of knowing.”

When asked, “What would you like to tell teachers?”, responses included:

1. Be confident in teaching mathematics in a different way.
2. Go ahead and keep trying to teach mathematics by including Indigenous culture.
3. Do more of it. Although we had two or three such lessons, we wish we had more.
4. Learning information from stories is another preferred way of learning.
5. Give us feedback to use for helping us reflect.
6. Use activities rather than textbooks.
7. Engage us intellectually, emotionally, physically, and spiritually. Different students have different preferred ways of communicating. Communicate over time, when possible, in all five senses (e.g., drumming communicated acoustically, and games often communicated emotionally).

Interestingly, the fifth message above corresponds to the fifth “recurrent learning strength” observed among most Indigenous students. See the text box inserted into the section Independent Final Interviews with the Teachers. The text box contains a list of Indigenous students’ recurrent learning strengths that should perhaps be studied by all teachers.

Further Observations and Insights

There appears to be specific challenges for teachers to address when embarking upon a journey to enhance some of their mathematics lessons with Indigenous mathematizing and Indigenous perspectives. These challenges are overcome when a teacher plans and teaches such a lesson *and* receives feedback from a knowledgeable mentor. The *collaborative* nature of this process seems critical. It produces suitable culture-based mathematics lessons available to other teachers.

Suitable lessons will help remediate the initial challenges otherwise faced by mathematics teachers when beginning their own journeys into teaching culture-based lessons. The research project's four co-researching teachers discovered many of the challenges and then incorporated reasonable solutions as they revised their initial lesson plans. Other mathematics teachers will be guided by these solutions embedded in the lessons found in Appendix E. The overall process exemplifies John Dewey's (1938) classic experiential learning theory-in-action.

Province-wide, culture-based lessons could be produced for Saskatchewan over several years by selected groups of teacher authors. As a result, a repository of suitable lessons for Saskatchewan provincial schools could be produced (see section Our Recommendations).

This project report's present section explores a series of the key challenges most often faced by mathematics teachers. Figure 2 summarizes them. These challenges identify some of the specific supports that teachers require in order to be successful either as authors of teaching materials or as effective teachers of those materials.

Inclusion Is Not Enough

The physical presence of an Indigenous game, painting, story, or activity is a good first step in *planning* a culture-based mathematics lesson. But it falls seriously short if students see it *only* as a pleasant diversion and not as an opportunity to gain specific understandings about either Indigenous mathematizing or Indigenous perspectives that are *connected to* Western mathematics content.

Here are four examples. Serena planned a hand-held drumming lesson in which rhythms and repetitions not only taught the concepts of multiplication, they also taught the cultural meaning that drumming holds for Indigenous drummers and the drummer's community. When watching Sharon videotape a geometry lesson based on making a dream catcher (Appendix F), Serena recognized that Sharon interspersed her Indigenous knowledge over time rather than presenting it all at once (see section Independent Final Interviews with the Teachers for Serena's model showing this interspersing in Figure 1).

Kevin introduced an Indigenous game called Picaria, an example of Indigenous mathematizing. Students connected Grandfather Rock's function in Picaria with Western mathematical spatial reasoning.

Danielle wrote stories and word problems that contained content from both Western mathematics (e.g., the number line) and Cree ways of living (e.g., hunting and fishing protocols). Each led to classroom discussions throughout the lessons thereby illustrating Serena's model.

Krysta showed examples of traditional and contemporary Indigenous beading, another example of Indigenous mathematizing. Students then beaded a small artifact, described it personally, and explained their bead selection process mathematically by constructing a probability tree. All four teachers illustrated how to move past the assumption that mere inclusion is enough. As a result, their students learned local Indigenous values, protocols, ways of knowing, and worldview perspectives.

In some activities, students participated in an Indigenous protocol. For instance, students can gather small stones for a *traditional* way to play Picaria. As Kevin described, students come to understand the Indigenous value of reciprocity when they offer a pinch of tobacco to Mother Earth for borrowing three stones with which to play the game. Students quickly learn the protocols for this simple Indigenous ceremony. Recall the old adage: "If I hear, I forget. If I see, I remember. If I do, I know."

Consider making bannock the authentic way. This activity teaches students, (a) how body measurements are used for the ingredients instead of quantitatively scaled measuring techniques, and (b) the core value of forging *relationships*. The latter is practised by using an *oral* recipe personally passed on to students from a person with that knowledge. Thus, students make a new relationship with that person. This contrasts with using Western measuring utensils and reading an impersonal book or internet recipes. There is no personal relationship formed under those circumstances.

In short, a suitable culture-based lesson clearly gives an answer to the ubiquitous questions: "What did my students learn about an Indigenous world?" "How did we participate in reconciliation?" Answers can arise from a teacher who researched a topic or brought in an Indigenous visitor, or from students' protocol-conscious investigations into Indigenous ways of knowing shared with their class.

When conducting student assessment, a teacher should be able to ask, for example:

- What is the connection between the Indigenous mathematizing we did (e.g., playing a game or making an artifact) and the school mathematics topic we dealt with?
- What do you now *understand* about a Plains Cree person that you didn't know before?
- Describe one way that Plains Cree math differs from school math?
- Describe the main parts of an Indigenous ceremonial pipe used in the school's pipe ceremony and explain what each part means to the group who uses it.

Indigenous perspectives are *explicitly* taught to students throughout a culture-based mathematics lesson. Students' understandings are explicitly assessed. Implicit appearances in a lesson are not enough. Seldom do students learn by osmosis.

This explicit Indigenous content will be identified in a lesson plan's section written parallel to the lesson's section identifying the mathematics content found in the curriculum. This strategy ensures that teaching goes "beyond mere inclusion" in some personal, meaningful, in-depth, coming-to-know way (described in the subsection Conclusions found in the section The Culture Immersion).

"Respect is more than tolerance and inclusion" (8Ways, 2012, p. 4). This Australian Aboriginal resource continued on to state that it requires students and teachers to participate in personal heart-felt dialogues dedicated to mutual understanding. This is much like sitting around a camp fire, wrapped in a deep conversation about an important topic requiring an exchange of fundamental perspectives. Vickers (2007, p. 592) of Tsm'syen ancestry called such meetings "camping spots where we can dialogue" between cultures. The Truth and Reconciliation Commission (TRC, 2015b, p. 2) must have had this in mind when it wrote its 63rd Call to Action: "Building student capacity for intercultural understanding, empathy, and mutual respect" (p. 7).

The Nature of Mathematics

Occasionally, a class discussion will occur that compares Indigenous mathematizing and Western mathematics. This is often an opportunity for upper elementary and high school students to learn *about* Western mathematics' human dimensions more personally, more meaningfully, and in greater depth. These lay beyond the conventional spatial, algebraic, and arithmetic ways of knowing in mathematics.

For example, a fundamental concept central to both Indigenous mathematizing and Western mathematics happens to be one of Saskatchewan's four curriculum goals: coming to know "mathematics as a human endeavour." Indigenous mathematizing and Western mathematics have arisen out of human needs and human creativity to become "a symbolic technology for humans to forge relationships between themselves and their social and physical environments" (Bishop, 1988, p. 146). Both mathematical systems will continue to evolve into the future in their own ways.

Anthropologists have characterized the mathematics invented in any culture (past or present, Indigenous or Western) as comprising six general processes: counting, measuring, locating, designing, playing, and explaining (Bishop, 1988). Therefore, a major similarity between school mathematics and Indigenous mathematizing can be stated in this way, which Grades 6-12 students can understand. Together, those six processes simply answer the challenging question, "What is mathematics?" Relevance can easily be associated with each of the six processes. This shifts the focus from Plato's abstract ideal mathematics to an everyday real mathematics.

Indigenous hand drumming is about *designing* or *playing* music. Many classical music composers today use complex mathematical functions to *design* parts of their music. Drumming exemplifies Indigenous mathematizing. Drumming is comprised of a rhythm of beats (a pattern) repeated many times. For aesthetic reasons, a pattern may alter but with the same number of beats per pattern. This situation has an *analogy* in Western mathematics. After Serena's Grade 5 students determined the number of beats per pattern of a piece about to be played, she asked them, "How many beats will be in a single drumming piece?" They counted the total number of beats as an Indigenous drummer played the piece.

Looking for a short cut to the answer, a few students discovered an analogy in Western mathematics, multiplication. For instance, a drumming piece with four beats per pattern, repeated five times is analogous to the following multiplication equation: $4 \times 5 = 20$. This Western mathematics analogy is a symbolic expression (a.k.a. symbolic technology) that establishes a relationship between students and the drumming music; in other words, between humans and their social or physical environments.

With this in-depth understanding of multiplication (as opposed to memorizing), one student pointed out how the drumming could also explain division; another analogy to the hand drumming and a hint that this student may have a math-oriented self-identity.

Classroom discussions arose in Krysta's lesson Freestyle Looming and Probability over the commonality between a beaded Wampum belt and a probability tree. Both are symbolic expressions – *a type of language* – that explain something important in each culture. The question, "What does each explain?" initiates a discussion about the nature of each culture's mathematical system.

Krysta's students *designed* their own beaded artifacts and their own probability tree. What did the students' beading designs mean to them? What might the design of a probability tree mean to a mathematician or to anyone who uses it? If we look for these human elements in Western mathematics and Indigenous mathematizing, we have a good chance at finding those human elements. (That is the purpose of this present subsection.) Their humanistic essences are something a large majority of students can relate to. School mathematics becomes more relevant to these students in a rigorous way.

To summarize, an Indigenous mathematical system differs from the Western mathematical system. So when both appear in a classroom, their similarities and differences can become teachable moments. One consequence for students is a deeper understanding of the nature of Western mathematics as a human endeavour. Several other consequences became apparent in Carrot River's classrooms.

In Danielle's lesson, Focusing on Negative and Positive Numbers, the number line was a visual expression – a "symbolic technology" within the Western mathematics lexicon, if you will – that students explored. Stories with Indigenous content, written in the English language, held arithmetic concepts. Students translated back and forth between the *two languages* in order to *"come to know"* (Cajete, 2000, p. 110) the number line rather than memorize facts about it. This is another example of how mathematics can be experienced as a language. All languages contain metaphors. This concept describes an important aspect to the nature of mathematics, and it can be made explicit for students to learn. For instance, the equation $y = ax + b$ is a metaphor for a straight line on a graph and vice versa. Some students feel more at ease with mathematics when they see it as a language and as a human endeavour; the way they enjoy their English, Social Studies, and Language Arts classes.

Western mathematics can be conceptualized as an important subculture within Canadian mainstream culture (Aikenhead, 2017b, section 7.1). That is why it is found in the curriculum – to be passed on to the next generation of Canadians. Some cultural features of Western mathematics can be identified by its values, beliefs, and ideologies (Aikenhead, 2017b, section 4.5; Ernest, 2016a).

Is the nature of mathematics the *ideal* pure thought invented in the ancient Greek culture and epitomized by Plato's philosophy of mathematics? For example, the image in our minds of a circle precisely partitioned into six equal segments.

Or is the nature of mathematics about the *real* world, where a circle becomes an apple pie being cut into six pieces? There are now messy crumbs, imperfections, and only approximately equal pieces of pie – good enough for the situation, though.

Which one is Western mathematics? The answer is, "Both are." There is an ideal world especially relevant for mathematicians, some scientists, some architects, some medical specialists, and for certain jobs in the trades and engineering. Then there is a real everyday world for most everyone else.

The distinction, ideal versus real, is not a case of nitpicking. It is a tool in critical thinking on issues involving mathematics. For example, the phrase "achievement gap," discussed earlier as being problematic (subsection Paying off Canada's Educational Debt), can now be understood as a dog whistle for a black and white doctrine that has no room shades of grey. If someone wants to suppress a contextual explanation for the result of subtracting two average test scores (e.g., non-Indigenous and Indigenous students' scores), then the context-free ideal world of Plato's mathematics will do the trick.

However, if someone else realizes the ideal calculation does have a real context covered up by a dog whistle word or phrase, then that person avoids getting the wool pulled over their eyes by finding a replacement word or phrase that identifies the important context; for example, "educational debt," in this case. In summation, Plato's mathematics is limited to the ideal world of the mind that has no context. It can be used to manipulate public opinion.

Therefore, citizens beware - Plato's mathematics pretending to speak for the real world needs critical analysis as to its credibility. Sometimes it is credible, but often it is not. Students are well aware of that when it comes to their grades in mathematics. What does 72% really mean in terms of a student's understanding of quadratic equations? It may have more to do with borrowing the family truck.

Obviously, when people *use* mathematics in the context of the real world, there are some values being drawn upon to guide decisions made such as mathematics' ideology of quantification. It is a doctrine that sees the world mainly in terms of numbers. For instance, human intelligence (whatever that means) becomes a mathematical quotient with implications for how a person is treated depending upon the numerical quantity associated with that person – the ideology of quantification in action.

Moreover, even ideal *pure* mathematics is also imbued with many values. Its moniker "pure mathematics," for instance, creates a value position with respect to real-world mathematics that is implicitly defined as "impure mathematics." Thus, purity becomes a value in Plato's ideal mathematics. It gives preference to ideal thought over real-world action. See the footnote in Figure 2 for other examples of values harboured by pure ideal mathematics.

Historically, one is reminded of Plato's Athenian culture. A strict class structure in which philosophers and politicians were privileged over trades' people, trades' people over women, and women over slaves. Plato's version of mathematics was virtually absent in Renaissance Europe. An everyday mathematics made sense to business interests and trades people. Plato's mathematics returned to a position of privilege and power in the early 1800s ensconced in the cloisters of university curricula (Ernest, 2016a).

Coincidently, the industrial revolution had created a need for a public school system to supply a schooled workforce. A prolonged and heated debate ensued over which philosophy of school mathematics would guide the school curriculum. In the mid-1800s, Plato's philosophy of mathematics won the debate, and the impure mathematics became all but absent ever since (Aikenhead, 2017a, section A Hidden Platonist Agenda). However, past decisions can always be revisited. This is especially so in Canada's era of reconciliation in which the agenda for paying Canada's educational debt is becoming a reality.

When we speak of culture-based school mathematics, it refers to at least *two* major culture groups in Canada. On the one hand, the culture of mainstream Canada (predominantly Eurocentric), and on the other, the cultures of its Indigenous citizens. Our research project focused on Indigenous cultures only to the extent that they are introduced into mainstream school mathematics. Enhancing school mathematics in reserve schools is a different issue and belongs to the jurisdiction of First Nations peoples.

Mathematics in the Everyday World: The Elephant in the Room

Another challenge faced by many mathematics teachers concerns the nature of mathematics viewed from the public arena. Especially in Grades 7 to 12, mathematics teachers must cope with a recurrent message from an influential public.

Premise 1: Mathematics is found everywhere around us in the everyday world.

Premise 2: All students must be prepared to live effectively in this everyday world.

Conclusion: All students must learn a large amount of mathematics as laid out in a crowded, mainly abstract curriculum.

This conclusion causes stress for teachers who want to innovate their teaching by adding culture-based reconciliatory lessons to their professional repertoire of lessons. For instance, a colleague may ask, "Why waste a large part of a class period on looming, when there is important curriculum content to teach?" Our collaborating teachers discovered it was time well-invested when it increased student engagement in learning the curriculum's Western mathematics content.

The highly influential recurrent argument above should be analyzed logically. Logical thinking is one of the curriculum's four goals. As it turns out, Premise 1 does not stand up to scrutiny, which makes the whole argument unsound or invalid. Here is the short reason why, followed by a thorough explanation.

The premises/conclusion stated above is a classic fallacious argument. Aristotle classified it as a fallacy of equivocation. The phrase *"everywhere around us in the everyday world"* implicitly changes its meaning between the premises and the conclusion, either consciously or unconsciously, in order to establish the argument's conclusion. The public meaning of Premise 1 refers to the way students and most adults experience their everyday worlds. In the conclusion, it has been changed to a highly restricted meaning of the way mathematicians experience *their* everyday world.

How do we know this? A more detailed explanation is relatively straight forward. Mathematicians' worldviews understandably harmonize with a mathematical predilection for making sense of their everyday world mathematically. This is not the case, however, for about 74% of Saskatchewan high school students (Aikenhead, 2017b, endnote xx). (The national figure is 66%; Aikenhead, 2017a, p. 124.) Just because mathematicians see the world through a lens of mathematics does not mean everyone does or should. For mathematicians to assume that everyone does, exemplifies the following type of Eurocentric thinking – My way of seeing the world is superior to all other ways. This ideology justified colonization.

The evidence points to a more accurate and honest replacement for the original Premise 1 stated as, "Mathematics is found everywhere in a *mathematician's* everyday life." The truth of this statement is easily verified by an internet search for "X in the everyday world" where X is a mathematics curriculum topic such as quadratic equations. What is the search result? Fabricated, inauthentic, or science/engineering contexts. This is not what most adults normally call their everyday world, which is all but absent in the internet search results. Further verification arises from asking business people, store clerks, trades people, office workers, health workers, etc. with whom you often interact: "What (abstract ideal) math do you use in your line of work?"

Here is what education decision makers need to know. In school mathematics classes, there is a spectrum of student characteristics related to learning mathematics. At one extreme are those students who have an inclination, aspiration, preference, aptitude, or interest in mathematics (some Elders call it a gift). At the other extreme are those who experience psychological stress when forced to engage in abstract mathematical reasoning as it is so foreign to who they are (Aikenhead, 2017b, subsection 3.3; François & Van Kerkhhove, 2010).

The rest of the students fill the complex region between these two extremes, skewed toward the psychological stress end of the spectrum. To whose everyday life does Premise 1 apply – the non-mathematicians' or the mathematicians' end of the spectrum? On the surface, it appears to apply to non-mathematicians. But when it comes to determining a mathematics curriculum, the premise certainly does not apply to about 75% of Saskatchewan's Grade 12 graduates. It actually applies to mathematicians' everyday world. The meaning of "everyday world" has been changed within the argument from Premise 1 to the conclusion; thus, the fallacy of equivocation.

Mathematicians also talk about applying mathematics to everyday situations. This process requires our minds to begin with a mathematical abstraction already learned and meaningfully stored in our minds. Then we superimpose it on an everyday situation as *interpreted by a mathematician* (Aikenhead, 2017b, subsection 3.3). Applying mathematics to everyday situations is naturally easy for the small minority of students whose worldviews harmonize with a mathematician's worldview but not so much for math-disinterested, math-shy, or math-phobic students.

Is the school's task to require all students to see their world the same way as mathematicians do? If so, students at the math-phobic, math-shy, and math-disinterested end of the spectrum would experience school mathematics as an attempt at indoctrination. These students' gifts likely steer them toward the abstractions found in the humanities. They are not necessarily lazy or academically challenged. Simply put, their worldviews and self-identities are different than those of math-oriented students.

When students are pressured to earn a decent grade in a foreign abstract mathematics course, Simeonov (2016, pp. 442-443) pointed out that most students memorize without meaningful understanding. Students learn to hate mathematics, and then as parents, they infuse their attitude into their children for elementary teachers to confront. As a result, many children suffer from anxiety over trying to appear competent. As they develop permanent feelings of failure, negativity permeates their feelings of agency and undermines their self-confidence. Simeonov concluded, "If a certain gift is needed in order to master mathematics, then why should we teach all those people who do not possess this gift" (p. 443)?

"[W]e suggest that the alienation that many children in school, and adults out of school, feel toward mathematics is partly the result of the lack of connections between their experience in mathematics classrooms and their experiences out of school" (Greer & Mukhopadhyay, 2012, p. 244). "Detached and taught in isolation, mathematics loses many of its attributes as an enormously important part of our society, culture, and science, and the students lose their ability to handle complex situations where mathematics resides in action" (Andersson & Ravn, 2012, p. 322).

Education standards are powerfully expressed in the form of mathematics curricula that are often out of synchrony with culture-based school mathematics (Greer & Skovsmose, 2012). The curricula's voluminous content alone prevents most teachers from exercising the flexibility needed to provide an appropriate culture-based mathematics program (Lipka, Webster, & Yanez, 2005; Nicol, Archibald, & Baker, 2013). For the vast majority of competent teachers, curricular constraints will stifle innovation toward incorporating Indigenous perspectives in school mathematics (Matthews, 2015).

A conscientious teacher labours over attempts to accomplish what Simeonov and others consider to be unreasonably difficult. Anxiety is a major result. As the mathematics curriculum is mostly abstract in a way that dislocates it from the general public's everyday worlds (especially for Grades 6-12), the curriculum lacks today's everyday cultural contexts where students can witness, experience, and learn how mathematics works in *their* everyday world and then develop abstract concepts accordingly.

Singh (2017) was a vocal Ontario teacher whose goal was to inspire students into loving the mathematics that Singh idolized. He quit teaching due to excess anxiety over his curriculum's four Bs, as he put it: "(a) boring; (b) benign; (c) banal; or (d) Byzantine" (website quote).

Saskatchewan's curriculum can be renewed to embrace Indigenous mathematizing and Indigenous perspectives as illustrated in this research project. Moreover, a renewed curriculum can be more in-line with students' current and future everyday worlds by including, for instance:

- 21st century financial literacy – a topic much different from obsolete financial algebra and currently a Grade 12 unit of study.
- Artificial intelligence savvy.
- An appreciation of the socio-cultural composition of Western mathematics itself including its values, ideologies, and limitations (i.e., the nature of mathematics).

These three examples come from a much longer list of everyday situations in which culture-based mathematics is relevant to many students and adults.

The participant teachers in our project diligently developed culture-based lessons that were all about engaging students in several dimensions of learning, especially the reconciliation dimension of respectfully understanding Indigenous mathematizing and Indigenous perspectives. At the same time, however, the teachers were pressed for time to finish teaching their 2007 curriculum's outcomes for that year, which cut into their time to innovate further or deeper.

Kevin introduced this issue when he spoke about open-ended classes and assignments in which students pose the problem and then solve it by drawing upon some aspect of mathematics.

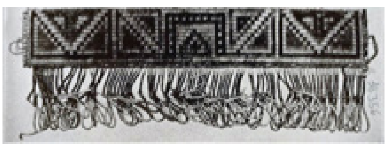
"When I've been given the time and freedom to teach like this, students learn much better. There are some curriculum stumbling blocks to overcome in order to acquire the time to conduct a student-centred class," like the culture-based lessons we've developed for this research project.

All three teachers interviewed at the end of the project singled out the curriculum as a barrier to their wishes to teach more culture-based mathematics (section Independent Final Interviews with the Teachers).

The current mathematics curriculum does not encourage, to any significant degree, reconciliatory efforts by mathematics teachers. In short, a strong case can be made for the Ministry of Education to take ownership, in collaboration with the school divisions, for developing a culture-based mathematics curriculum and implementing culture-based school mathematics over the next decade (see section Our Recommendations).

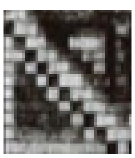
Avoiding Subtle Appropriation

The problem of subtle appropriation can arise when *Indigenous designs or ideas are unconsciously translated into Western mathematical geometry and other ideas*. This translation process creates a high risk of appropriating Indigenous designs. For example, consider the Indigenous looming below.

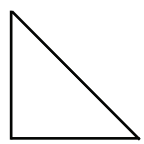


A very old Indigenous looming with porcupine quills

It has *Indigenous mathematical designs*. Some of these patterns, for example:



can be imagined as a triangle:



but only when *seen through the eyes of* Western mathematics. Exactly how does our mind interpret the Indigenous pattern as a triangle? The answer helps us avoid subtle appropriation, thereby helping us prevent our language from being a colonizing influence on Indigenous students.

But first, the following ever-so-brief history will put this subsection into a broader context:

Ancient Indigenous civilizations invented many designs long before similar geometric shapes were invented in non-Indigenous civilizations (about 3100 BCE). Simply put, the geometric triangle figure to the above right can be thought to resemble, *in an analogous way*, the Indigenous design shown in the small photo to the left. To a mathematician, they seem almost equivalent. To a person appropriating the Indigenous pattern, they *are* the same.

The pattern's Indigenous name might provide an insight into what it means to its Indigenous designer, but the designer is not available to tell us. Its meaning is thus unknown. Meanwhile, our study of geometry has taught us what a right triangle means to Western cultures (e.g., its three interior angles add to 180°, and it is a basis of a field of Western mathematics called trigonometry).

But be assured, Western and Indigenous mathematics have very different meanings. For instance, suppose a contemporary Indigenous artist creates a pattern and tells us that it signifies respect for our winged relations. Suppose a mathematician claims the pattern is "a tessellation" and defines that term mathematically. Obviously, both people hold two very different meanings of what the pattern means.

In 1930, Einstein shared his fundamental insight into the process of observing (quoted in Director, 2006). It helps explain why the artist and mathematician can have divergent understandings of the same physical object.

> It seems that the human mind has first to construct forms independently, before we can find them in things. Kepler's marvelous achievement is a particularly fine example of the truth that knowledge cannot spring from experience alone, but only from the comparison of the inventions of the intellect with observed fact. (p. 113).

The pre-observation form independently constructed in our minds plays a pivotal role in perception. Now we are able to answer the question, "Exactly how do our minds imagine the Indigenous pattern appears to be a triangle?" There seems to be four consecutive processes at work.

1. When viewing the small photograph of the quilled looming (previous page), our mind recalls an *image* of a Western mathematics triangle; and then

2. Our mind *superimposes* that image onto a section of the Indigenous looming artifact.

3. If there is a good enough fit, our mind *deconstructs* that section of the artifact by:

    a. focusing only on features that best fit our triangle image; and

    b. ignoring other features.

4. By ignoring those other features, our mind has not respected the artist's Indigenous culture and has *constructed* a Western geometric triangle in the Indigenous artifact.

Moreover, when our minds deconstruct the Indigenous artifact pattern and reconstruct a geometric triangle in its place, the two processes strip the artifact of its original Indigenous meaning and replace that meaning with a Western mathematics meaning (i.e., a triangle). That is called appropriation. To recap: we *recall* an image, and then we *superimpose*, *deconstruct*, and *reconstruct* it to fit our original geometric image that mathematicians call a triangle (Aikenhead, 2017b, p. 121). In short, this appropriation process is: image recall, superimposition, deconstruction, and reconstruction.

This four-step process has also been called projectionism (Aikenhead, 2017b, section 9.3). To recap, it is a very subtle way to both appropriate Indigenous knowledge and marginalize Indigenous students. The Indigenous meaning of a pattern or idea is eliminated, and a Western meaning is inserted in its place. No respect was shown for the meaning, or possible meaning, of the original Indigenous pattern.

If we cannot locate the Indigenous meaning conveyed by the pattern, at the very least we can acknowledge that its meaning is missing. Acknowledging is one way to show respect for another culture's artifacts, values, ways of knowing, and worldviews. In Danielle's second lesson, she had her students do this with patterns they identified on Pow Wow regalia. The students were made conscious of the fact that their descriptors were *analogies* to those Indigenous patterns. There was a conscious translation process, not an unconscious appropriation process.

Similarly Serena, in her second lesson, consistently pointed out that regalia patterns had a different purpose for the dancer than for a math class. This distinction is reinforced by two questions in the lesson's Student Assessment Handout (discussed in detail below in this subsection).

In Krysta's culture-based lesson, she avoided appropriation as it was her students who created their own freestyle looming designs. No Indigenous mathematics was translated into Western mathematics. The looming beads activity served as a clever and successful segue into the topic of mathematical probability.

If we introduce into our mathematics classes Indigenous knowledge that we have learned from local Indigenous knowledge holders or Elders, we can avoid appropriation by using one of these protocols.

1. Learn the authentic Indigenous word and its meaning that we then teach our students.

2. Get permission to use the knowledge in our mathematics classes or in a public forum (e.g., lesson plans shared with other teachers).

3. Tell students where (or from whom) this Indigenous knowledge originated for us (e.g., who gave us permission to share it with others).

When students *come to know* this Indigenous knowledge, they tend to gain respect for the people who hold that knowledge. This is a fundamental understanding of reconciliation according to the Truth and Reconciliation Commission (TRC, 2015a). This describes how our research project's teachers and their students participated in reconciliation.

Our first example of appropriation was about a right triangle. This next example comes from Mohawk mathematics professor, Dr. Doolittle, at the First Nations University of Canada. Some mathematics textbooks state, "A tipi is a cone." Dr. Doolittle objected to this statement (2006).

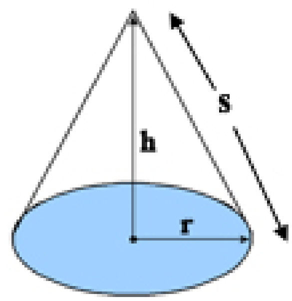
> I have heard that countless times. But that is surely wrong; the tipi is not a cone. …It bulges here, sinks in there, has holes for people and smoke and bugs to pass, a floor made of dirt and grass, various smells and sounds and textures. There is a body of tradition and ceremony attached to the tipi which is completely different from and rivals that of the cone. My feeling is that Indigenous students who are presented with such oversimplification feel that their culture has been appropriated by a powerful force for the purpose of leading them away from the culture. The [contextualized teaching materials] may be reasonable but the direction is away from the culture and toward some strange and uncomfortable place. Students may, implicitly or explicitly, come to question the motives of teachers who lead them away from the true complexities of their cultures. (p. 20)

In summary, the statement “a tipi is a cone” ignores, or strips away, the Indigenous meaning of a tipi and reconstructs in its place a Western mathematics meaning as described by Dr. Doolittle.

Blackfoot tipi

Whenever teachers come across this subtle type of appropriation, it becomes a teachable moment to make students aware of this type of appropriation and its negative consequences for Indigenous people.

Our research project paid careful attention to avoiding this subtle form of appropriation. Accordingly, our project differs in this regard from most similar projects found in the mathematics education literature (see Aikenhead, 2017b, section 9.3).



Based on Dr. Doolittle’s example, we can now generalize based on the linguistics domain of *language-laden cognition* (Kawasaki, 2002). Most words are surrounded by culturally related meanings that contribute to a richer and more authentic understanding of that word. These are connotations held by people of that culture. For instance, Dr. Doolittle described connotations associated with the word tipi. Such connotations inhabit an Indigenous perspective. At the same time in the culture of Western mathematics, mathematicians associate their own connotations with the word cone such as:

$$\text{Surface Area} = \pi rs + \pi r^2$$

$$\text{Volume} = 1/3\,(\pi r^2 h)$$

where, as shown in the diagram above, ***s*** (slant) is the length from the bottom edge of the cone to the tip of the cone, ***r*** is the radius of its base, and ***h*** is its height.

To learn about cones in a culture-based lesson, students would be taught, on the one hand, a selection of these associated connotations about a cone found in the curriculum. On the other hand, to learn about tipis, students would be taught a selection of its connotations associated with a local Indigenous culture such as: (a) tipis usually have 13 or 15 poles; (b) each pole is identified by a value (e.g., obedience, respect, humility, love, etc.); and (c) there are specific protocols to follow when raising a tipi.

If a tipi is not a cone, and a cone is not a tipi, then what *is* the relationship between the two words tipi and cone? The answer solves the potential problem of subtly appropriating from Indigenous cultures.

The two words, “tipi” and “cone,” can be understood as **analogues** (or analogies) located in two different cultures. For a mathematician, a cone is **analogous** to a tipi, but it is certainly not equivalent or the same as a tipi. By not making this distinction perfectly clear to students, a mathematics teacher is appropriating an Indigenous understanding of a tipi. The mechanism for such appropriation was described above as: image recalling, superimposing, deconstructing, and reconstructing.

In a culture-based mathematics program, we do not ignore (i.e., deconstruct) the Indigenous meaning of an artifact or activity. Instead we teach it to our students. We do not *replace* the Indigenous meaning with a Western meaning. Instead, we introduce the Western meaning to our students as an **analogy** to a different culture's idea. By doing so, we convey equal respect for the knowledge found in each culture. To summarize, rather than replace the Indigenous idea with a Western idea, we *add* the Indigenous idea to a student's fund of Indigenous knowledge and keep the Western idea associated with Western mathematics. Simply put, they both coexist (see the sub-subsection Two-Eyed Seeing for further ways of avoiding appropriation - pg. 58).

In Serena's second culture-based lesson, for example, she avoided both appropriation and colonizing language by having her students recognize that the *meaning* of a pattern depends on its context of use. She illustrated this in several different ways:

1. By the directions she gave to her class: "[In photos of Cree regalia] you are going to find patterns that have First Nations meanings, but [in math class] we see them as quadrilaterals."

2. By the questions she posed to students. For instance, when referring to a First Nations pattern of concentric circles, she asked: "What is it representing?"

3. By the language she used: "[There are] different purposes for the patterns First Nations people make [compared to mathematical patterns]."

4. By the student assessment questions posed:

   "What does your beaded object mean to you in a personal way?

   "What does your beaded object mean to a mathematician?"

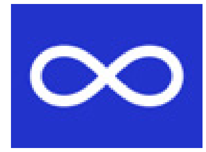
Serena's lesson communicates an important feature of mathematics' epistemology (i.e., how we know what we know, and what kind of knowledge it is) through an activity of Indigenous mathematizing (i.e., loom beading) followed by a reflective class discussion of students' answers to the two questions in Number 4 above.

A similar discussion took place between the two of us directly after her class. We spoke about the Métis flag. Placed in the context of that flag being one of several flags displayed in the room, its pattern obviously has a strong cultural meaning.

> "The figure in the centre of a blue field represents the joining of two cultures [Indigenous and French], and the immortality of a nation repressed by colonial measures for the purpose of eradicating their culture" (Racette, 1987).

Placed in the context of mathematics, however, it represents the concept of infinity.

The connotation of infinity has metaphoric overtones in the meaning of the flag. Nevertheless, the symbol on the Métis flag means: "The existence of a people forever" (Manitoba Métis Federation). Therefore, the symbol on the flag is *not* "the infinity symbol" as we often hear in mathematics classes.



The infinity symbol belongs in Western cultures' mathematics. The implication of this distinction has far-reaching consequences including respect for Canada's Métis Nation.

To replace "the existence of a people forever" with infinity is an act of mathematical *appropriation* that amounts to colonial subjugation: "One of the most powerful weapons in the imposition of Western culture," claimed mathematics educator Bishop (1990, p. 1). The colonizing influence of mathematics was documented by Ernest (2016b) in his research chapter on Mathematics Education Ideologies and Globalization.

Mathematics' power to suppress non-Western cultures is subliminal through the process of subtle *appropriation*. This power is challenged when we explicitly respect the Indigenous meaning of an idea or artifact by not replacing it with a mathematical word. A tipi is not a cone. Indigenous patterns on regalia are not geometric figures. The symbol of the Métis flag is not the infinity symbol. Instead, they are analogously similar, but each has its own distinct meaning. Conveying this distinction brings reconciliation into mathematics classrooms. It is a reconciling way of teaching mathematics classes.

More examples of how to avoid language that appropriates and colonizes are found in Aikenhead (2017b, section 9.3).

In summary, when associating an Indigenous idea or activity with a Western mathematics idea or activity, we treat those ideas and activities as analogies of each other, located in different cultures, hence embracing different meanings. This encourages Indigenous students' interest and achievement in school mathematics rather than discourages them as described in Dr. Doolittle quotation above.

What do we know about most *non*-Indigenous students' engagement and achievement in culture-based school mathematics? As experienced by this project's four teachers, most students respond positively or enthusiastically, on average, to mathematics instruction enriched by learning a modicum of Indigenous mathematizing and Indigenous perspectives (Aikenhead, 2017b, p.1). Students tend to learn more about what appropriation can mean and that can influence their respectful understanding of Indigenous peoples.

Learning Indigenous Perspectives Is a Learning Journey for Teachers

Teachers' anxieties naturally rise when they first think about teaching Indigenous culture-based school mathematics. This anxiety does not rise exactly from what teachers *do not know* about Indigenous perspectives. Instead it rises more from *not even knowing the new territory* of what they do not know.

At a culture immersion, messages from Elders and knowledge holders sketch out a storied picture of some Indigenous content. Their messages about that content can often come in broad-brush strokes depicting their culture in ways unfamiliar to many teachers. Thus, teachers' initial expectations of what they will hear clash with what they do hear. For instance, Elders offer a holistic picture of their culture's rich values and ways of knowing and living. On the other hand, teachers are situated in the mainstream subculture of education. They expect to hear what they can do on Monday morning.

More importantly, in a culture immersion, a teacher's *heart* becomes engaged nevertheless. This was the expectation of those who planned our research project's culture immersion. Engaging the heart is a prerequisite to engaging the brain that does the planning for Monday morning's Indigenous mathematizing lesson (Aikenhead et al., 2014, Ch. 8). As a result, a teacher's *brain* begins to enter the new unfamiliar territory of what it did not know. This naturally produces anxiety at first. The journey begins when the heart becomes engaged!

Elders and knowledge holders always advise:

1. Learn like we did, by making mistakes and learning from them.

2. Repeat to students what you can remember from hearing what we said. Use what you remember and do not worry about the rest.

3. Attend community events such as a Pow Wow. You will discover that everyone is warmly welcomed.

4. Read what we suggest you read in order to learn more.

5. Be patient.

Next, we explore the second point above.

How to Always Be Truthful

Looking ahead for a moment, when it comes time to teach their first culture-based lesson, teachers worry most over making a mistake. "I don't want to tell my students something that is not correct about an Indigenous perspective," teachers exclaim. They want to be truthful. *Here is how we can always be truthful.* Simply preface what is said to students with the honest expression, "As I understand it, …" (or expressions similar to it). That is what Indigenous people sometimes say to each other. More often, their "As I understand it" is assumed within an Indigenous group as chances are very high that they will meet someone who understands it somewhat differently.

For example, some Cree groups give special attention to the numeral zero. When they count, they always start with zero. Whereas a Dakota speaker explained that their people count by beginning with one, just like Western mathematics.

Place-Based Knowledge

The example just above correctly suggests that Indigenous knowledge has features fairly unique to *the place* where a community lives. Differences from place to place are naturally taken for granted. Therefore, most Indigenous knowledge is *place-based* knowledge rather than generalizable to all places. However, Western mathematics' knowledge is generalizable, absolute, or *universal*, such as, "The interior angles of a triangle add to 180°." Place-based and universal are two very different ways of knowing the world.

Canadian mathematics educators Sterenberg and O'Conner (2018) concluded:

> We have come to understand the importance of designing mathematical activities situated in places relevant to the experiences of the children in the community, of including [E]lders in the process, and of attending to content knowledge." (p. 184)

Acknowledging Your Sources

For teachers, one simple implication is clear: When Indigenous knowledge is described or explained to students, its source (i.e., its place of origin) should be acknowledged. For instance, acknowledge the person who taught you or the Indigenous group associated with the source (e.g., a specific First Nation, the Métis general location, or the Inuit location).

The connection to place indicates an *authenticity* to what is being described or explained. It also indicates that you are following the *protocol* of making an explicit connection to the source of what you are saying. Simultaneously, you are consciously avoiding appropriation, as described in the subsection Avoiding Subtle Appropriation, that is: (1) learning the authentic Indigenous meaning; (2) getting permission to use the knowledge; and (3) telling students where (or from whom) this Indigenous knowledge originated.

By making a connection to place, we avoid inappropriate generalizing to all Indigenous groups on *specific* matters. Here are two examples of correct communication: (1) *Many* Canadian Indigenous peoples follow the four-coloured medicine wheel (i.e., an authentic overall description that does not generalize). (2) Place-based differences do occur with the colours used and with their orientation (horizontal-vertical or 45° angular) within the circle (i.e., appropriately avoiding a generalization by expressing a place-based understanding of differences).

Two-Eyed Seeing

Pause for a moment to consider what the expression "As I understand it" actually means to mathematics teachers. It means that their journey into culture-based school mathematics includes *adding* some place-based (non-generalizable and non-absolute) knowledge to their repertoire of understanding the world.

Place-based understanding is a way of knowing that goes back tens of thousands of years; a way of knowing that is invariably *pluralistic* knowledge[9], meaning there is a number of culture-based ways of knowing something. Each major culture usually has, or has had, a mathematical system based on their unique worldview.

Western mathematics teaches an absolute *universal* way of knowing. It is entirely framed by the binary "true or false," found in deductive reasoning. But Indigenous cultures

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[9] Pluralism should not be confused with *relativism* – defined by the Cambridge English Dictionary as, "the belief that truth and right and wrong can only be judged in relation to other things and that nothing can be true or right in all situations" (https://dictionary.cambridge.org/dictionary/english/relativism). This relativistic knowledge is independent of any systematic way of knowing such as a place-based cultural perspective. Relativistic knowledge is highly individualistic. Any acclaimed assertion can become accepted knowledge. We mention this distinction because people who subscribe to the absolutist or universalist view of knowledge (e.g., many mainstream mathematicians), tend to think that pluralistic knowledge is equivalent to relativistic knowledge. Notice the hidden binary in their way of thinking. Their binary is: absolute universal knowledge or *not* absolute universal knowledge. That latter half of the binary refers to both pluralism *and* relativism, grouped together as one category, an intellectual slight of hand, if you will. Culture-based knowledge is not relativistic; it is pluralistic.
The equivalent pluralistic feature of science is well-established (Ogawa, 1995; Aikenhead & Ogawa, 2007; Higgins, 2019), although rejected by universalist science educators who embrace scientism, realism, or radical realism.

recognize a plurality of understandings established by time-honoured place-based ways of knowing. Instead of thinking only in terms of true or false, Indigenous cultures tend to see the world in terms of varying degrees of both true and false depending on the place and circumstances (Battiste & Henderson, 2000, Ch. 2).

This fundamental difference between Western thinking and Indigenous thinking is but one of a plethora of cultural clashes that many, but not all, Indigenous students experience in mathematics classes. Teachers who are unaware of these types of cultural clashes most often see the world only through the true-or-false lens of their Western culture – mainstream Canadian culture. They are not aware of pluralistic mathematics. How can these teachers journey outside of their monocular world into a pluralistic world of knowing, embraced by culture-based school mathematics?

Elder Albert Marshall of Mi'kmaw ancestry described how. Teachers and students are advised to live his metaphor of two-eyed seeing (Hatcher, Bartlett, Marshall & Marshall, 2009). It means learning the strengths of both Indigenous mathematizing and Western mathematics and then idiosyncratically drawing upon bits and pieces from either knowledge system in order to solve a specific problem or make sense out of a specific issue. Culture-based mathematics teachers teach the integrity of both ways of doing mathematics. Students decide which way of knowing (or which combination of ways) they will draw from in any situation that presents itself.

> "We have come to understand that Western and Indigenous mathematics can be viewed as having complementary strengths. Recognizing the strengths of each view will maximize mathematical learning for all students" (Sterenberg & O'Conner, 2018, p. 185).

This is precisely what Carrot River students were learning:

- from Danielle when they went back and forth between Indigenous stories and the Western mathematics' story about the number line.
- from Krysta when explicitly comparing possible stories associated with a wampum belt and a probability tree.
- from Serena when recognizing that patterns seen on regalia have a different meaning for the Pow Wow dancer than for Western mathematicians.
- from Kevin when the mathematical strengths of Western statistics revealed gross social inequities between privileged non-Indigenous communities and socially subjugated Indigenous communities. In this case, the two-eyed seeing corresponded to two different *normal* living conditions.
- from Sharon when she taught a dream catcher geometry lesson (see Appendix F). A photo shows a student in the midst of two-eyed seeing – Indigenous dream catcher shapes and geometry shapes.

Two-eyed seeing is a challenge at first for most mathematics teachers whose journeys invariably begin with a singular universalist or absolutist way of knowing due to what and how they were taught. Two-eyed seeing contradicts what our education system has instilled in us: the Eurocentric habit of one-eyed seeing, a foundation of Western mathematics and science, is hard to break. Its ideology of supremacy over other cultures' knowledge can hamper some teachers' progress.

As shown during our research project, however, this monocular view is quickly expanded into two-eyed seeing by the experiences of teaching culture-based lessons under the initial mentorship of a school division Indigenous consultant. Some ideas can only be learned through personal experience – in this case, having one's lesson plan's edited by an Elder, knowledge holder, or educator experienced in Indigenous perspectives.

As described in the section Culture-Based Mathematics Lessons Taught and Discussed, all the lessons conveyed a two-eyed seeing way of understanding mathematics. Some were explicit, some were implicit. If there were two different cultural contexts, then there were likely two different cultural meanings analogous to each other.

Two-eyed seeing was adopted in 1997 as the framework for Mi'kmaw Kina'matnewey (the First Nations school division in Nova Scotia). Their high school graduation rate rose to 88% compared to the national First Nations average of 35% (CBC News, 2013) and now to 90% (Lunney Borden, 2018). This certainly is *strong evidence* for the potential success in Saskatchewan of culture-based school mathematics that embraces a two-eyed seeing approach (see section Our Recommendations).

Conclusions

Learning to teach Saskatchewan Indigenous mathematizing and perspectives comes in baby steps, accumulated over several years, and accelerated each time a culture-based mathematics lesson is taught, and at first along with mentoring support. It is not so much a professional development exercise as it is a personal life journey with far-reaching professional rewards.

As personal as it is, however, it is a journey best taken by a supportive group of educators within a school networking toward a common goal. Sari called it a professional learning community. If truth be told, it is an unending journey through stimulating camping spots of dialogue with other professionals, with one's own students, and often with one's family.

The professional development aspects are summarized in Figure 2. It depicts a type of learning curve, if you will: the brain, the brain needs the heart, inclusion is not enough, reconciliation, avoiding subtle appropriation, two-eyed seeing, and mathematics as a human endeavour.

Simultaneously, however, continuous explicit support must also come from the administration in schools, school divisions, and the Ministry of Education. The Ministry has the authority to renew the mathematics curriculum to enhance teachers' efforts:

- to bring Canada's 21st century era of reconciliation into their classrooms.
- to address effectively the diversity of learners from the math-phobic, math-shy, and math-disinterested to the math-curious, and math-oriented.
- to motivate all students to reach their potential given their mathematical preferences, aspirations, aptitudes, and self-identities.
- to contextualize learning in the general public's actual experiences in *their everyday* worlds rather than the much narrower experiences of a mathematician's everyday world. An exception, of course, is made for the math-curious and math-oriented students.
- to identify math-oriented students and encourage their preparation for future mathematics-related employment, their contribution to creating cutting-edge

algorithms for artificial intelligence, and their dedication to ensuring best ethical and social practices of artificial intelligence for the good of humanity.

- to foster two-eyed seeing in all students by developing their awareness of fundamental aspects to Indigenous perspectives such as relationships with everything in creation, reciprocity, the non-superiority of humans, place-based knowledge, verb-based understanding of Mother Earth (e.g., mathematizing), holistic reasoning, and medicine wheel teachings.

Our project report makes a specific novel contribution to the mathematics education research literature when it puts Doolittle's (2006) "a tipi is not a cone" into an explicit social justice concept: *avoiding subtle appropriation*. An analysis of ethnomathematics with respect to the concept of avoiding subtle appropriation reveals a blind spot in that paradigm (Aikenhead, 2017b, section 7.2). "The hegemonic power imbalance favouring [Western] mathematics curricula over Indigenous communities is not *sufficiently* challenged by ethnomathematics" (p. 86).

Transferring Culture-Based School Mathematics to Other Schools

Sari Carson acknowledged that for transfer to occur to other schools, the school division's administrator's support is basic. "I think that is the logical next step. Creating opportunities for administrators in the division to learn more about the project is important. They need to hear it from Sharon and the teachers; perhaps an administrator's meeting would be a good forum. The main purpose of such a meeting would be to invite all administrators to support individual school efforts to take on the challenging adventure we took on, but not the research portion of it."

"A workable transfer process may be embedded in the work of schools' and the divisions' professional learning communities. Our annual teacher conference is a professional development event that would reach our fellow educators and administrators as well. Sharon's mentorship in the transfer process is essential. Collaboration is imperative."

"If the school's teachers were going to be involved as sources of pedagogical *and* Indigenous knowledge they learned this year, two big hurdles will have to be addressed: their feeling worthy of such a position, and their deep need to hear from an Elder or knowledge holder for explicit permission to share the Indigenous knowledge they learned this year." Elder Albert Scott's ubiquitous presence in the hearts and minds of the teachers throughout the year testifies to the power of being given permission, as he gave to them.

"Any transfer process from our school will be facilitated by the fact that our participating teachers represent the wide diversity of teachers employed in our division. For instance, involved in the culture-based math project was a first-year teacher and a teacher with 19 years of experience. The grade levels represented went from Grade 5 to 12. Those cross-sections are just fantastic."

"I think the senior high teachers were shocked that Indigenous perspectives could fit so smoothly into a senior math class. I have never seen such excited senior students in classes that engaged them with Indigenous mathematizing activities."

Is there something at the Minister of Education level that should be going on to support the reconciliation firmly embedded in culture-based school mathematics? "I'm not sure I am the right person to answer that. Our Superintendent, Stacy Lair, attended an afternoon of the culture immersion." Director Don Rempel has not only been enthusiastically supportive, but he also supported the research project by making the project's video taping a division task. That was most helpful."

"I am intrigued with how culture-based school mathematics could meld with what's coming down the pike – 'Visible Learning.' It means pick out what has had positive and negative effects on students. Develop the former further, eliminate the latter. Too often in education, we do things because we've always done it, not because it has been shown to be successful. I feel the results of this research project fit nicely into our work with the visible learning initiative."

In the teacher interviews toward the end of the project conducted by two project team members, Kelley Cardinal and Daniel Sylvestre, the participating teachers shared their ideas on, "Where do we go from here?" They suggested that North East School Division administration group together clusters of neighbouring schools so that one school in each cluster has had some success at including culture-based teaching at their school in any subject.

It would seem that, with the school division organizing the clusters and with sufficient division funding and/or provincial grants, a Professional Culture-Based Teaching Community (PCBTC) could be established in each cluster. Their mandate could be:

1. to share what has been accomplished in each cluster especially in mathematics.

2. to implement those accomplishments in other schools, as feasible, on a small scale during the 2019-20 school year.

3. to develop a three-year action plan to be carried out during the subsequent school years. The goal for each PCBTC is to create a significant presence of culture-based teaching throughout their cluster especially in mathematics.

Engagement with the Ministry of Education throughout the process described above should be a very high priority.

The project team takes a more extensive and perhaps more ambitious position described in the section Our Recommendations of this project report. Importantly, it does not negate the ideas just above.

Independent Final Interviews with the Teachers

Introduction

At the completion of the culture-based teaching for the year, team members Kelley and Daniel interviewed Kevin, Danielle, and Serena individually to learn of their ideas *relevant to the project's research questions and objectives*. The teachers had not met Kelley previously. Daniel had spent the August 31, 2018 professional development day with them.

Each interview lasted about an hour. Kelley and Daniel took notes. Later, on the drive back to Saskatoon, they discussed what they had learned from the teachers. Five and nine days later, Glen audio recorded Daniel and Kelley separately. They told him what they had learned prompted by their notes. Glen transposed (but not transcribed) their taped reports into a written record of the interviews that were pertinent to the project's research questions and objectives. Quotations were recorded for pivotal points. This present section is a synopsis of that written record. Kelley and Daniel have read this synopsis and affirmed its accuracy.

During the interviews, the teachers recounted the highlights of lessons they developed and taught. These comments, by and large, repeated what teachers had contributed to this project report's section Culture-Based Mathematics Lessons Taught and Discussed. Therefore, this content is not repeated here. When this situation occurred for other topics, cross-referencing is similarly written in footnotes in order to reduce repetition in this synopsis.

On occasion, a note of clarification or highly relevant information is inserted by Glen as a footnote or a textbox. Glen confirmed with Serena the accuracy of her figure depicting a braiding model of culture-based instruction.

Synopsis

Adamantly, all three teachers emphasized the following five points:

1. Culture-based teachers must first and foremost be learners.

2. Culture-based teachers first require a substantial culture immersion experience.

3. Mentoring by school division consultants, Indigenous knowledge holders, or Elders is a necessary but insufficient key to success.

4. The depth of student engagement determines the degree of their success at learning mathematics.

5. A major roadblock to culture-based school mathematics is the highly restrictive, over-crowded, outdated curriculum.

Each of these points is addressed, in turn, before moving on to further comments.

All three teachers affirmed with emphasis that *teachers must be learners* including learning from, or with, their students when they get stuck with a problem. Indigenous mathematizing invariably involves, to some degree, student-centred problem posing and problem solving. Lessons can become open-ended. A teacher cannot always predict what assistance students may need. Thus, the need for a teacher's flexibility and the occasional time to become a co-learner with students is crucial. Also important is becoming a pupil of Indigenous students who are happy to share their knowledge and experiences with their teacher.[10]

[10] It is remarkable how the classroom atmosphere changes when students learn their teacher is open to learning from them. Teacher-student relationships strengthen.

The fundamental importance of a culture-immersion experience for teachers and administrators was a major topic in each interview as was the teachers' reliance on Sharon's mentoring.[11]

Personal anecdotal evidence clearly showed Serena the link between engagement and student learning; a topic mentioned by the other teachers as well. The interviewers heard about a concrete Western math-in-action event in her classroom. A connection was made by her students between Indigenous drumming (an example of Indigenous mathematizing) and multiplication (a Western mathematics process). The concreteness of drumming broadened the usual range of sensual inputs for students.

For instance, consider, on the one hand, the *visual* input from reading a textbook page that explains multiplication, and on the other hand, the tactile or auditory sensual inputs experienced during a drum mathematizing activity. The tactile auditory sensations of drumming give greater access to curricular content for a wider variety of learners (often labelled reluctant learners in the literary genre of reading) whose preferred way of learning is more tactile or auditory. Thus, three students in her class became more engaged learners in a context that matched their preferred sensual input for learning. Serena marvelled at how well her normally reluctant learners could multiply after participating in this specific culture-based lesson. She concluded that matching the context of learning with a student's preferred sensory input for learning makes a great difference to their achievement.

Directly related to preferred sensual inputs for learning is the notion of learning styles. Contrary to popular belief, however, there is little evidence that a stereotype learning style for Indigenous students exists. Instead, much more credible evidence points to the idea of *recurrent learning strengths* found among all students. The evidence also suggests there is a tentative profile for many Indigenous students, and this profile is different from their typical Western cultural counterparts (Hughes, More & Williams, 2004). The following updated version is copied from Aikenhead et al. (2014, p. 135): Indigenous students tend to prefer:

1. holistic more than analytic.
2. visual more than verbal.
3. oral more than written.
4. practical more than theoretical.
5. reflective more than trial and error.
6. contextual more than decontextual.
7. personal relational understanding more than an impersonal acquisition of isolated facts and algorithms.
8. experiential more than passive.
9. oriented to storytelling sessions more than didactic sessions.
10. taking time to reflect rather than quickly coming to an answer.

All three teachers spoke out about how the mathematics curriculum was a major detriment to their innovative work on the project.[12]

[11] The teachers' detailed ideas are recorded in the major sections The Culture Immersion, and Mentoring the Collaborative Teachers.

[12] This issue was thoroughly addressed in the subsection Mathematics in the Everyday World: The Elephant in the Room.

The three teachers also suggested ideas about how to follow up this year's achievements. Their first idea was to expand their culture-based teaching to all curriculum subjects within the school. This was also a request made by the student focus group. As a result of this expansion, teachers anticipated that each teacher would have the support of more teachers.[13] There is a great difference when a few classrooms engage in culture-based teaching, and when the whole school is devoted to it.

Without substantial financial and administrative support, however, one teacher pointed out that they will individually become responsible for making community contacts with Indigenous people who could serve as authenticity consultants to support teachers as they develop more culture-based lessons locally.[14]

The power of two-eyed seeing was mentioned by a teacher. Another pointed out that at first it is a challenge as not only do teachers have to *learn* new ideas (e.g., the Medicine Wheel teachings), but some teachers will have to *unlearn* some Eurocentric ideas (e.g., Western thought is far superior to all others and should be privileged over the others).[15]

Other teachers mentioned a poignant "Oh, I get it now" moment when they were able to move forward in their journey to become culture-based teachers. "Once I understood that I could see the world through two different independent lenses (Western and First Nations), it was easy for me to make relationships between the two, and then teach what I was expected to teach as a culture-based teacher." However, it was hard for her elementary *students* to wrap their minds around two-eyed seeing explicitly.[16]

A model for sequencing a culture-based mathematics lesson emerged from an interview. One teacher realized that a misconception of two-eyed seeing might mislead a teacher into the simplistic teaching sequence: "First the Indigenous information, then the Western information, and then that's the end." This leaves only one opportunity to connect the two at that one interface.

Serena realized that more opportunities to relate the two could take place if the sequence is: "Focus on the Indigenous for a shorter time, then focus on the Western for a shorter time, followed by another focus on the Indigenous content and so on during a lesson or sequence of lessons over time." Each occasion in which the focus changes, there is a connection with which to create a relationship, that is, where a teacher can clarify a connection between the two lenses of two-eyed seeing.

Flailing her arms around to gesticulate what she meant, Serena suddenly imagined a two-stringed braid. It was the birth of her braided instruction model for teaching culture-based school mathematics. The figure that follows is a representation of this new model.

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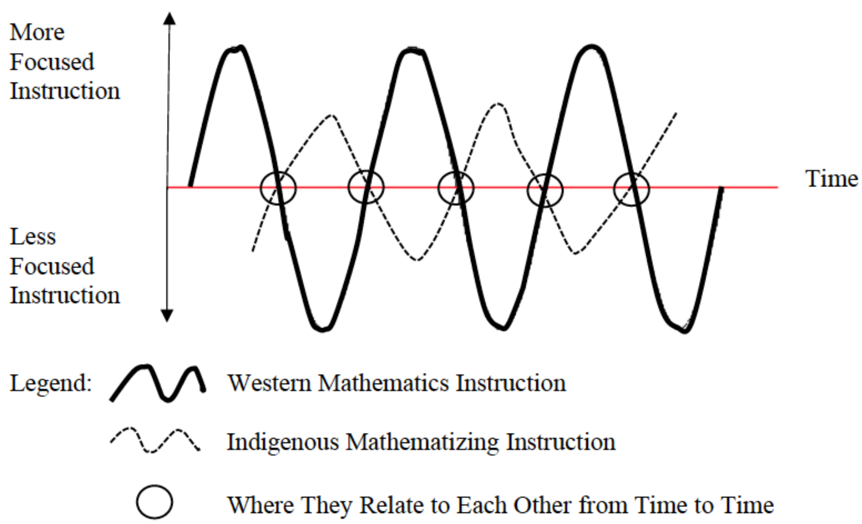
[13] Given the current, fairly rich resources available to science teachers for enhancing their teaching with Indigenous perspectives, science teachers may find this move easier to accomplish.
[14] Sharon and Glen believe that this labour-intensive pathway risks substantial teacher burnout. Thus, it lacks sustainability.
[15] Detailed input from teachers on this point is found in the section Project Report Summary.
[16] Some abstractions seem to require a degree of social and intellectual maturity.

Figure 1.

A Braiding Model of Instructing Culture-Based Mathematics[17]



Two teachers talked about learning Indigenous protocols such as how to show respect, reciprocity, humility, etc. They also talked about learning protocols that exist around sacred ceremonies such as smudging. A teacher can learn some protocols by having their school invite a consultant to introduce some protocols to teachers and/or students. Best of all, learn them at a culture immersion. Two teachers related how they create opportunities in class to talk about, demonstrate, or perhaps involve students in an Indigenous protocol. This strategy is present in Kevin's lesson plan, Picario, when students borrow small stones from Mother Earth.

All three teachers were continuously striving to build their foundational knowledge of Cree and other Indigenous cultures. They realized it was a life-long process.[18]

One teacher spoke about the need to be ready to explain why Indigenous mathematizing belongs in school mathematics. He spoke of the moral imperative, "Because it's the right thing to do in Canada's era of reconciliation."[19]

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[17] Serena describes her original epiphany in the section Culture-Based Lessons Taught and Discussed, subsection Serena's Second Lesson in the table's row called Teachers' Reflections.

[18] There are many current excellent resources. These include:

a. The Indigenous lens sections in *Natural Curiosity, 2nd Edition* (Anderson, Comay & Chiarotto, 2017): pages 5-10, 57-64, 81-87,103-108, & 133-139.
b. Aikenhead and Michell (2011), *Bridging Cultures*. Chapters 6-8. (Just substitute math for science.).
c. Earlier books by Thomas King: 1. *Medicine River*; 2. *Green Grass, Running Water*; 3. *Coyote's New Suit (child's story)*; 4. *One Good Story, That One*; 5. *The Truth about Stories*; 6. *A Coyote Solstice Tale (child's story)*; 7. *An Inconvenient Indian*; 8. *The Back of the Turtle*.
d. Books by Richard Wagamese: *Keeper'n Me; One Native Life; and Embers.*

[19] The subsection Paying Off Canada's Educational Debt suggests another moral imperative.

A teacher explained that experiential and student-centred learning harmonizes with an Indigenous way to learn. It can be a natural way to teach Indigenous mathematizing such as beading. This type of learning requires culture-based teachers to be flexible: "Go with the flow defined by your students' dynamics," was the teacher's advice.

Teachers wondered aloud about how to assess what students learn in an experiential, student-centred, or problem-posing way. "NESD has rubrics for that," was Danielle's advice. She had used them.[20]

The influence on teachers from learning Indigenous ideas became evident when one teacher phrased their personal educational goal as, "So kids can live in a good way."

On the one hand, teachers expressed appreciation, "Other schools should have the school administrative support like we did." On the other hand, a couple of teachers noticed a lack of explicit interest from the school division office in what the teachers were accomplishing through extended dedicated work. This was interpreted as a lack of support.

Our Recommendations

As mentioned earlier, the TRC's Calls to Action include: "developing culturally appropriate curricula" (TRC, 2015b, p. 2) and "Building student capacity for intercultural understanding, empathy, and mutual respect" (p. 7). Achieving these two goals in Saskatchewan mathematics education would go a long way to increase the high school graduation rate for Indigenous youth.

Major results could follow.

1. The race-related marginalization of Indigenous students in school mathematics would be reduced if not eliminated.

2. Many more Indigenous youth would be better qualified for entering Saskatchewan's job market.

3. Reconciliation would be a greater part of all students' school experience.

4. A major barrier to teachers' innovative mathematics teaching would be removed in order to accomplish consequences 1-3.

5. The revised curriculum would make a significant payment toward reducing Saskatchewan's educational debt to its Indigenous citizens (subsection Paying Off Canada's Education Debt).

In the Saskatchewan Instructional Development and Research Unit's (2014) research report into what Indigenous parents, teachers, and students say about improving Indigenous student learning outcomes, an Indigenous graduate student in mathematics education stated:

> "I think that part of my research challenges the *colonial, Eurocentrism of mathematics.* I think people need to see that. I think the people making those curricula decisions need to see that" (p. 62, emphasis added).

[20] Another resource is Chapter 7, Culturally Valid Assessment, in Aikenhead et al. (2014).

B.C.'s Education Minister pointed out in 2015, "The Ministry was already working on integrating Indigenous content, knowledge and worldviews as part of a large-scale redesign of B.C.'s K-12 curriculum" (Bellringer, 2019, p. 23). B.C.'s provincial Auditor-General Bellringer (2019) assessed the result. She noted that over the last four years, the percentage of Indigenous students completing Grade 12 (within 6 years in public schools) climbed from 62% to 70% (p. 11). That is 2% per year on average.

Furthermore, "Our 2015 report highlighted the impact of the *racism of low expectations*. This is the phenomenon of educators and district staff having lower expectations for students based on preconceptions or biases stemming from social attitudes" (Bellringer, 2019, p. 13, emphasis added). The racism of low expectations is certainly in our "to unlearn" category for all educators (section Project Report Summary).

The phenomenon seems to emerge from a lack of knowing that a gap is more honestly conceptualized as "an education debt." If the problem were defined as a gap, it will lead to very different solutions than it would if defined as an educational debt. It would seem, the latter coincides with reconciliation.

Some statistics reported for Saskatchewan are shown in the textbox below (Canadian Press, 2019; Government of Saskatchewan, 2013, p. 17; Hill, 2017; Levy, 2019) concerning the percentage of students *completing Grades 10-12 in three or five years*. Saskatchewan's Deputy Minister of Education stated, "We know we have a ways to go, but we are trending in the correction direction" (Levy, 2019, website quote). It is obvious that both B.C. and Saskatchewan have a large educational debt to service.

School yr.	Indigenous Students		Source	Non-Indigenous Students
2010-11	3 Years	33%	Gov. Sask.	72%
	5 Years	48%	Gov. Sask.	81%
2015-16	3 Years	42%	Hill	
2016-17	3 Years	43%	Hill	
2017-18	3 Years	43%	Levy	
	3 Years	44%	Can. Press	86%
	5 Years	60%	Levy	91%
2020 target set by the Ministry of Education and Saskatchewan School Boards Association	3 Years	65%		

But to claim Saskatchewan is making some progress over the last three years (from 42% to 43% or 44%) is to use the context-free ideal world of Plato's mathematics (see subsection The Nature of Mathematics) to make political points by concluding that there is an absolute *mathematical* difference of one or two percentage points over three years. But using everyday real mathematics, we could conclude that educationally significant gains have not been realized recently.[21]

Even to claim that Saskatchewan Indigenous students' graduation rate made an 11% gain over the last seven years (2011 to 2018, highlighted in the textbox) is to ignore the fact that during the same period of time, non-Indigenous students made a 14% gain. In other words, Saskatchewan's educational debt to Indigenous students was 39% in 2011 (72 – 33), and it *climbed* to 42% in 2018 (86 – 44).

[21] At the time of writing this report, the 2018-19 figures were not available.

The 2019-20 target (i.e., a 65% graduation rate for Indigenous students in 2020) is certainly unrealistic.

Once implemented, our recommendations will begin to create *much* greater progress in classrooms where Indigenous culture-based school mathematics is being taught in a culturally responsive way. We must keep in mind that mathematics, more than other school subjects, is responsible for students not graduating from high school (Abrams, Taylor & Guo, 2013; Anderson & Richards, 2016).

As reported in subsection Objectives, the overall Nova Scotia Mi'kmaw graduation rate was 90% for 2017-2018 (Lunney Borden, 2018). They are on par with Saskatchewan's *non-Indigenous* students (91%). This is what Nova Scotia's Mi'kmaw Kina'matnewey province-wide school division was able to accomplish since 1997, the date planning began to implement their Indigenous culture-based school program. When will Saskatchewan's Indigenous culture-based mathematics program be initiated? Saskatchewan's *science* culture-based program began in 2008.

We recommend that Saskatchewan's Ministry of Education remove barriers that currently discourage teaching culture-based school mathematics. The Ministry could cull obsolete and inappropriate curriculum content taught to most students. Examples include:

- Replacing financial algebra (questions that require formula manipulation) with financial literacy (problem posing and solving, using the same algorithms that bank employees use).
- Replacing what mathematicians know about probability with:
    - ✔ what critical thinking citizens should know about polling.
    - ✔ how to make decisions when risk is involved.
    - ✔ how to critically analyze statistics similar to those found in the textbox.
    - ✔ evaluating claims based on statistics found in social media, advertisements, or public discussions/arguments, etc.

Such a renewed curriculum would give time for teachers to innovate with: (a) Indigenous mathematizing; (b) a multicultural understanding of mathematics; and (c) teaching Western mathematics in Canada's mainstream cultural contexts.

This last point, *Western* culture-based school mathematics, goes beyond the scope of our project that addresses *Indigenous* culture-based school mathematics. Yet the topic offers a logical extrapolation pertinent to a curriculum revision. A short tangential comment here provides concrete examples of Western culture-based school mathematics that harmonizes with our project.

The content of a renewed curriculum could lend itself to include open-ended, student-centred, critical-thinking investigations requiring mathematical input (i.e., *Western* math-in-action) on topics such as:

- Everyday employment in the majority of workplaces not requiring mathematics specialists; for example: business managers, bank clerks, financial advisors, office workers, sales people, many health care workers, therapists, most trade workers, teachers of humanity subjects, lawyers, police officers, many entrepreneurs, power plant operators (Martin, 2014; Tencer, 2016).

- The computer revolution over the past 40 years has radically transformed and created many jobs, yet the junior and senior secondary school mathematics "has not changed substantially" (Larson, 2016, website quotation) since World War I when trigonometry was introduced into the curriculum in order to prepare male students for future infantry positions in the military, in case another war broke out.
- Where mathematics has direct influence on peoples' lives, such as AI (artificial intelligence), all designed with mathematics at its core.
- Advanced mathematics taught in specialized contexts of problem posing and problem solving found in science, architecture, engineering, certain fields of technology, and ideal pure mathematics. This is mostly about learning procedural mathematics in specific professional contexts and then generalizing the mathematics to abstract concepts as needed. Some topics would be taught from the conventional, context-free, ideal world of Plato's mathematics as well.

Teaching both Indigenous- and Western-based curriculum content would tend to decrease the negative consequences that accrue for a large minority of high school students who are led to believe they are academically inadequate (Simeonov, 2016). Many learn to hate mathematics (see subsection Mathematics in the Everyday World). When they become parents, this negativity tends to be passed on to their children, who then become a challenge for elementary teachers teaching mathematics.

Our research project discovered how the current mathematics curriculum monopolizes classroom teaching time that works against this project's sustainability.

A revised curriculum for the 21st century, plus substantial *support* from all levels of administration, could enhance mathematics teachers' efforts:

1. to bring Canada's era of reconciliation into their classrooms.

2. to address effectively the diversity of learners from the math-phobic, math-shy, and math-disinterested to the math-curious and math-oriented.

3. to contextualize learning in the general public's actual experiences in *their everyday* worlds rather than in the much narrower experiences in a mathematician's everyday world.

4. to foster two-eyed seeing in all students.

5. to teach at least six to eight Indigenous culture-based lessons a year (similar to those found in Appendix E) for each grade level to Grade 9; and then for Grades 10-12, the same number each year for each mathematics program (some programs might share a lesson plan or more).

6. to motivate all students to reach their potential in reasoning arithmetically, algebraically, and/or spatially given their mathematical preferences, aspirations, aptitudes, and self-identities.

7. to increase the average academic achievement of both Indigenous and non-Indigenous students. A plethora of research demonstrates this outcome.

8. to identify the small minority of math-curious and math-oriented students and encourage:

   - ✔ their preparation for future mathematics-related employment.
   - ✔ their future contribution to creating cutting-edge algorithms for artificial intelligence.
   - ✔ their dedication to ensuring best ethical and social practices of artificial intelligence for the good of humanity.

Our research project illuminates a way forward. For the developers of a *revised curriculum*, our research has identified a number of intellectual and emotional understandings to be learned and/or unlearned. These apply equally to those who develop culture-based *teaching materials*. Our collaborating teachers described our project as a once in a lifetime *professional development* experience. The most succinct answer to our Research Question 1 (What is the needed support for teachers implementing Indigenous culture-based school mathematics?) is:

1. a revised mathematics curriculum.

2. Saskatchewan authentic teaching materials.

3. a professional development experience for teaching Indigenous culture-based mathematics.

A culture immersion is an effective way to begin the journey.

These recommendations also provide a strong framework for scaling up our project to a province-wide effort (i.e., a strategy for producing teaching materials that match a revised curriculum). Scaling up requires more personnel and greater efficiency.

This is our recommendation for scaling up over the next five to 10 years. The Ministry of Education could establish cadres of developers of teaching materials; each cadre housed within a different school division. The cadres would be comprised of the following groups of people.

A. Mathematics teachers who are already familiar with, or highly interested in learning, a Saskatchewan Indigenous culture. Indigenous teachers who practice their culture and speak Western mathematics fluently would make ideal candidates. Teachers could be paid to repeat a scaled-up version of our project.

B. Elders and knowledge holders to ensure authentic local content and protocols and to promote the local language to some reasonable degree in the teaching materials produced by groups A and D. These Elders and knowledge holders are not consultants. They are *collaborators* as they were in the development of the province's science textbook series. They control the Indigenous content and how it is written to ensure an authentic translation into English as much as possible. Each of the five major Indigenous language groups in Saskatchewan would have at least one cadre devoted to their language.

C. A selected cross-section group of students who have experienced the instruction of group A's materials. They would suggest to personnel in groups A and D what worked well for them and what might be modified. Students are the primary target audience of the final teaching materials. Therefore, they can be very helpful (Aikenhead, 2002). Listen to their suggestions in some significant way. (A better, but more time-consuming method is to observe such students as they are being taught, edit the material spontaneously based on what is observed in the classroom, and consult with students afterward. This all but guarantees effective teaching materials for the targeted group of students [Aikenhead, 1994].)

D. Teacher writers for polishing the work of groups A, B, and C into publishable teaching materials that emphasize culturally responsive teaching (Aikenhead et al., 2014). Inexpensive modules could be printed for distribution.

A heavy involvement by Saskatchewan's school divisions and by the Saskatchewan School Board Association (SSBA) throughout the processes of A to D is essential. Their involvement would contribute to a more effective and efficient implementation of the teaching materials as they are being produced. Implementation would require effective professional development experiences for some school division administrators, for some SSBA members, and for all mathematics teachers over a period of time.

Our pervasive policy is simple: Indigenous students should not have to set aside or devalue their cultural knowledge or self-identities in order to achieve in school mathematics.

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Figure 2: An Intellectual/Emotional/Professional/Personal Journey

The Brain

Knowing that Western math is but one system among a plurality of mathematical systems. It evolved from ancient civilizations and the Greek and Islamic empires; then it was appropriated by Western Europeans.

The Brain Needs the Heart

Making an emotional connection to current circumstances of Indigenous people. Paying our educational debt.

Inclusion Is Not Enough

Enhancing a math lesson with Indigenous mathematizing that relates explicitly to Western math content.

Reconcilation

Exploring Indigenous perspectives to gain knowledge that instills respect for Indigenous worldviews.

Social Equity

Recognizing, and escaping from, an unconscious cultural ethos of Eurocentric superiority that suppresses humility and pluralist thinking, thereby marginalizing most Indigenous students in order to maintain the assumed superiority of Western culture in general, and Western math in particular.

Avoiding Subtle Appropriation

Not labelling an Indigenous artifact, pattern, process, or idea with a Western math term. Respect the real term.

Two-Eyed Seeing

Knowing that Indigenous mathematizing and Western math coexist non-competitively. Learning the best from each knowledge system. Making explicit connections between the two. Connecting the two with analogies of each other. Respecting their separate and independent integrities. Teaching Indigenous perspectives more interspersed throughout a lesson and less an introductory block of information.

Mathematics as a Human Endeavour

Conveying the *nature* of Western and Indigenous math, their power, and their limitations. Moving beyond the popular yet erroneous assumption that pure ideal math is free from human values, ideologies* and cultural features. All of these have been suppressed by those who champion the ancient Platonic philosophy of math, ever since the political educational decision made in the early 1800s.

* Ernest (2016a) documents the ideology of purism ("This ideology denigrates applied mathematics and calculation as technical and mechanical;" p. 109), plus fundamental values or types of values, including truth, rationalism, universalism, objectivism, beauty, ethics, and purity. "All are shared cultural values attributed to mathematics knowledge" (p. 211). "Overall my claim is that far from being value-free, mathematics is imbued with a broad range of different types of values drawn from epistemology, ontology, aesthetics and ethics" (p. 212).

Indigenous mathematizing is also rich in values. They all deal with living in a good way for the survival of the community. Each of the most important 13 to 15 values are represented by the 13 to 15 poles of a tipi. Beginning with the left entry pole, here is one sequence of values: obedience, respect, humility, happiness, love, faith, kinship, cleanliness, thankfulness, share, strength, good child rearing, hope, ultimate protection, and all my relations.
(Cree Elder Mary Lee. *Four Directions Teachings*. http://www.fourdirectionsteachings.com/transcripts/cree.html)

Table 1. A Summary of Research and Development Action at Carrot River School

Step #	Teacher Research	Student Learning	Research Activities by Meyer and Aikenhead
1	Collaborate with Saulteaux Elder Albert Scott and Cree knowledge holder Sharon Meyer to help select an **Indigenous mathematizing activity** that will relate to the mathematics curriculum.		Collaborate with and mentor the teacher.
2	Learn: (a) how to do it; and (b) how it is related to the Indigenous community's worldview.		Collaborate with and mentor the teacher. Gather data on contextual features that support or hinder a teacher's progress.
3	Propose how to relate the Indigenous mathematics to analogous content in Western mathematics that appears in the curriculum.	Respond to a pre-lesson open-ended questionnaire.	Collaborate with and mentor the teacher. Gather data on contextual features that support or hinder a teacher's progress.
4	Compose a lesson or series of lessons.		Collaborate with and mentor the teacher. Less so with subsequent activities.
5	Get permission from an Elder or knowledge holder to carry out the lesson(s) so appropriation does not occur.		Mentor the teacher over the subtleties of appropriation when translating from Indigenous mathematizing to Western math.
6	Teach the lesson(s) while gathering evidence on ways it did or did not reach a teacher's expectations.	Engage in the lesson.	Observe lesson(s). Record data related to the teacher and students with respect to: (a) the teacher's aims; and (b) the project's research questions.
7	Post-lesson(s) discussion over the evidence collected by a teacher and by the researchers. Consider revisions based on the evidence.	Respond to a post-lesson open-ended questionnaire.	Collaborate with the teacher regarding: editing/ revising the lesson plan(s). Help teachers with the Indigenous mathematizing and Western math if needed. Emphasize the *process* they have gone through.
8	Articulate what was learned from Steps 1-7 as a prescription for improving the pedagogy during the next Indigenous mathematizing activity to be taught.		Record teacher's ideas and the reasons behind those ideas. Repeat Steps 1-7 with a different Indigenous activity.

Table 2. Number and percentage for each choice on **pre**-questionnaire: Grade 12, November 2018 (see Appendix D for the questionnaire)

Statements	Number and Percentage of Students for Each Choice *								
	Disagree		Disagree Somewhat		Agree Somewhat		Agree		Number of Students Providing a Choice
1. I like school math better than most other subjects.	4	23.5%	1	5.9%	7	41.2%	5	29.4%	17
2. I understand math better when I can see examples of math taken from my everyday home.	5	33.3%	5	33.3%	3	20.0%	2	13.3%	15
3. When I graduate, I would like a job related to math like an information technologist, coder, computer programmer, developer of artificial intelligent systems, or a math teacher.	7	41.2%	6	35.3%	3	17.6%	1	5.9%	17
4. I like to see examples of Indigenous math in the math I'm learning.	4	23.5%	5	29.4%	8	47.1%	0	0.0%	17
5. School math is more interesting to me when we learn some First Nations ideas in math class.	7	41.2%	3	17.6%	7	41.2%	0	0.0%	17
6. ** (blank response = 0.)	0		0		0		0		17
7. I understand an Indigenous people's culture.	Not at all		Just a little bit		Fairly well		Quite well		17
	1	5.9%	10	58.8%	5	29.4%	1	5.9%	
8. Michelle said, "Math helps me understand what goes on in my community." Cody disagreed, "Math has little to do with what goes on in my community." Do you agree more with Michelle or Cody, or do you have another idea?	Michelle		Cody		Another idea		[blank]		17
	3	17.6%	10	58.8%	4	23.5%			

* The student choice, "I don't understand," is not shown in this table. That choice was assigned a value of zero. This process of reporting gives greater accuracy to the numbers that do appear in this table.

** Item 6: "Please list the Indigenous understandings you've learned this year in your math class." Not applicable for the pre-questionnaire data in Table 3.

Table 3. Some students' explanations for their choices on **pre**-questionnaire: Grade 12, November 2018

Statements	Quotes from Students' Explanations for Their Choices (A representative sample. Spelling corrected.)			
	Disagree	**Disagree Somewhat**	**Agree Somewhat**	**Agree**
1. I like school math better than most other subjects. What is your favourite school subject?	ELA History Phys Ed Shop Science Wildlife			Math
2. I understand math better when I can see examples of math taken from my everyday home life.	I don't want it or need it to be related to my culture. I understand math fully without any real-world applications.	I like using formulas and core math. I do understand math better when examples are used, but it doesn't matter what the example is based around. I don't see examples very often so it does not impact my learning.	It is just something I have been doing since I started math classes.	
3. When I graduate, I would like a job related to math like an information technologist, coder, computer programmer, developer of artificial intelligent systems, or a math teacher.	I've had time to think about my career, and it's not around math. I would like to become a teacher, but not a math teacher. I want to be a lab tech/x-ray tech.	I enjoy math, but do not want a job that is surrounded in it. I find math very fascinating, but I look forward to a job in linguistic translation.	I love having math in the mix with my future job. Math is fun to me, but I don't want my job to be only math. I want to be a plumber. Math can be enjoyable with hands-on work.	I want to be an elementary school teacher, which involves math. I help others with math a lot.
4. I like to see examples of Indigenous math in the math I'm learning.	I don't think it's important. It makes it more confusing. I like straight out of the textbook. It makes zero difference to me what the examples are. I just want to learn the material clearly.	I am used to what I have been taught throughout all the years of my schooling. I like logic. It can relate to math and make connections, but it doesn't help my understanding. I don't have an interest in Indigenous culture. It doesn't matter to me. Not sure. I've never had Indigenous math examples done before.	Why not? It's cool to learn how they do things different than what we are generally taught now. It is something new and interesting to learn. If it helps me learn math in a way that can make more sense, then I agree.	
5. School math is more interesting to me when we learn some Indigenous ideas in math class.	Math is math. I like normal math. I'm not interested in learning about other cultures.	Math is interesting regardless of its context but doing hands-on projects are fun.	It would make it more interesting, but I do not enjoy math.	

<table>
<tr><td>[Item 6*]

7. I understand Indigenous people's culture.</td><td>Not at all

To understand their culture means I know their history. But I don't.</td><td>Just a little bit

I only know from history and English classes.

I am a friend with some Indigenous people, so I know their culture a bit.

I've always enjoyed learning about Indigenous people and hearing stories and learning about who they are and what they believe.</td><td>Fairly well

I have learned about it some way in every class each year.

I have friends in that culture and understand what they do and all that.</td><td>Quite well

I've learned lots in other subjects over the years.

I love learning about other cultures, and recently I've been learning a lot about Indigenous culture.</td></tr>
<tr><td>8. Michelle said, "Math helps me understand what goes on in my community."

Cody disagreed, "Math has little to do with what goes on in my community."

Do you agree more with Michelle or Cody, or do you have another idea?</td><td>Michelle

Math – favourite subject:

You can understand more of what goes on around you if you have a better understanding of math (ex. shopping).

Likes math somewhat:

I've learned a lot about financial stuff this year.</td><td colspan="2">Cody

Math – favourite subject:

I never use the math I learn in Grade 12 outside the classroom.

I do not think of math when I look at the things going on in my community.

I haven't applied any math in my community other than in school.

Math is math and does not relate to what goes on in my community.

Likes math somewhat:

I don't see much math with what goes on in the community.

Math has nothing to do with societies or cultures at all. It is numbers, and jobs that involve numbers.

I don't see how it helps me in the real world.

Does not like math much:

The math we learn is completely useless in real-world situations. The only time we see it is in school.

I rarely hear people talking about math in my community

Math – least favourite subject:

I see it in money but not really in other forms.

I don't understand math very well.

In my life right now, I have seen math have little to do in the community except for maybe five or six times.</td><td>Another idea

Likes math somewhat:

What we learned in financial math has helped my understanding. Other topics seem to have little relevance to our community.

Math is used in our everyday lives (ex. currency and measurement). Math doesn't give me a better understanding about the community; it just helps me understand some of the different math processes that are used in the community.

I don't use math to understand what is going on in my community.

From what I have seen, it does help me understand.</td></tr>
</table>

* Not applicable for the pre-questionnaire data in Table 3.

Table 4. Number and percentage for each choice on the **post**-questionnaire: Grade 12, November 2018

Statements	Number and Percentage of Students for Each Choice *								
	Disagree		Disagree Somewhat		Agree Somewhat		Agree		Number of Students Providing a Choice
1. I like school math better than most other subjects.	4	23.5%	4	23.5	4	23.5%	5	29.4%	17
2. I understand math better when I can see examples of math taken from my everyday home.	9	52.9%	3	17.6%	4	23.5%	1	5.9%	17
3. When I graduate, I would like a job related to math like an information technologist, coder, computer programmer, developer of artificial intelligent systems, or a math teacher.	9	52.9%	4	23.5%	3	17.6%	1	5.9%	17
4. I like to see examples of Indigenous math in the math I'm learning.	7	41.2%	5	11.8%	7	41.2%	0	0.0%	17
5. School math is more interesting to me when we learn some First Nations ideas in math class.	6	35.3%	3	17.6%	8	47.1%	0	0.0%	17
6. ** (blank response = 0.)	15	88.2%							17
7. I understand an Indigenous people's culture.	Not at all		Just a little bit		Fairly well		Quite well		17
	1	5.9%	5	29.4%	9	52.9%	2	11.8%	
8. Michelle said, "Math helps me understand what goes on in my community." Cody disagreed, "Math has little to do with what goes on in my community." Do you agree more with Michelle or Cody, or do you have another idea?	Michelle		Cody		Another idea				17
	4	23.5%	10	58.8%	3	17.6%			

* The student choice, "I don't understand," is not shown in this table. That choice was assigned a value of zero. This process of reporting gives greater accuracy to the numbers that do appear in this table.

** Item 6: "Please list the Indigenous understandings you've learned this year in your math class." Fifteen out of 17 cited examples in post-questionnaire, none in pre-questionnaire.

Table 5. Differences between the post- and pre-questionnaires' results: Grade 12, November 2018.

Statements	Post– and Pre-Questionnaires: Students' Choices and Percentage *Differences*				
	Disagree post-pre	Disagree Somewhat post-pre	Agree Somewhat post-pre	Agree post-pre	Number of Students Providing a Choice
1. I like school math better than most other subjects.	4 - 4 = 0	4 - 1= 3 + 17.6%	4 - 7= -3 - 17.6%	5 - 5 = 0	17
2. I understand math better when I can see examples of math taken from my everyday home.	9 - 5 = 4 + 26.7%	3 - 5 = -2 -13.3%	4 - 3 = 1 +6.7%	1 - 2 = -1 -6.7%	15
3. When I graduate, I would like a job related to math like an information technologist, coder, computer programmer, developer of artificial intelligent systems, or a math teacher.	9 - 7 = 2 +11.8%	4 - 6 = -2 -11.8%	3 – 3 = 0	1 – 1 = 0	17
4. I like to see examples of Indigenous math in the math I'm learning.	7 – 4 = +3 +17.6%	2 – 5 = -3 - 17.6%	7 – 8 = -1 - 6.7%	1 – 0 = 1 +6.7%	17
5. School math is more interesting to me when we learn some First Nations ideas in math class.	6 – 7 = -1 - 6.7%	3 - 3 = 0	8 – 7 = 1 +6.7%	0 - 0 = 0	17
[Item 6*] 7. I understand an Indigenous people's culture.	Not at all 1 - 1 = 0	Just a little bit 5 – 10 = -5 -29.4%	Fairly well 9 – 5 = 4 +23.5%	Quite well 2 – 1 = 1 +6.7%	17
8. Michelle said, "Math helps me understand what goes on in my community." Cody disagreed, "Math has little to do with what goes on in my community." Do you agree more with Michelle or Cody, or do you have another idea?	Michelle 4 – 3 = 1 +6.7%	Cody 10 - 10 = 0		Another idea 3 - 4 = - 1 + 6.7%	17

* Item 6: "Please list the Indigenous understandings you've learned this year in your math class." Student responses: pre-questionnaire = 0 students post-questionnaire = 15 out of 17 students.

Table 6. Number and percentage for each choice on the **pre**-questionnaire: Grade 10, November 2018 (see Appendix D for the questionnaire)

Statements	Number and Percentage of Students for Each Choice *								
	Disagree		Disagree Somewhat		Agree Somewhat		Agree		Number of Students Providing a Choice
1. I like school math better than most other subjects.	4	25.0%	2	12.5%	5	31.3%	5	31.3%	16
2. I understand math better when I can see examples of math taken from my everyday home.	4	25.0%	4	25.0%	4	25.0%	4	25.0%	16
3. When I graduate, I would like a job related to math like an information technologist, coder, computer programmer, developer of artificial intelligent systems, or a math teacher.	9	50.0%	4	12.5%	3	37.5%	1	0.0%	16
4. I like to see examples of Indigenous math in the math I'm learning.	1	7.1%	2	14.3%	7	50.0%	4	28.6%	14
5. School math is more interesting to me when we learn some First Nations ideas in math class.	2	13.3%	3	20.0%	7	46.7%	3	20.0%	15
6. ** (blank response = 0.)									
7. I understand an Indigenous people's culture.	Not at all		Just a little bit		Fairly well		Quite well		16
	2	12.5%	7	43.8%	5	31.3%	2	12.5%	
8. Michelle said, "Math helps me understand what goes on in my community." Cody disagreed, "Math has little to do with what goes on in my community." Do you agree more with Michelle or Cody, or do you have another idea?	Michelle		Cody		Another idea***		[blank]		16
	5	31.3%	8	50.0%	3	18.8%			

* The student choice, "I don't understand," is not shown in this table. That choice was assigned a value of zero. This process of reporting gives greater accuracy to the numbers that do appear in this table.

** Item 6: "Please list the Indigenous understandings you've learned this year in your math class.." Not applicable for the pre-questionnaire data.

*** See Table 7 for examples of students' reasons for the choices they made.

Table 7. Some students' explanations for their choices on pre-questionnaire: Grade 10, November 2018

Statements	Quotes from Students' Explanations for Their Choices (A representative sample. Spelling corrected.)			
	Disagree	Disagree Somewhat	Agree Somewhat	Agree
1. I like school math better than most other subjects. What is your favourite school subject?	ELA History Phys Ed Shop Science Wildlife	I like most of my grades in math, but ELA is my favourite.		Math
2. I understand math better when I can see examples of math taken from my everyday home life.	I don't really think about math, only at school or homework. I don't do stuff involving my home culture.	I don't need examples of culture to understand things more. I don't relate my school work to my home.	I don't need examples of culture to understand things more. I don't relate my school work to my home.	It helps me understand how to use it in real life. I learn better. I do work better at home.
3. When I graduate, I would like a job related to math like an information technologist, coder, computer programmer, developer of artificial intelligent systems, or a math teacher.	I don't do math. I like to do more physical work than math.		Math is right or wrong, and there's not a lot of room to have varying answers.	
4. I like to see examples of Indigenous math in the math I'm learning.		I never had it, so I wouldn't know. It doesn't matter what examples as long as I understand.	Because I am Indigenous. Why not? It does not matter to me.	It would be interesting to learn. I've never seen Indigenous math. It's nice to see people adding Indigenous math into the math we learn at school.
5. School math is more interesting to me when we learn some Indigenous ideas in math class.			Because it is more hands-on learning.	It is sometimes interesting to see new perspectives. Math is math.

(6. Not applicable)	Not at all	Just a little bit	Fairly well	Quite well
7. I understand an Indigenous people's culture.	No thanks.		We learned a lot about it in science (everything has a spirit/is living). I understand what was taught in school. I've lived in an Indigenous community.	I'm Indigenous, and my reserve has culture. I lived with very traditional people.
8. Michelle said, "Math helps me understand what goes on in my community." Cody disagreed, "Math has little to do with what goes on in my community." Do you agree more with Michelle or Cody, or do you have another idea?	Michelle *Math – favourite subject:* Taxes. *Likes math somewhat:* Math would definitely help what's going on. I think it helps. The community is filled with jobs that handle money, and everyone handles math in a community. *Math – least favourite subject:* The math we learn tries to relate to what goes on.	Cody *Math – favourite subject:* Most people just go with common sense (e.g., "Oh, a circle" not "Oh, a circle with 360°.") Because we don't use math to talk to people. *Likes math somewhat:* Math isn't used in most of the things I do. It's more about hard work. I don't associate math with my community. *Does not like math much:* It can be both depending on who you are or what you believe in. But I don't think math has much to do with my community.		Another idea *Math – favourite subject:* Little bit of both. Some careers use a lot of math, some wouldn't. *Does not like math much:* It depends on how you look at it; everything is about perspective.

Table 8. Number and percentage for each choice on the **post**-questionnaire: Grade 6, November 2018 (see Appendix D for the questionnaire)

Statements	Number and Percentage of Students for Each Choice *				Number of Students Providing a Choice
	Disagree	Disagree Somewhat	Agree Somewhat	Agree	
1. I like school math better than most other subjects.	4 25.0%	1 6.3%	4 25%	7 43.8%	16
2. I understand math better when I can see examples of math taken from my everyday home.	1 6.3%	1 6.3%	11 68.7%	3 18.8%	16
3. I like to see examples of First Nations math in the math I'm learning.	3 23.1%	2 15.4%	1 7.7%	7 53.8%	13
4. I like to see examples of Indigenous math in the math I'm learning.	5 38.5%	1 7.7%	4 30.8%	3 23.1%	13
5. Please list the Indigenous understandings you've learned this year in your math class. (Scored 0 or 1)	Blank or inauthentic examples 4 students 25%		Authentic examples 12 students 75%		16
6. I understand an Indigenous people's culture.	Not at all 0 0.0%	Just a little bit 6 40.0%	Fairly well 6 40.0%	Quite well 4 26.7%	15
7. Michelle said, "Math helps me understand what goes on in my community." Cody disagreed, "Math has little to do with what goes on in my community." Do you agree more with Michelle or Cody, or do you have another idea?	Michelle 8 50.0%	Cody 4 25.0%	Another idea 4 25.0%	[blank]	16

* The student choice, "I don't understand," is not shown in this table. That choice was assigned a value of zero. This process of reporting gives greater accuracy to the numbers that do appear in this table.

** See Table 9 for examples of students' reasons for the choices they made.

Table 9. Some students' explanations for their choices on **pre**-questionnaire: Grade 6, November 2018

Statements	Quotes from Students' Explanations for Their Choices (A representative sample. Spelling corrected.)			
	Disagree	Disagree Somewhat	Agree Somewhat	Agree
1. I like school math better than most other subjects. What is your favourite school subject?	Phys Ed ELA Art	Phys Ed	Art Social studies and Math Phys Ed	Math Math and Phys Ed Math sometimes. It depends on what kind of math we're doing.
2. I understand math better when I can see examples of math taken from my everyday home life.	I do fine anywhere.	When my parents teach me new ideas. Because we don't have a lot of family home math.	My dad likes math, so he helps me. It's easier to learn when you can make connections. I don't really care. Farming (bails, crops, animals). I want to be able to understand.	Because I see it, it helps. It helps me understand it better when it is a real-life example. If I see it, I do better.
3. I like to see examples of First Nations math in the math I'm learning.	I don't need First Nations math.	We should do math with examples of other countries instead of all First Nations. It makes it more confusing for me.	I have never seen Indigenous math before.	It is cool to know different kinds of math. I would like to learn a First Nations culture in Math. So it's more easy for me. It can really help us. Fun to learn and a break from textbook math. It shows ways to do math in case you don't understand something.

4. School math is more interesting to me when we learn some First Nations ideas in math class.	I like our kind of math. It does not make a difference, just more work. I always find math interesting.	I like all types of math not just First Nations math.	I like all types of math not just First Nations math.	I like First Nations things; it's interesting. Because it is nice to learn about other cultures for once. It's more fun, period. When it's very interesting.
5. Please list the Indigenous understandings you've learned this year in your math class.	They use drums a lot. I learned story-telling math. Story Indigenous math equations. Little Bear story. How to tell Indigenous stories with integers.		In integers, we learned how to do it the Indigenous way. Why is EVERYTHING about that? How to use a story for integers.	
6. I understand First Nations people's culture.	Not at all	Just a little bit We learnt about it enough. I learned some, but I forget it. Because I have six relatives who are First Nations.	Fairly well I understand because we had a First Nations person come in and talk to us. It is easy to learn about. I think I understand it pretty good, but I would like to learn about something else that is First Nations. I know some stuff but not a lot. I know a little bit from my favourite subject, Social Studies.	Quite well I have two First Nations students in my class. That is 90% of what we learn about!!! I am Indigenous. Because we have First Nations people come in and talk.

7. Michelle said, "Math helps me understand what goes on in my community." Cody disagreed, "Math has little to do with what goes on in my community." Do you agree more with Michelle or Cody, or do you have another idea?	<u>Michelle</u> *Math – favourite subject:* You need to use math every day. Math is all around us. If the school is having a pancake breakfast, you would need to know how many are coming. *Likes math somewhat:* Because math is everyday life like time, money, and other things. Math helps me with time, e.g. when I have to go home from the park. Math is in money, farming, and lots more. Without it, life could be confusing. Because of the stupid carbon tax.	<u>Cody</u> *Math – favourite subject:* I don't use math a lot. I only really count. I need to learn about it more. Don't like math that much!	<u>Michelle</u> *Math – favourite subject:* What goes on in your community can help with your math, and you can make connections. In some situations, it could help (taxes, rent, groceries), but sometimes it can't. *Math – least favourite subject.* I agree with both. It depends on what goes on.

Table 10. Number and percentage for each choice on the **pre**-questionnaire: Grade 5, November 2018 (see Appendix D)

Statements	Number and Percentage of Students for Each Choice *				
	Disagree	Disagree Somewhat	Agree Somewhat	Agree	Number of Students Providing a Choice
1. I like school math better than most other subjects.	10 58.8%	2 11.8%	2 11.8%	3 17.6%	17
2. I understand math better when I can see examples of math taken from my everyday home.	2 13.3%	2 13.3%	3 20.0%	8 53.3%	15
3. I like to see examples of First Nations math in the math I'm learning.	3 27.3%	1 9.1%	2 18.2%	5 45.5%	11
4. School math is more interesting to me when we learn some First Nations ideas in math class.	5 38.5%	1 7.7%	2 15.4%	5 38.5%	13
5. Please list the Indigenous understandings you've learned this year in your math class. (Scored 0 or 1)	Blank or inauthentic examples 18 100.0%		Authentic examples 0 0.0%		18
6. I understand First Nations people's culture.	Not at all 4 5.0%	Just a little bit 8 50.0%	Fairly well 2 12.5%	Quite well 2 12.5%	16
7. Michelle said, "Math helps me understand what goes on in my community." Cody disagreed, "Math has little to do with what goes on in my community." Do you agree more with Michelle or Cody, or do you have another idea?	Michelle 11 4.7%	Cody 6 35.3%	Another idea** 0 0.0%	[blank]	17

* The student choice, "I don't understand," is not shown in this table. That choice was assigned a value of zero. This process of reporting gives greater accuracy to the numbers that do appear in this table.

** See Table 11 for examples of students' reasons for the choices they made.

Table 11. Some students' explanations for their choices on pre-questionnaire: Grade 5, November 2018

Statements	Quotes from Students' Explanations for Their Choices (A representative sample. Spelling corrected.)			
	Disagree	**Disagree Somewhat**	**Agree Somewhat**	**Agree**
1. I like school math better than most other subjects. What is your favourite school subject?	Social Studies Art Language Arts Gym Home time Science Gym/Science Phys Ed	Science Gym	Language Arts/ Math Art Phys Ed Social Studies and Math	Math
2. I understand math better when I can see examples of math taken from my everyday home life.		When my parents teach me new ideas.	It makes it easier when I see examples. Seeing helps me.	Because I see it. My teacher makes us understand by explaining the way most of us will get. It's cool to know different kinds of math. It helps me understand it better when it's a real-life example. If I see it, I do better.
3. I like to see examples of First Nations math in the math I'm learning.		I don't know Indigenous math.		I would like to learn First Nations culture in math. It makes it easy to see an example first.
4. School math is more interesting to me when we learn some First Nations ideas in math class.	I like our kind of math (favourite subject).			
5. Please list the Indigenous understandings you've learned this year in your math class.				

<table>
<tr>
<td>6. I understand First Nations people's culture.</td>
<td>Not at all</td>
<td>Just a little bit

I don't understand it very well, but I kind of get it.

Because it's not my culture.</td>
<td>Fairly well</td>
<td>Quite well

I really understand it well, because we have First Nations people come in and talk.</td>
</tr>
<tr>
<td>7. Michelle said, "Math helps me understand what goes on in my community."

Cody disagreed, "Math has little to do with what goes on in my community."

Do you agree more with Michelle or Cody, or do you have another idea?</td>
<td>Michelle

Math – favourite subject:

Because I love math.

You need to use math everyday.

It makes me happy.

Likes math somewhat:

Because I am buying stuff everyday.

Math helps me with time, when I have to go home from the park, for example.

Math is everyday life like time, money, and stuff.</td>
<td colspan="2">Cody

Likes math somewhat:

I don't use math a lot. I only really count.

Does not like math much:

When I go shopping or count money.</td>
<td>Another idea

Math – favourite subject:

Math – least favourite subject:</td>
</tr>
</table>

Table 12. Number and percentage for each choice on the **pre**-questionnaire: Grade 5, December 2018

Statements	Number and Percentage of Students for Each Choice *				
	Disagree	**Disagree Somewhat**	**Agree Somewhat**	**Agree**	**Number of Students Providing a Choice**
1. I like school math better than most other subjects.	8 50.0%	3 8.8%	3 18.8%	2 12.4%	16
2. I understand math better when I can see examples of math taken from my everyday home.	2 12.4%	2 12.4%	2 12.4%	10 62.5%	16
3. I like to see examples of First Nations math in the math I'm learning.	2 12.4%	0 0.0%	3 18.8%	11 68.8%	16
4. School math is more interesting to me when we learn some First Nations ideas in math class.	2 13.3%	0 0.0%	3 20%	10 66.7%	15
5. Please list the Indigenous understandings you've learned this year in your math class. (Scored 0 or 1)	Blank or inauthentic examples 1 5.9%		Authentic examples 16 94.1%		17
6. I understand First Nations people's culture.	Not at all 1 5.9%	Just a little bit 9 52.9%	Fairly well 3 17.6%	Quite well 4 23.5%	17
7. Michelle said, "Math helps me understand what goes on in my community." Cody disagreed, "Math has little to do with what goes on in my community." Do you agree more with Michelle or Cody, or do you have another idea?	Michelle 13 76.5%	Cody 4 23.5%	Another idea** 0 0.0%	[blank]	17

* The student choice, "I don't understand," is not shown in this table. That choice was assigned a value of zero. This process of reporting gives greater accuracy to the numbers that do appear in this table.

** See Table 13 for examples of students' reasons for the choices they made.

Table 13. Some students' explanations for their choices on **post**-questionnaire: Grade 5, December 2018

Statements	Quotes from Students' Explanations for Their Choices (A representative sample. Spelling corrected.)			
	Disagree	**Disagree Somewhat**	**Agree Somewhat**	**Agree**
1. I like school math better than most other subjects. What is your favourite school subject?	Social Studies Art Language Arts Gym Home time Science Gym/Science Phys Ed	Science Gym	Language Arts/Math Art Phys Ed Social Studies and Math	Math
2. I understand math better when I can see examples of math taken from my everyday home life.	I never see math at home. I don't see math at home.	I feel like First Nations math is simpler than my math in my culture.	Because the stuff that I do at home is more fun. It makes it easier to see examples first.	My parents were taught a different way and it helps. Because my mom helps me, and it's easier. They taught me math that way. I feel like I can understand it better.
3. I like to see examples of First Nations math in the math I'm learning.	Because it was loud.		It helps me understand. Sometimes I don't get the Indigenous math.	Because it's fun to bring their culture with math. I never knew you could mix the drum beat in multiplying. I like it. Because it is easy. It is more fun to learn the Indigenous ways. It is really interesting. I want to learn about others. I like learning new things.
4. School math is more interesting to me when we learn some First Nations ideas in math class.	Because it is boring.		I like my way of math and their way of math. I want to learn about different types of math.	It's different. It's fun to count beats. It's easier.

5. Please list the Indigenous understandings you've learned this year in your math class.	Multiplication with the drum. Drumming multiplication. Drum math. Drumming is the heartbeat of Mother Earth. Patterns and beats. Different types of drumming. I understand that drumming is part of their culture. Finding rhythms and patterns. Counting drum beats and multiplying them. They use the drum when they do math. Most drums don't have drawings.			
6. I understand First Nations people's culture.	<u>Not at all</u>	<u>Just a little bit</u> We haven't learned a lot about it. I understand the drum is important to them.	<u>Fairly Well</u>	<u>Quite Well</u> Yes, because we had a First Nations man talk instead of just a teacher. I really like learning about First Nations math, and I get it quite well.
7. Michelle said, "Math helps me understand what goes on in my community." Cody disagreed, "Math has little to do with what goes on in my community." Do you agree more with Michelle or Cody, or do you have another idea?	<u>Michelle</u> *Math – favourite subject:* You need math to help you do everything. *Likes math somewhat:* I use math lots on trips. I hardly ever us math in the community. I have to add and divide in the store.	<u>Cody</u> *Math – least favourite subject:* Math does not make sense. You use it when you shop. You do math every day.		<u>Another idea</u> *Math – favourite subject:* You have to use it in your daily life. *Math – least favourite subject:* I agree with both. It depends on what goes on.

Table 14. Differences between the post- and pre-questionnaires' results: Grade 5, November 2018

Statements	Post– and Pre-Questionnaires: Students' Choices and % *Differences*				
	Disagree post-pre %	Disagree Somewhat post-pre %	Agree Somewhat post-pre %	Agree post-pre %	Number of Students Providing a Choice post - pre
1. I like school math better than most other subjects.	8 - 10 = -2 - 11.8%	3 - 2 = 1 2.9%	3 - 2 = 1 2.9%	2 - 3 = - 1 - 2.9%	16 / 17
2. I understand math better when I can see examples of math taken from my everyday home.	2 - 2 = 0 0 %	2 - 2 = 0 0 %	2 - 3 = - 1 - 6.7%	10 - 8 = 2 13.3%	16 / 15
3. I like to see examples of Indigenous math in the math I'm learning.	2 – 3 = -1 - 9.1%	0 – 1 = -1 - 9.1%	3 – 2 = 1 9.1%	11 - 5 = 6 54.5%	16 / 11
4. School math is more interesting to me when we learn some First Nations ideas in math class.	2 – 5 = -3 - 23.1%	0 – 1 = -1 - 7.7%	3 – 2 = 1 7.7%	10 - 5 = 5 38.5%	15 / 13
5. Please list the Indigenous understandings you've learned this year in your math class. (Scored 1 or 0)	**Pre**-questionnaire authentic examples 0		**Post**-questionnaire authentic examples 17		17 / 17
6. I understand an Indigenous people's culture.	Not at all 1 – 4 = -3 -18.8%	Just a little bit 9 – 8 = 1 6.3%	Fairly well 3 – 2 = 1 6.3%	Quite well 4 – 2 = 2 12.5%	17 / 16
7. Michelle said, "Math helps me understand what goes on in my community." Cody disagreed, "Math has little to do with what goes on in my community." Do you agree more with Michelle or Cody, or do you have another idea?	Michelle 13 – 11 = 2 11.8%	Cody 4 – 6 = -2 -11.8%		Another idea 0 – 0 = 0	17 / 17

Appendix A

Culture-Based School Mathematics for Reconciliation and Professional Development: A Summary of the Project for the Public

Sharon Meyer, Glen Aikenhead, Kelley Cardinal, Daniel Sylvestre, Ted View

In Canada's era of reconciliation, cross-cultural respect through mutual understanding was emphasized by the Truth and Reconciliation Commission in its description of reconciliation. It matters *how* we do things among our three founding nations – Indigenous, English, and French.

The Saskatchewan Chamber of Commerce (SCC) recognized this as important in their #TransformSK report issued in April 2017. Its call to action stated, "Ensure cross-cultural learning opportunities are embedded or offered in all primary, secondary, and post-secondary institutions." The SCC saw this action as important for "building a resilient, thriving and diversified economy."

A Stirling McDowell Foundation research project, *Culture-Based School Mathematics for Reconciliation and Professional Development*, responds to this call to action by exploring *how* math can be taught in a cross-cultural way, Western math and Indigenous math.

The research project was inspired by the successes of cross-cultural math projects in Alaska, Hawai'i, New Zealand, and the Maritimes. Indigenous students' interest and achievement increased dramatically while the non-Indigenous students responded favourably. It is a win-win situation.

How can we make this happen in Saskatchewan? The Stirling McDowell Foundation's research project looks at how school divisions can assist teachers in enhancing their teaching of Western math by bringing some examples of local Indigenous math into their classrooms. The two cultural math systems have similarities and differences that create interest among most students.

By learning examples of local Indigenous math, teachers and students develop an understanding of their Indigenous neighbours. Therein lies a tangible act of reconciliation.

In this project, Indigenous and non-Indigenous researchers will work collaboratively with four non-Indigenous teachers in a small rural town. The teachers will learn to go back and forth between two ways of interacting with the world mathematically (Western and Indigenous).

They will instruct their students through activities followed by discussions with the researchers about what they have learned concerning Western and Indigenous math. These outcomes will be closely monitored by two of the researchers.

At the same time, the teachers will develop their own capacity for cross-cultural teaching that will continue to evolve after the research project is completed. Moreover, their cross-cultural teaching can expand into other subjects such as science that has had a cross-cultural curriculum and textbooks for several years.

Appendix B

Agenda for the August 31, 2018, Introduction to the Project
Culture-Based School Mathematics for Reconciliation and Professional Development

Morning session for the four participating teachers (and Principal Sari Carson).
Afternoon session for all teachers and Sari Carson.

Morning Session		Afternoon Session	
9:00 – 10:30	Opening	1:00 – 2:15	Introduction to the project
10:30 – 10:45	Break	2:15 – 2:30	Break
10:45 – 12:00	Opening continued	2:30 – 3:15	Introduction continued
12:00 – 1:00	Lunch		

Morning Session

Elder Albert Scott will begin the meeting in a good way according to Saulteaux (Nakawē) tradition.

A. Introductions by all project participants: Sharon Meyer (Team Leader), Glen Aikenhead (Team Contact Person), Danny Sylvestre (Team Member), Serena, Danielle, Kevin, Krysta, plus guests if any.

B. Culture-Based School Math (includes an activity)

C. Reconciliation (as it occurs naturally in the project)

D. Professional Development (includes an activity)

E. Our Stirling McDowell Foundation Contract (information handouts, e.g., an ethics contract)

F. Culture Immersion (description)

G. Planning for the Afternoon Session, Teacher Participants

Afternoon Session

H. Introduction of Sharon Meyer, Glen Aikenhead, and Danny Sylvestre

I. The Medicine Wheel Model for Teaching – A short introduction, Elder Albert Scott

J. A Panel Presentation by the Teacher Participants

K. Question and Answer Session

Elder Scott will end the meeting in a good way.

Appendix C

Culture Immersion Agendas

Elder Albert Scott, October 2 Sharon Meyer, October 3

Elder Albert Scott	Indigenous and Western Worldviews, Pipe Ceremony and Feast
9:00	Start the day with acknowledgement (prayer). Albert Scott
9:15 – 9:30	Introduction, updates, and current events. Sharon and Glen.
9:30 – 10:15	Worldview PowerPoint presentation. Albert.
10:15 – 10:30	Refreshment break.
10:30 – 11:00	Meaning of feasts, protocols. Albert and Wayne.
11:00 – 11:15	Preparing for feast and setup. Albert and Wayne.
11:15 – 11:45	Distribution and prayer. Albert and Wayne
11:45 – 12:15	Eating time
12:15 – 12:45	Honouring of Mother Earth. Prayer and distribution of fruit.
12:45 – 1:00	Bringing the pipe down. End of feast. Albert and Wayne.
1:00 – 1:15	Putting pipe away and clean-up.
1:15 – 1:30	Refreshment break.
1:30 – 2:00	Questions and answers about the feast. Albert
2:00 – 3:00	Wrap-up. Glen and Sharon.
3:00 – 3:15	Closing the day in a good way. Acknowledgement. Albert.

Sharon Meyer	Relationships and reciprocity with the land connections between Indigenous activities and math
9:00 – 9:10	Opening smudge
9:10 – 10:00	Treaty understanding (Why am I a treaty person?)
10:00 – 10:30	Traditional First Nations relation to the land
	10:30 – 10:45 BREAK
10:45 – 11:30	Using even numbers to create a dream catcher (everyone will use counting skills to create a dream catcher). Brainstorm as a team, how does a dream catcher become a math tool? How could we use it in our own classroom?
11:30 – 12:00	Looming: (a) We will begin to create our own loom; (b) Create our own pattern using grid paper; and (c) Begin to loom our own designs.
	12:00 – 12:45 LUNCH
12:45 – 1:30	Continue to complete the loom designs. Then brainstorm: where does looming fit in our classroom delivery of math?
1:30 – 2:15	First Nation games: sticks and stones + math Using current games and improvise sticks, bones, seeds, and stones for game pieces; brainstorm how do games fit into our math?
	2:15 – 2:30 BREAK
2:30 – 3:00	Current events (using example of media story of how underfunded First Nations education is), how do we use statistics and current events in math?
3:00 – 3:15	Closing circle: reflections, questions, and closing in a good way.

The goal is to lead the teachers in hands-on Indigenous activities and then get them to generate some relationships between the activities to the mathematics they teach in their classrooms. Building the association between the two!

Appendix D

Secondary and Elementary Student Questionnaires

Your Ideas About Your Math Class: Grades 10 and12

Your Ideas About Your Math Class: Grades 5 and 6

Your Ideas About Your Math Class **Grades 10 and 12**

We want to know your honest views about your math class ***this year***.

We want you to be anonymous, so we don't know who wrote which answers.

You might do this questionnaire again later, so please make up a name for yourself.

You'll use that same made-up name again if you do this questionnaire a second time.

But we'll not know who you really are.

My made-up name is: ______________________________ (Please remember it.)

Do you identify as a non-Indigenous student or an Indigenous student? ________

1. Put a check mark (√) right on the box closest to what you think.

I like school math better than most other subjects.	Disagree	Disagree somewhat	Agree somewhat	Agree	I don't understand
What is your favourite school subject?					

2. Put a check mark (√) right on the box closest to what you think.

I understand math better when I can see examples of math from my home culture.	Disagree	Disagree somewhat	Agree somewhat	Agree	I don't understand
What is your reason?					

3. Put a check mark (√) right on the box closest to what you think.

When I graduate, I would like a job related to math like an information technologist, coder, computer programmer, developer of artificial intelligent systems, or a math teacher.	Disagree	Disagree somewhat	Agree somewhat	Agree	I don't understand
What is your reason?					

4. Put a check mark (√) right on the box closest to what you think.

I like to see examples of Indigenous math in the math I'm learning.	Disagree	Disagree somewhat	Agree somewhat	Agree	I don't understand
What is your reason?					

Turn over for page 2.

5. Put a check mark (√) right on the box closest to what you think.

School math is more interesting to me when we learn some Indigenous ideas in math class.	Disagree	Disagree somewhat	Agree somewhat	Agree	I don't understand
What is your reason?					

6.

Please list the Indigenous understandings you've learned this year in your math class.

7. Finish this sentence by putting a check mark (√) on the box closest to what you think.

I understand Indigenous people's culture.	Not at all	Just a little bit	Fairly well	Quite well	I don't understand
Please explain your choice.					

8. Finish this sentence by putting a check mark (√) on the box closest to what you think.

Michelle said, "Math helps me understand what goes on in my community." Cody disagreed, "Math has little to do with what goes on in my community." Do you agree more with Michelle or Cody, or do you have another idea?	Michelle	Cody	Another idea
Please explain your choice.			

Your Ideas About Your Math Class **Grades 5 and 6**

We want to know your honest views about your math class ***this year***.

We don't want to know your real name, because that will be a secret.

You might do this questionnaire again later, so please make up a name for yourself.

You'll use that same made-up name again if you do this questionnaire a second time.

But we'll not know who you really are.

My made-up name is: ______________________________ (Please remember it.)

Do you identify as a non-Indigenous student or an Indigenous student? ________

1. Put a check mark (√) right on the box closest to what you think.

I like school math better than most other subjects.	Disagree	Disagree somewhat	Agree somewhat	Agree	I don't understand
What is your favourite school subject?					

2. Put a check mark (√) right on the box closest to what you think.

I understand math better when I can see examples of math from my home culture.	Disagree	Disagree somewhat	Agree somewhat	Agree	I don't understand
What is your reason?					

3. Put a check mark (√) right on the box closest to what you think.

I like to see examples of First Nations math in the math I'm learning.	Disagree	Disagree somewhat	Agree somewhat	Agree	I don't understand
What is your reason?					

4. Put a check mark (√) right on the box closest to what you think.

School math is more interesting to me when we learn some First Nations ideas in math class.	Disagree	Disagree somewhat	Agree somewhat	Agree	I don't understand
What is your reason?					

Turn over for page 2.

5.

Please list the Indigenous understandings you've learned this year in your math class.

6. Finish this sentence by putting a check mark (√) on the box closest to what you think.

I understand Indigenous people's culture.	Not at all	Just a little bit	Fairly well	Quite well	I don't understand
Please explain your choice.					

7. Put a check mark (√) on the box closest to what you think.

Michelle said, "Math helps me understand what goes on in my community." Cody disagreed, "Math has little to do with what goes on in my community." Do you agree more with Michelle or Cody, or do you have another idea?	Michelle	Cody	Another idea
Please explain your choice.			

Appendix E

Revised Culture-Based Lesson Plans

Each lesson plan is located separately in a Word file named according to the boldface titles below.

E-B.2 has a second file.

Each lesson plan may take about two to four periods to complete.

E-A Krysta:	**Freestyle Looming and Probability** Grade 12 Foundations of Math (http://mcdowellfoundation.ca/isl/uploads/2018/07/1.-E-A.-Freestyle-Looming-and-Probability.pdf)	1.4 MB
E-B.1 Kevin:	**Picario** Grade 10 Mathematics Workplace and Apprenticeship (http://mcdowellfoundation.ca/isl/uploads/2018/07/2.-E-B.1-Picario.pdf)	263 KB
E-B.2 Kevin:	**Water, First Nations Cultures, Statistics** Grade 9 PowerPoint: Teacher presentation for water poster assignment (http://mcdowellfoundation.ca/isl/uploads/2018/07/3.-E-B.2-Water-First-Nations-Cultures-Statistics.pdf)	411 KB 6.1 MB
E-C.1 Danielle	**The Language of Negative and Positive Numbers** Grade 6 (http://mcdowellfoundation.ca/isl/uploads/2018/07/4.-E-C.1-The-Language-of-Negative-and-Positive-Numbers.pdf)	26 KB
E-C.2 Danielle	**Stick Games and Theoretical/Experimental Probability** Grade 6 (http://mcdowellfoundation.ca/isl/uploads/2018/07/5.-E-C.2-Stick-Games-and-Theoretical-Experimental-Probability.pdf)	234 KB
E-D.1 Serena:	**Multiplication and First Nations Drumming** Grade 5 (http://mcdowellfoundation.ca/isl/uploads/2018/07/6.-E-D.1-Multiplication-and-First-Nations-Drumming.pdf)	32 KB
E-D.2 Serena:	**Quadrilateral Patterning Through Indigenous Beading** Grade 5 (http://mcdowellfoundation.ca/isl/uploads/2018/07/7.-E-D.2-Quadrilateral-Patterning-Through-Indigenous-Beading.pdf)	2.9 MB

Appendix F

Videos of Two Lesson Excerpts and a Collegial Discussion [22] [23]

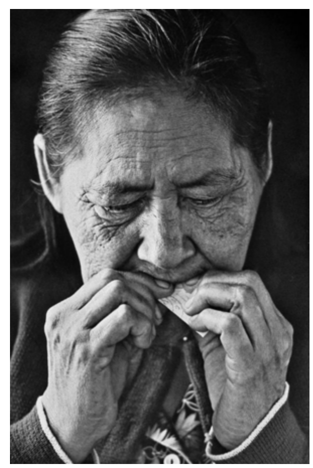
Video: Birch Bark Biting (6:38 minutes)
(https://www.youtube.com/watch?v=EUGEdUWs1cU&feature=youtu.be)

The storyline goes from students holding real birch bark and *concrete* birch bark artifacts to students learning birch bark biting and learning the ideal *abstract* concepts of right angles, complementary angles, and lines of symmetry.

Cree birch bark basket with trimmings of red willow, dyed dried grasses.

Sharon Meyer talks to Grade 5 students about birch bark and its many medicinal, culinary, and structural features. Stories about Indigenous living are accompanied by objects such as birch bark baskets.

Sharon then introduces birch bark biting by following an Indigenous protocol. She acknowledges Angelique Merasty from whom she learned the art of birch bark biting. Sharon hopes her students will do the same.



Angelique Merasty

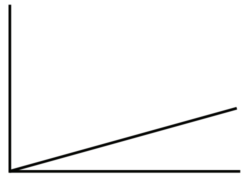
A dental hygiene moment is inserted in a relevant way; a further example of holistic thinking in a culture-based mathematics lesson. Angelique's teeth deteriorated because of a lack of health care in her community. She had to get false teeth that ended her ability to bite birch bark. "Always tell students to take care of their teeth," she said.

Due to the cost of birch bark, students simulate the process with plain paper and carbon paper placed together. As Sharon demonstrates how to fold the paper and carbon paper combination before biting it, she clearly identifies the mathematical lines and angles on her paper and then points to the appropriate diagrams on the board, shown below. These

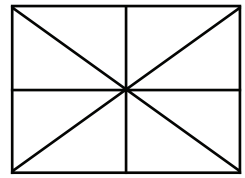
[22] Regulations regarding video taping students were followed. To do so, no full-face shots that would identify a student and no individual's answer to questions can be articulated. These restrictions reduced the authenticity and spontaneity of a normal classroom. But still, a great deal of information about culture-based school mathematics is conveyed.
[23] All other photos are by Glen Aikenhead except for Angelique Merasty's.

diagrams are the *abstract* representations of the *concrete* object that Sharon holds in her hand during this part of the lesson.

Right Angle



Complementary Angles



Lines of Symmetry

When Sharon tells the students that she is going to make a flower by biting on her multiple-folded combination of plain paper and carbon paper, she says, "You have to think in your head what the bite will look like once the paper is unfolded."

A student's simulated birch bark biting. How many lines of symmetry are there?

This is a challenge. It usually takes many trial and errors for the brain to work out 3-D space like that. But it is a good goal for students to work toward. When students imagine what the pattern will look like, but they discover they made a mistake predicting, they can still learn much from analyzing their mistake. What will they try next time? This is how students develop a facility in spatial reasoning. Without a challenge, there is little development in 3-D thinking.

This challenge is another instance of a student moving between their concrete world (i.e., the bite) and an abstraction (i.e., imagining what it will look like). This spatial reasoning is found in both Indigenous mathematizing and geometric mathematics.

Due to the regulations regarding video taping students, the lesson ended with students answering their teacher's oral questions related to right angles, complementary angles, and lines of symmetry. Students used their own birch bark biting artifacts to formulate a response. Deep engagement in this class discussion occurred because students created the artifacts being analyzed. The artifacts were not photos or diagrams in a textbook.

Video: [Dream Catcher](https://www.youtube.com/watch?v=28MGizBhEBc&feature=youtu.be) (6:10 minutes)
(https://www.youtube.com/watch?v=28MGizBhEBc&feature=youtu.be)

The storyline goes from willow trees to geometric shapes. Sharon Meyer introduces a Grade 6 class to making a dream catcher. Her lesson begins by students recognizing the willow branch Sharon was holding. She goes on to tell them about the medicinal properties of such plants. They are gifts from Mother Earth according to Nehiyaw (Plains Cree) teachings.

When taking a willow branch from the land, Nehiyaw protocol requires you to offer a small gift of sacred tobacco in return. The Nehiyaw ideology of reciprocity is learned or reinforced. Other Nehiyaw ideas are interspersed throughout Sharon's directions on how to pick and prepare a willow branch for making a dream catcher. She explains where dream catchers originated and how they can help the owner sleep better.

Introducing a dream catcher

For the sake of time, the video camera is turned off while Sharon distributed the materials and guided the students while they went through the many steps to make their own dream catcher.

The video resumes with the students examining their dream catchers. The transition from Indigenous mathematizing (i.e., the process of designing and making a dream catcher) to Western mathematics begins now. Each dream catcher's web has its unique combination of patterns formed by the knots and string. Sharon photocopied each dream catcher.

Sharon points to a photocopy of the boy's dream catcher with one hand. She is handing out a sheet that shows standard geometric shapes and their names.

The knots and string visually define the web's natural patterns that emerged from how the dream catcher was constructed by a student. Because a tobacco protocol was followed when the branches were taken, these patterns are associated with Mother Earth. When forming those patterns, students may have forged a personal relationship to them. That is one way *to see* the patterns in the web.

Then there is a mathematical way *of seeing* the patterns. How closely does each pattern resemble a geometric shape of interest to mathematicians?

A student is experiencing a **two-eyed seeing** event,[24] observing *as if*:

1. Out of one eye, they see their own personal *concrete* **patterns** formed by string and knots they made with their own hands, with which they formed some sort of relationship; and

2. Out of the other eye, they see *abstract* ideal mathematical **patterns** displayed on Sharon's handout. This two-eyed seeing continues in the video represented by the photo just above. The boy is superimposing a cut-out pattern (taken from a photocopy of his dream catcher) onto standard geometry patterns (e.g., rectangle, parallelogram, pentagram, and rhombus). Which mathematical pattern best fits the cut-out pattern? The ideal world of mathematics meets the real world of the student, so to speak.

In other words, the student's problem to solve is to treat his dream catcher's patterns *as if* they look like[25] standard geometric shapes that have specific names. He completes his mathematics task by remembering the shapes and learning new mathematical names.

---

[24] In this project report, see the subsection Two-Eyed Seeing.

[25] For students old enough to understand metaphors, a generalized translation of "they *look like*" is, "A geometric shape (e.g., a rectangle or rhombus) is a metaphor for what is observed in the real world." This idea is another example for the subsection The Nature of Mathematics.

This memorable activity that produces *concrete patterns* in a dream catcher's web, seen through the eye which perceives feelings and relationships, will help this student remember the *abstract ideal shapes* as seen through the eye of Western mathematics. In short, he may have used both eyes of the "two-eyed seeing" metaphor in order to complete his mathematics task.

Video: Sharon and Serena (18:34 minutes)
(https://www.youtube.com/watch?v=p1rlphwI6RM&feature=youtu.be)

A conversation between Sharon Meyer and Serena Palmer highlights key events and notable insights gained from Serena's participation in the research project *Culture-Based School Mathematics for Reconciliation and Professional Development*. Personal details animate: the importance of a culture immersion, how to plan an Indigenous culture-based lesson, student engagement, and collaboration within the school and with others outside the school.

Motivated from the positive results of her students when engaged with real-life Indigenous mathematizing, Serena will innovate an everyday approach in all her mathematics classes next year, whenever possible. She will teach them from a perspective of students' real-life experiences and assess students on the basis of show-what-you-know performances. She anticipates including one Indigenous culture-based lesson in each mathematics unit next year.

It takes a year-long professional development program, comprised of many "baby steps" along the way, for a teacher to feel confident enough to continue on with a few colleagues in the school. A large degree of confidence was acquired during the preparation and teaching of her first lesson, and a noticeable increase in confidence occurred as a result of her second lesson. Now she feels confidently independent to chart her own course for a third lesson about to occur.

One of those "baby steps" was her realization that the Indigenous knowledge taught in a lesson should not stand alone as an introduction. Instead, it should be sprinkled here and there over the full lesson if possible. A lesson may take a few days. This sprinkling increases the number of times that Indigenous perspectives connect with Western mathematics. (See Figure 1, A Braiding Model of Instructing Culture-Based Mathematics located in the section Independent Final Interviews with the Teachers.)

Appendix G

URLs of Photos and Diagrams from the Internet

Subsection Avoiding Subtle Appropriation

Ancient Indigenous looming with porcupine quills (p. 51)

https://www.penn.museum/sites/journal/630

Bird tessellation (p. 52)

https://www.google.com/search?q=photos+of+bird+tessellation&tbm=isch&source=univ&client=firefox-b-d&sa=X&ved=2ahUKEwjo6-6F6JzjAhWRaM0KHY2tAkMQ7Al6BAgFEA0&biw=1141&bih=626#imgrc=Nr-SxIwN-z_SSM:

Blackfoot tipi (p. 54)

https://www.brooklynmuseum.org/exhibitions/tipi

Cone (p. 54)

https://www.google.com/search?q=diagrams+of+math+cones&tbm=isch&source=univ&client=firefox-b-d&sa=X&ved=2ahUKEwiv-tuy75zjAhUFQ80KHT1hD9YQ7Al6BAgCEA8&biw=1141&bih=626#imgrc=5S0Gu_e-MyomAM:

Métis flag (p. 56)

http://www.mmf.mb.ca/history_of_the_metis_flag.php

Appendix F

Angelique Merasty (p. 112)

https://www.google.com/search?q=photos+of+birch+bark+biting&client=firefox-b-d&tbm=isch&source=iu&ictx=1&fir=uZSRRMais3NcAM%253A%252Ci9IHOxPEoeM_zM%252C_&vet=1&usg=AI4_-kRr1_