Indigenizing Mathematics: Sharing Two Projects from Saskatchewan

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Introduction

Alana Underwood's (2019) informative article, "Mathematics Catcher: Indigenizing Mathematics Through Culturally-Based Storytelling," led readers through her fascinating journey experimenting with Grade 4/5 learners' understanding Indigenous peoples' cultures in a genuine way.

She clearly documented how she became less "afraid of making mistakes or offending" (p. 8). Moreover, Alana discovered how to learn from, and with, her students, by contemplating and critiquing their reaction to her lessons. For instance, "When I gave my students this task, I was feeding into the tokenism that I was trying to avoid" (p. 9, emphasis added).

Indigenous Elders usually advise teachers to go ahead: (a) Indigenize a mathematics lesson; (b) see what happens; and (c) learn from any mistakes (as Alana did), because that is the way Elders claim to have learned most things themselves.

This present article adds to Alana's engagement with Indigenous worldviews in lessons that drew on the "Little Number" stories and their animated videos (Jungic, 2020). I report on two different but related developments in Saskatchewan:

1. A research project, "Culture-Based School Mathematics for Reconciliation and Professional Development" (Duchscherer[1] et al., 2019; Meyer & Aikenhead, 2021);
2. The construction of a professional development website "SaskMATH" (Provincial Education Sector, 2020), which is a compendium of evidence-base best practices for teaching mathematics, Grades 1-12. It emphasizes number sense and Indigenous ways of knowing.

But first, let me briefly address Alana's worry over making a mistake with Indigenous knowledge and offending an Indigenous person.

How to Always Be Truthful in What You Tell Learners

You want to be truthful when repeating wisdom and stories you heard from Elders, or when you talk about Indigenous perspectives you have read in an authoritative source. Here is what I learned from Indigenous academics from different regions of Canada. We can always speak the truth if we simply preface what we say with the honest expression, "As I understand it, …"; or phrases similar to it, such as, "This is what I recall from what Elder Scott told me …". Indigenous people either say "As I understand it" to each other, or it is assumed, because they know that different Indigenous communities have their own place-based understandings.

Besides, rather than being offended, most Elders appreciate genuine heart-felt attempts to bring informed Indigenous perspectives into mathematics classrooms, as Alana did.

As mentioned above, Elders understand that mistakes are a part of learning: students learning mathematics and teachers learning Indigenous perspectives. The two projects I report on share incidents that can help teachers avoid some common mistakes made by fellow teachers (e.g., during the first project) and by internet resources produced by mathematicians (e.g., during the second project).

The First Project: Indigenous Culture-Based School Mathematics

Educator and Nehiyaw (Plains Cree) Knowledge Holder, Sharon Meyer, and I[2] mentored and collaborated with four mathematics teachers, Grades 5 to 12, in the small rural town of Carrot River,

[1] This is the project's full report. The teachers are listed first among its 10 co-authors because a large amount of the content was generated by them, mostly through interviews and creating lesson plans.

[2] I am a privileged White male and strong ally of Indigenous peoples' social justice. I have 25 years experience conducting collaborative research and developing teaching materials for Indigenous culture-based science, and more recently for Indigenous culture-based mathematics.

Saskatchewan, during the 2018-2019 school year. Sharon is the school division's First Nations and Métis consultant. Nakawē (Saulteaux) Albert Scott served as the project's Elder.

Motivation for the Project

Decades of international research concludes that when Indigenous mathematizing is taught several times a year connected to specific curriculum content, Indigenous learners increase their mathematics achievement dramatically while their non-Indigenous classmates' achievement increases noticeably on average (Aikenhead, 2017, p. 75). It is a win – win outcome. Canada's era of reconciliation was another key motivation.

Research Question

What supports do teachers need to enhance their teaching of mathematics by bringing some examples of local Indigenous mathematizing into their classrooms?

Bishop (1988, pp. 147-151) described an anthropological definition of a mathematical system in any culture – Western or Indigenous: *six foundational activities (cultural practices) in which counting, measuring, locating, designing, playing, or explaining quantitatively occur* (all verbs). In the Carrot River project, for example, the teachers' mathematizing lessons included looming, traditional game playing, beading, hand drumming, and regalia worn for pow wow dancing. In each of these Indigenous culture-based school mathematics events, explicit connections were made between the Indigenous mathematizing and the Western mathematics curriculum content.

Method

In order to determine what these supports for teachers really are, the teachers prepared and taught lessons that included Indigenous mathematizing, contextualized by features of the local Nehiyaw worldview. Before the teachers began, however, Elder Scott and Sharon held a two-day culture immersion (Duchscherer et al., 219, pp. 18-24), an essential experience before teaching Indigenous understandings.

As a follow-up, Sharon later mentored each teacher during a halfday release time, focussing on various mathematizing activities (cultural practices). The teachers were entirely on their own to identify an analogous idea in, or a connection to, some specific curriculum content.

Spontaneously, they formed a support network to help each other throughout the year in this creative analytical process of lesson development.

Each teacher designed a draft lesson plan that included: (1) an Indigenous mathematizing activity (e.g., local authentic stories about berry picking and hunting, traditional games, etc.), and (2) a connection to curriculum content. The two often intermingled intermittently as shown in the "Braiding Model of Instructing Culture-Based Mathematics (Duchscherer et al., 2019, p. 66).

A lesson plan usually took two to four class periods to teach, including the curriculum content. These lessons are effectively memorable to learners if at least two are taught each semester.

A teacher's draft lesson plan received feedback from Sharon and me before the lesson was taught. This feedback became critical to what teachers needed to learn in their journey into Indigenous culture-based school mathematics. I observed the lessons, preceded by a discussion about how it was developed and what was intended. A post-lesson discussion was also held to analyze what occurred (Duchscherer et al., 2019, pp. 26-37). The lessons were collaboratively revised accordingly.

Three videos were produced showing excerpts of Sharon teaching two model lessons, and a conversation between Sharon and Serena about developing lesson plans and about her learners' reactions to them. The following two lessons and this interview are summarized in Duchscherer and colleagues (2019, pp. 112-114):

1. "Birch Bark Biting" lesson (6:38 min.)
   https://www.youtube.com/watch?v=EUGEdUWs1cU&feature=youtu.be
2. "Dream Catcher" lesson (6:10 mon.)
   https://www.youtube.com/watch?v=28MGizBhEBc&feature=youtu.be
3. "Sharon and Serena" conversation (18:34 min.)
   https://www.youtube.com/watch?v=p1rlphwI6RM&feature=youtu.be

And finally, at the project's completion, two Indigenous consultants from two other school divisions held a final interview with each teacher privately, in order to acquire an independent reaction about what support the teachers valued during the project, and what

conclusions they reached about teaching Indigenous culture-base mathematics.

Results: Composed by the Researchers

A. Teachers needed initial support for (Duchscherer et al., 2019, p. 25):

1. Finding authentic Indigenous sources of information;
2. Learning some features of local Indigenous cultures; and
3. Locating examples of Saskatchewan Indigenous mathematizing (e.g., on the internet).

B. Teachers needed continuous support for unlearning certain ideas and mindsets that initially interfered, or would have interfered with their success (pp. 42-60):

Unlearning or previously unlearned:

1. certain Euro-Canadian ways of understanding Western mathematics; e.g., unlearning Plato's anti-humanistic philosophy of mathematics, [4]
2. certain Euro-Canadian ways of perceiving the world,
3. beliefs that interfere with cross-cultural understanding of Western mathematics; for example, the belief that all learners are able to excel at doing Western mathematics. This belief is predicated on Plato's corollary that Western mathematics is non-cultural (see footnote 3). Therefore, all learners – non-Indigenous and Indigenous – are stereotyped as having a worldview that harmonizes with most mathematicians' worldviews. This stereotype ignores the culture or self-identity clashes that a majority of learners experience, to varying degrees, in mathematics classes (Aikenhead, 2017, pp. 82-85; Meyer & Aikenhead, 2021, pp. 103-106). Certainly, almost all learners can realistically improve their mathematical proficiencies, with respect to their personal experiences and needs. However, to believe all learners have the desire, interest, or potential to achieve at the highest levels is a stereotypical position to take.

[4] One of Plato's corollaries is of specific interest to teachers. It states that pure mathematics must be: value-free, decontextualized, non-cultural, nonideological, purely objective in its use, and generalizable. Upon analysis during the past four decades, these fundamental features have been shown to be inaccurate (Aikenhead, 2017, pp. 86-87). For instance, Western mathematics is guided by such ideologies as purism and quantification; and that beauty. "All are shared cultural values attributed to mathematics knowledge" (Ernest, 2016, p. 211).

Learning or previously learned:

1. What is mathematics? – a human endeavour above everything else (Bishop, 1988; Ernest, 2016).

2. Plurality of mathematical systems; for instance: Greek, Islamic, Japanese, Western, and First Nations systems. Western mathematics is only one among many mathematical systems.

3. Inclusion of Indigenous perspectives in a classroom is not enough. It takes heart-felt dialogue and collaboration with Indigenous learners and colleagues.

4. How to avoid subtle appropriation.

5. Two-eyed seeing (Duchscherer et al., 2919, pp 58-60, 113-114) is defined by Mi'kmaw Elder Albert Marshall as learning the strengths of Indigenous mathematizing and Western mathematics. As a result, people will be able to see the everyday world through two very different cultural lenses. This was a key idea the teachers learned.

6. When identifying learners who may have potential to excel at mathematics or who may struggle to succeed, social justice encourages teachers to do their best to compensate for mainstream Canadian culture's inequities associated with, for example, learners' ethnicity. For instance, British Columbia's Auditor General (Bellringer, 2019, p. 23) noted: "Our report [on graduation rates involving Indigenous and non-Indigenous high school students] highlighted the impact of the racism of low expectations … based on preconceptions or biases stemming from social attitudes." Such public attitudes require teachers to provide equitable compensation for targeted learners, because equal treatment tends to perpetuate these social norms. Special attention to encourage and support Indigenous students may be a reasonable reaction to Bellringer's assessment. The Carrot River teachers had already learned to treat learners equitably.

Results: Composed by the Teachers

A. Lesson Plans (Duchscherer et al., 2019. p. 111):

Krysta5: 1. E-A. -	Freestyle Looming and Probability	**Grade 12**
Kevin: 2. E-B.1 -	Picario *A Traditional Indigenous Game to Develop Spatial Reasoning, and Analytical and Critical Thinking Skills*	**Grade 10**
Kevin: 3. E-B.2 -	Water, First Nations Cultures, Statistics	**Grade 9**
Danielle: 4. E-C.1 -	The Language of Negative and Positive Numbers	**Grade 6**
Danielle: 5. E-C.2 -	Stick Games and Theoretical-Experimental Probability	**Grade 6**
Serena: 6. E-D.1 -	Multiplication and First Nations Drumming	**Grade 5**
Serena: 7. E-D.2 -	Quadrilateral Patterning Through Indigenous Beading	**Grade 5**

B. Conclusions from the Consultants' Interviews (Duchscherer et al., 2019, pp. 62-67)

1. Teachers must be learners, first and foremost; learning *with* and *from* their students.
2. Experience with any type of culture immersion is essential.
3. Initial individual mentoring by a school division Indigenous consultant is essential.
4. The depth of learner engagement determines the degree of meeting their potential at learning mathematics.
5. Any major roadblocks? The restrictive over-crowded mathematics curriculum.

On their own initiative, most of the teachers continued to produce an Indigenous culture-based lesson during the 2019-2020 school year. They had discovered first-hand the positive effects such lessons had on their learners.

Implications

Underwood's (2019) successful culture-based story-telling and story-writing approach had the advantage of using teaching materials already developed. The Carrot River teachers, on the other hand, went through a rigorous learning experience to create their own materials. The two approaches are complementary. The Carrot River teachers may have benefited from a more indepth approach by having their learners engage in authentic hands-on Indigenous mathematizing, a strategy that Underwood (2019, p. 13) championed as, "allowing students to experience First Nations' cultures." A *mathematizing* approach using already prepared lesson plans would take less time. Compared to Alana's minds-on approach that engaged learners in open-ended questions and mathematical discussions, learning how to mathematize requires concrete resources and time to learn how to use them. The openness of both approaches "gave students with different experiences and strengths an opportunity to contribute confidently to the discussion" (Underwood, p. 12); and "more students became engaged, and the role of a teacher changed in a way that encouraged closer relationships with students" (Duchscherer et al., 2019, p. 38). The Carrot River methodology generated a template with which the Saskatchewan Ministry of Education can scale-up the production of locally authentic, Indigenous culture-based, lesson plans for the whole province (Duchscherer et al., 2019, pp. 71-72).

[5] By the teachers' choice, pseudonyms are not used. Krysta went on maternity leave before completing a second lesson.

The Second Project: "SaskMATH"

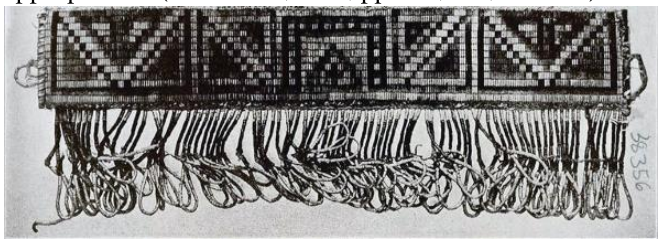
In December 2019, the Provincial Education Sector, a consortium of the Saskatchewan Ministry of Education with 28 Boards of Education, assembled a ten-member executive committee to organize and manage about 45 mathematics teachers (Grades 1-12) and school division consultants, chosen for their expertise. This working group helped develop the components of a website of evidence-based best practices for teaching number sense and mathematics as a human endeavour; two of Saskatchewan's four curriculum's goals. The Provincial Education Sector mandated that the website be Indigenized by integrating "Indigenous ways of knowing" where ever possible. This ensured a humanistic, culturally responsive approach to teaching mathematics. Sharon and I were appointed to the executive committee. We collaborated with the working group by providing some of their professional development experiences, as well as participating in their deliberations during several one-day and two-day meetings. Their judgments concerning the authenticity of website content related to Indigenous ways of knowing became our responsibility. Some Indigenous-related Canadian website resources are included in SaskMATH; for example, the seven lesson plans from the Carrot River project. Our selection criteria were: (1) authenticity of an Indigenous perspective, (2) authenticity of the context from an Indigenous point of view, (3) potential applicability to Saskatchewan after appropriate research and editing, and (4) an absence of subtle appropriation.

Subtle Appropriation

Subtle appropriation seems to be a deep-seated ideology in the culture of Western mathematics; a characteristic of a mathematician mindset, if you will. A typical example is a mathematics teacher claiming, "A tipi is a cone." Mathematics professor Dr. Doolittle (2006) of Mohawk ancestry objected to such a statement:

> 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 their culture. (p. 20, emphasis added)

How does this appropriation process occur exactly? We can think of it as a four-step process: image recall, superimposition, deconstruction, and reconstruction. For example, consider the Indigenous artefact made from looming porcupine quills (Photo 1). It expresses many Indigenous patterns, some of which can be imagined to be a triangle, but only when seen through the eyes of Western mathematics. The following four steps describe subtle appropriation (Aikenhead, 2017, pp. 101, 116, 122-124).



1. *Image Recall:* In 1930, Einstein shared his fundamental insight into the process of observing (quoted in Director, 2006).

> 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).

Thus, when viewing the quilled looming (Photo 1), our mind recalled an image of a Western mathematics triangle shape. An Indigenous looming artist and a mathematician would likely have very different understandings of the same pattern.

2. *Superimposition:* Our mind superimposes that image onto a section of the Indigenous looming artifact (Aikenhead, 2017, pp. 122-124).
3. *Deconstruction:* 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. *Reconstruction:* Our mind reconstructs a Western geometric triangular shape in the Indigenous artifact. By not acknowledging or not understanding the original Indigenous pattern, we have not respected the artist's Indigenous culture.

In short, we have stripped the artifact of its original Indigenous meaning and replaced that meaning with a Western mathematics meaning (i.e., a triangle). This is *subtle appropriation* (Aikenhead, 2017, pp. 98-100; Duchscherer et al., 2019, pp. 51-56).

Hypothetical Contexts

A mathematician's mindset tends to place puzzles and problems in a *hypothetical* context rather than in a *real-world* context with which learners can easily identify. This is justified by the fact that the real world can have extenuating circumstances and unexpected variables that cause the puzzle or problem to become far more complex than anticipated; as is the case with project-based instruction (Boaler & Selling, 2017). A hypothetical world does not usually cause such problems. However, in particular situations, it does cause tokenism or subtle appropriation to occur, which in turn has a similar marginalizing effect on many Indigenous learners as claiming a tipi is a cone.

The first exception relates to a SaskMATH criterion for selecting internet resources (i.e., criterion [2] listed above: the authenticity, from an Indigenous perspective, of the context found in Indigenous-related mathematics puzzles or problems). SaskMATH members generally labelled as tokenistic some internet resources that had inauthentic Indigenous contexts, even though they were

[6] The example described here is one of several discussed in Duchscherer and colleagues (2019, pp. 51-56).

more subtle in their tokenism than teaching learners that "2 tipis plus 4 tipis equals 6 tipis" and then claiming Indigenous content was included in the lesson.

Secondly, the working group expressed the view that they, as non-Indigenous mathematics educators, should not make up an imaginary traditional Indigenous story, even for the sake of getting Indigenous learners motivated to learn mathematics. It would be appropriating an Indigenous genre to fit a *Western* mathematics context. This contravenes SaskMATH's selection criterion (4) above: "an absence of subtle appropriation."

Educational researchers Beatty and Blair (2015, p. 5) would concur: "appropriation is taking Indigenous knowledge to use within a different cultural context, without truly understanding the cultural significance of the knowledge." The correct process to follow would have been to get permission to repeat the story from an Elder, Knowledge Holder, or the family whose story it was to share.

Learners' Comfort/Discomfort with Hypothetical Mathematics Contexts

The essence of hypothetical mathematics problems is "let's pretend." On the one hand, many students learn to suspend any of their disbeliefs concerning the problem's context. On the other hand, some learners react to this requirement by thinking, "Why bother? It's not real."

A pedagogical challenge for teachers is *the distribution* among learners' predispositions to suspend or not suspend their disbeliefs concerning a context of a mathematics problem with which some learners normally expect to identify.

This spectrum goes *from the one extreme* where math-oriented learners want more puzzles to solve. The middle of the spectrum consists of learners with *degrees of* willingness to suspend their disbeliefs simply to maintain a self-identity as a good student, or just to pass the course.

At the other extreme of predispositions, hypothetical contexts do not comfortably fit these learners' worldviews. Instead, some learners may pay attention only to contexts potentially relevant. Hypothetical problems will seem foreign to these learners. Therefore, mathematics associated with hypothetical problems may not make sense. Doolittle (2006, p. 19) provided this example:

Question: Imagine you and three friends are sitting on the ground with 72 [quarters] piled in front of you. What would you do so that each of you got the same number of [quarters]?

Learner: Pass them out until they are all gone.

This learner gave a correct answer according to their Indigenous worldview, but not according to the worldview of Western mathematics education. Indigenous verb-based languages reflect a common sense of action; not a mathematician's mindset of abstractions in hypothetical contexts.

This pedagogical issue becomes more significant when we consider that many mathematics teachers tend to see their everyday world solely through the lens of their mathematical predisposition. They unconsciously superimpose mathematics onto their surroundings and assume that all learners can if they put their mind to it. They tell students, "Mathematics is all around you." This erroneous assumption becomes a criterion for learner assessment – applying mathematics to the learner's everyday world. That is a challenging task for many learners whose self-identities are much more comfortable with contexts in the humanities, social sciences, or when dealing with the survival of their reserve.

This is a situation that causes significant miscommunication over understanding and dealing with hypothetical contexts. Such miscommunications repeated over time cause many learners to lose interest in school mathematics, or even worse, develop a dislike for it (Simeonov, 2016).

Conclusion

Solutions to reduce miscommunications that discourage student interest in learning Western mathematics include the following:

1. Teach an Indigenous culture-based mathematics lesson plan on at least two significant occasions per semester (Duchscherer et al., 2019; Underwood, 2019);
2. by teachers who wish to learn and unlearn what Alana Underwood and/or Krysta, Kevin, Danielle, and Serena did;
3. who try diligently to avoid tokenism and subtle appropriation, by critically self-monitoring their mathematical mindsets;
4. with the help of an informal support network of like-minded colleagues who can temporarily slip out of their mathematician mindsets into a culturally responsive mindset illustrated by Underwood (2019) and the Carrot River lesson plans and videos (Duchscherer et al., 2019);

5. all within in the domain of explicitly understanding Western mathematics as a human endeavour.

Your support network's self-initiated professional development project will make a significant contribution to Canada's era of reconciliation.

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