ENVIRONMENTAL SCAN

INDIGENOUS MATH EDUCATION AND TOOLS

Final Report

Yukon First Nation Education Directorate
Firelight Research Inc.

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yfned | YUKON FIRST NATION EDUCATION DIRECTORATE

the firelight group

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ACRONYMS AND ABBREVIATIONS

CRC	Culturally Responsive Curricula
CRE	Culturally Responsive Education
CRmE	Culturally Responsive Mathematics Education
IK-HABME	Indigenous Knowledge Has Always Been Mathematics Education
IRS	Indian Residential School
MCC	Math in a Cultural Context
MIC	Math in an Indigenous Context
SFU	Simon Fraser University
SSDEC	South Slave Divisional Education Council
STEM	Science, Technology, Engineering and Mathematics
TEA	Treaty Education Alliance
YDE	Yukon Department of Education
YFNED	Yukon First Nation Education Directorate

1. INTRODUCTION

Today, mathematics education (hereinafter referred to as 'math') lies in western teaching practices and approaches that are divided from Indigenous ways of knowing and understanding. Yet, all Indigenous cultures developed math systems that enabled counting, data collection, navigation, pattern recognition, visuospatial reasoning, and more. Still, mainstream education continues to rely almost exclusively on western frameworks and pedagogies to describe and teach math, and as a result, math education is not meeting the needs of all students and people. In the Yukon, data has shown gaps between First Nations and non–First Nations students on standardized math tests, demonstrating that western approaches to math education often have little meaning and relevancy to First Nations students (Auditor General 2019).

Therefore, the Yukon First Nation Education Directorate (YFNED) has conducted an environmental scan of math education approaches and tools for Indigenous students, in an effort to gain a better understanding of potential options for improving math literacy in Yukon. The data compiled and highlighted in this report, collected through a literature review and interviews with academic researchers and math educators, reported on the experiences and learnings of Indigenous-led decolonizing math projects and programs. The report primarily draws upon initiatives based in Canada as well as New Zealand, Australia and the USA, notably those in rural and remote Indigenous contexts. The report also highlights promising practices through case studies of Indigenous math education programs and tools that have been developed to support Indigenous students.

The purpose of this research is to provide the YFNED with knowledge about existing programs and information on available and appropriate tools and resources as they begin to undertake the development of a pilot math program that aims to make math education more meaningful and engaging for First Nation students in the Yukon.

1.1 ORGANIZATION OF THE REPORT

This report was prepared to support the YFNED in developing culturally-relevant and innovative pilot math programs for students in the Yukon. The bulk of the report is detailed in the summary of key findings (Section 4), case studies (Section 5) and potential implementation outcomes (Section 6).

The report is organized as follows:

Section 1 – **Introduction:** provides a background of the purpose and scope of the research.

Section 2 – **Methods**: describes the approach to conducting the study, the data sources that form the content of this report, and the approach used in the analysis of the data.

Section 3 – **Background:** presents Indigenous understandings and concepts of numeracy, logic and geometry, and the history of Indigenous peoples' interaction with western educational systems and its impacts on present-day math outcomes.

Section 4 – **Findings:** details the findings of the environmental scan on Indigenous math education according to key themes, including decolonizing mathematics (Section 4.1), Indigenous-centered content and curriculum (Section 4.2), finding math in student's everyday lives (Section 4.3), grounding teaching in Indigenous approaches (Section 4.4), centering and supporting Indigenous students (Section 4.5), and building skilled and competent educators (Section 4.6).

Section 5 – **Case Studies:** examines existing programs and tools, including Math in a Cultural Context (Section 5.1); Math First Peoples: Teacher Resource Guide (Section 5.2); South Slave Divisional Education Council Math Approach (Section 5.3); TEAM-Learning (Section 5.4); and IndigiLogix (Section 5.5).

Section 6 – Potential Implementation Outcomes: lists the potential results of implementing culturally-relevant math education programs for Indigenous students, educators and communities, including increased student and community engagement (Section 6.1), higher academic achievement levels (Section 6.2), improvements in student's overall learning and cultural competencies (Section 6.3), and improvements in educator's overall skills and teaching quality (6.4).

Section 7- **Conclusion:** summarizes the findings of the report.

2. METHODS

An environmental scan was conducted through a literature review of relevant documents, reports and research articles, as well as key informant interviews with educators experienced in developing and delivering Indigenous-focused math education programs.

The literature reviewed for this study drew upon various documents – including reports, studies, academic papers, and other sources – to gain a comprehensive understanding of the needs, priorities and barriers faced by Indigenous students learning math in the mainstream school system. It further investigates approaches to math pedagogies that have been created or adapted by Indigenous peoples, promising practices in the delivery of math programs for Indigenous students, and best approaches to teaching math in a cultural context. The literature detailed experiences of Indigenous-led math education models, frameworks and programs from Canada, the United States, Australia, and New Zealand. It included examples from Indigenous communities such as Mi'kmaq, Blackfoot, Inuit, Yup'ik, Maori, and Australian Aboriginals[1], among others. Some articles describe the integration of Indigenous knowledge with math curricula (e.g., Borden 2010; Garcia-Olp et al. 2019; Lipka 1994), while others focus on the philosophies of Indigenous ways of knowing, learning, and teaching math (e.g. Czuy 2020; Sterenberg 2013).

Interviews for this study were conducted with individuals from a range of Indigenous-based math education programs who work with Indigenous and non-Indigenous students in Canada and abroad. Interviews took place between June 24, 2021 and August 24, 2021. They ranged from 45 minutes to 1.5 hours in length. Each interview was audio recorded and notes were recorded digitally. Participation was voluntary, and free, prior and informed consent was obtained before each interview (see Appendix B). Written consent was provided when possible, otherwise verbal consent was recorded prior to conducting the interviews. Due to the current context of the COVID-19 pandemic, all interviews were completed remotely via videoconferencing software (i.e., Zoom). Interview questions were open-ended to allow for a range of responses to be shared by the participants (see Appendix A). Core topics for the interview questions were developed from the literature review and through conversations with the YFNED team.

The findings of this report are based on a thematic analysis of what participants were able and willing to share, as well as findings from the literature review. The data collected was analyzed using standard qualitative practices of thematic coding. Interview notes were reviewed, and key themes were identified. The thematic coding process aimed to identify promising practices, key challenges and barriers, and opportunities.

[1] The term 'Aboriginal' is used in this report in the context of Australia, as this is the preferred term used by Indigenous people of mainland Australia.

2.1 PARTICIPANTS

Interview participants were identified in the environmental scan, and through the direction of the YFNED team. Additional organizations were identified by participants during their interview. Seven different organizations or programs were interviewed for this study, spread across the Northwest Territories, British Columbia, Saskatchewan, and Washington (USA).

Participating organizations in this study include:

- Treaty Education Alliance, Fort Qu'Appelle, SK;
- Simon Fraser University, Vancouver, BC;
- South Slave Divisional Education Council, NWT;
- First Nations University of Canada, Regina, SK
- University of Saskatchewan, Saskatoon, SK;
- Pacific Institute for the Mathematics Sciences, Vancouver, BC;
- Salish School of Spokane, Spokane, WA.

It is important to acknowledge the time, knowledge, and teachings generously shared by all participants, and the critical role their voices hold in shaping this report.

2.2 LIMITATIONS AND OPPORTUNITIES

Given the unprecedented circumstances of the COVID-19 pandemic, it was not possible to conduct in-person interviews or hold face-to-face engagements for this study. In an effort to prioritize and protect the health and safety of participants and communities, the project team worked within current health and safety parameters and completed this study through virtual means.

Additionally, some educators and school staff were unable to participate in interviews due to time constraints related to the end of the school year. To mitigate this, additional potential interviewees were contacted based on the recommendation of previously interviewed participants.

3. BACKGROUND

Indigenous epistemologies possess embedded logics and ideas classified as math or numeracy under a Western framework, underscoring that Indigenous knowledge "has always been mathematics education" (Neel 2008; Garcia-Olp, Nelson and Saiz 2019). Whether it be the utilitarian employment of math technologies that helps to serve the material needs of a community (i.e., engineering fish weirs and dams, or designing dwellings such as tipis), or the scientific, land-based understandings of topography and astrology as navigational methods employed for developing trade routes, it is evident that Indigenous communities globally have a strong and long-standing application of 'math' knowledge (Jungic 2021; UNESCO 2008).

In addition to engineering and technological use, mathematical concepts were also employed by artists practicing many different mediums. Form line artwork of Northwest Coastal Nations highly valued precise symmetry, negative space, and proportional weight in their design. Geometry, precise measurements and ratios were a crucial technique for carvers and painters to master in order to build their prestige (Thomas & Schattschneider 2011). Similar techniques were employed by quill workers across the prairies (Thompson 2013). In gambling games, such as Slahal/Lahal and Dene Handgame, experienced players used a number of strategies to increase their chances when guessing, and a fast-paced scorekeeper used a scoring system to track sudden changes and tally points (FNESC 2020).

These examples speak to the general application of numeracy concepts in Indigenous communities, but it is important to note that there are highly specific and complicated examples of mathematical disciplines from Nation to Nation. For example, the Kwakwaka'wakw 'Pəssa is a complex form of accounting to track the wealth of Clans engaged in Potlatch ceremony, which is integral to the governing structure, culture and spiritual traditions of the Nation. Advisors and overseers calculate the dividends of Potlatches, as well as plan investments for future gatherings, while maintaining specific rules and regulations according to the laws of the Big House (Recalma-Cluetsi 2007).

Colonialism deeply impacted Indigenous ways of being and knowing, and systematically removed Indigenous people from their traditional territories and communities. By being forcibly removed and disconnected from the land, Indigenous ways of life, including complex knowledge systems and pedagogical structures, were disrupted. Instead, Indigenous peoples were subjected to institutions that did not intend to educate its students, but enforce a federally-sanctioned program of assimilation and forced labour (Harris 2004). This was the formative experience of Indigenous people with public education, and the harms caused by the Indian Residential Schools (IRS) reverberate in communities to this day (TRC 2011). This historical experience of western education systems is an important point to note in understanding the current context of Indigenous education. It is important to understand that western educational system practices of siloed disciplines, culturally unsafe assessment tools, and school environments all contribute to Indigenous students' performance in public education.

The impacts of historical and ongoing colonialism on the education of Indigenous peoples has also resulted in a long-standing gap in education outcomes for Indigenous students, including lower high school completion rates compared with other students (Richards & Mahboubi 2018; FNIGC 2018; Auditor General 2019). There is further evidence to support that Indigenous

students who complete secondary school have a far lower completion rate for Grade 12 pre-calculus math courses compared to their counterparts (Archibald & Jungic 2016).

While Yukon-specific data is limited, the 2019 Report of the Auditor General to the Yukon Legislative Assembly reported that the Yukon Department of Education continues to struggle to close gaps in education outcomes for First Nations students. The Auditor General (2019) found that:

- the percentage of Grade 7 students who met or exceeded expectations on the Yukon Foundation Skills Assessment in numeracy, reading and writing was much lower for First Nations than for non–First Nations students;
- a higher percentage of First Nations students needed more support in two or more areas of early learning;
- a smaller proportion of First Nations students who entered Grade 8 in the 2011–12 school year completed high school within six years compared to non-First Nations.

While there has not been a specific, comprehensive study of Yukon First Nations achievement rates in math specifically, it reasonable to assume that the data above, in addition to national-level data and anecdotal evidence, points to lower math literacy for First Nation students. Low participation and achievement rates in math can have multiple impacts, where few Indigenous students enrol in higher-level math, few pursue post-secondary studies that require math, and few are represented in careers that use math, including advanced trades (Archibald & Jungic 2016). There is a need for further data collection and analysis on math outcomes for Yukon First Nations students across the territory to be able to make informed decisions about supports that are needed to address these gaps.

Importantly, Indigenous students are not deficient learners. Instead, as stated in the findings of the Auditor General's report (2019), the education system is not doing enough to understand and address long-standing gaps in student outcomes or to deliver education programs that are inclusive and fully reflective of Yukon First Nations culture and languages – a legislated responsibility in the *Education Act*.

Thus, to improve math literacy in Indigenous communities, educators must embrace the living, evolving, holistic knowledge of the Indigenous Nations they serve, and work in partnership with those Nations to develop engaging and meaningful curricula that makes math accessible and relevant to Indigenous students (Stavrou and Murphy, 2019; Sajo, 2021). This report will demonstrate that by addressing student's needs and developing a math curriculum that is culturally-relevant and responsive to their experiences, Indigenous students can thrive.

4. FINDINGS

The following section is based on analyses of both key informant interviews and the literature review. Although there are similar findings across different jurisdictions and regions, these findings are nested within unique regional contexts and circumstances of varying levels of resources, access, and networks. This section is therefore organized by common trends in Indigenous math education approaches and programming, detailing the local contexts and circumstances where necessary. The following findings serve as high-level examples of what could be done in the spirit of sharing knowledge, as well as strengthening, encouraging, and recognizing existing Indigenous-led programs and initiatives.

Thus, the following section is organized as follows:

- Section 4.1 Decolonizing Mathematics;
- Section 4.2 Developing Indigenous-Centered Math Content and Curriculum;
- Section 4.3 Finding Math in Everyday Environments;
- Section 4.4 Grounding Math Teaching Strategies in Indigenous Approaches;
- Section 4.5 Centering and Supporting Indigenous Students; and,
- Section 4.6 Building Skilled and Competent Educators.

4.1 DECOLONIZING MATHEMATICS

Prior to delving into Indigenous-centered math pedagogies and curricula, it is important to acknowledge and dismantle the colonial underpinnings of the subject of math itself. Efforts to improve and Indigenize education are limited without also decolonizing education simultaneously. Mainstream math education in particular, and its "political-social high status […] is a major barrier to reconciliation and to a renewed curriculum and instruction" (Aikenhead 2017, 82). Math is seen as mainstream education's most prestigious subject (Aikenhead 2017, 82; Garcia-Olp, Nelson & Saiz 2019, 694). A shift in hierarchical structures that uphold mainstream math education as both culture-free and exceeding in rank, status and importance is at the very root of the endeavour of making math education more equitable (Aikenhead 2017). According to Nicol et al. (2019),

> *[m]athematics education, in particular, adheres to mathematical standards and systemic structures that use high-stakes tests to promote accountability. Pedagogically, this implies that there is a prescribed pathway to excellence for all students. Theoretically, it suggests that mathematics is universal and culture-free.*

Yet, it is a misconception that math is 'culture-free'. Much, though certainly not all, of math taught in western education institutions was created by white men. Therefore, western worldviews have greatly influenced the subject of math, and therefore, decolonizing requires confronting and challenging the colonizing practices that have influenced education in the past, and which are still present today. It is also important to confront the power relations within these institutions: Who is in control of knowledge? What maintains their power? (Nicol et al

2019). Math should and does belong to everybody. Everybody deserves access to its power – and everybody should be able to push back when the discipline is used to oppress and marginalize.

Decolonizing math education will require a complete shift in pedagogical approaches, because math in a western context is quantitative and hierarchical in nature. Aikenhead has found that "[q]uantification encourages people to believe that they can objectify things, events, or people by stripping them of their qualitative, subjective, and spiritual attributes" (2017, 83). From an Indigenous perspective, nothing can be completely objective and "objectification through quantification can show a lack of respect at the very least and can border on oppression at worst" (Aikenhead 2017, 84). Decolonizing math allows students to place math in the web of connections and relations that exists in the world. Aikenhead attests that "students will feel very comfortable with the ideology of quantification found in most school mathematics and physical science classes, if and only if their worldview harmonizes with a quantitative perspective that makes sense to their lived experiences" (2017, 84).

Another common misconception about math is that it requires raw intellectual talent or brilliance. This harmful myth has far-reaching consequences for Indigenous students, because historical and ongoing colonialism have created narratives which stereotype Indigenous peoples as lacking brilliance, and subsequently, the myth that success in math requires this trait becomes a barrier. Students' math identities – how they see themselves as learners of math and the extent to which math is meaningful to them – are important when thinking about teaching and learning in math. Ruef, Jacob, Walker & Beavert state that "equity focuses on the identities students construct for themselves in relation to knowing and doing mathematics. […] How do we know who we are? We recognize ourselves, in part, within the reflections we see and hear in the voices of the people we consider as our community" (2020, 314).

Therefore, it is important "not only to build pathways to appropriate mathematics education, but also to address some of the effects of a colonial past that continue to subvert local teaching and learning approaches" and alienate students from the subject of math (Nicol et al. 2019). In addition, there is also a need to explore ways for students to be involved in the process of developing math curriculum and providing input into what math education will work best for them within their cultural and experiential contexts.

4.2 Developing Indigenous-Centered Math Content and Curriculum

Indigenous identity and worldviews are rooted in diverse places, cultures, and traditions lived and practiced since time immemorial. Though there may be similarities across contexts, it is crucial to remember the distinct identities of communities when developing Indigenous-specific math curricula and content. Ruef, Jacob, Walker & Beavert recognize that people are "complex; culture is complex. People are ever-evolving embodiments of entangled identities; culture reflects the ever-evolving social interactions of its participants" and as such, "a good curriculum is flexible and responsive with room to recognize and honor cultural complexities" (2020, 316). Decolonizing mathematics as explained above, must be followed by the creation of Indigenous-centered, cultural, math content, as Aikenhead explains that,

> *[t]o experience mathematics as a human endeavor is to engage in a repertoire of its sense-making cultural practices…This view of culture as everyday practice lends itself to teaching and producing projects in which students must negotiate, supported by their teachers, among multiple ways of understanding (2017, 87).*

Developing Indigenous-centered content can take many forms in "everyday practice", but typically includes adaptive and flexible curricula models, the use of Indigenous languages to describe math concepts, and authentically involving students, community members and knowledge-keepers in curricula design.

4.2.1 Building Locally-Adaptive and Flexible Curricula

Scholars argue that for decolonization in education to be successful we need to be grounded in what it means to be Indigenous, based on the local perspective of the Indigenous peoples wherever learning takes place (Hawera and Taylor 2011; Aikenhead 2017; Garcia-Olp, Nelson and Saiz 2019; FNESC 2020; Lipka, Webster & Yanez 2005; Czuy 2020). By "seeing self" in math content, students are able to understand and engage critically through various ways of knowing and understanding the world around them (Czuy 2020). Particularly in math or STEM education, this allows students to focus on learning complex concepts in flexible, adaptative ways that are meaningful to them.

While all curricula is culturally based, the key question is to understand *whose* culture it is based on (i.e. Indigenous, or Western culture), as this greatly impacts the ability of Indigenous students to succeed in math learning. Lipka, Webster and Yanez (2005) recognize that math curriculum can be specifically tailored in a culturally-safe manner to meet the needs of students. For example, in Alaska the Math in a Cultural Context (MCC) program is designed as an adaptive curriculum, where Yup'ik Elders, teachers, and mathematicians collaborate to translate practical Indigenous knowledge into math education (see also Section 5.1). MCC recognizes that everyone teaches and learns in their own ways, rather than assuming that one curriculum fits all teachers, students, and circumstances (Lipka, Webster and Yanez 2005, 4).

In Yup'ik communities, cultural knowledge around kayak building, sewing patterns, and navigating skills using the stars, are incorporated into math through consulting and collaborating with Elders (Lipka, Webster and Yanez 2007, 3). Similarly, by acknowledging Indigenous peoples' relationships with the land, ancestors, and diverse knowledge systems, math content can reflect that there are multiple ways in which knowledges are formed on the land, which can be incorporated into curricula (Garcia-Olp, Nelson and Saiz 2019, 690). These are both flexible and context-specific examples of how Indigenous culture, knowledge, and worldviews can be incorporated into math education. This is achieved through tapping into the sources of cultural knowledge, such as Elders and community members themselves (see Section 4.2.3), and Indigenous languages (see Section 4.2.2).

4.2.2 Incorporating Indigenous Language in Content

Pedagogy in Indigenous societies (like pedagogy in non-Indigenous societies) is culturally specific – it is based in a distinctive language and way of looking at the world (FNESC 2020, 14). Grounding education in Indigenous ways of knowing and being, and Indigenous language, is often more straight-forward in subjects such as social studies and arts, but continues to be a

challenge in math and science. Nonetheless, interviewees underscored that language is a crucial facet in developing Indigenous-centred math content.

For instance, in Glen Aikenhead's interview, he provided examples where language was incorporated in curriculum to explain math terms. As he explains below, the circumference of a circle was translated in *active* terms in Cree as "running around a small stone":

> *If you want to translate [math concepts] into Cree […], it's a two-step process: you get one Cree person to translate it into Cree, then you get a totally different Cree person to translate the Cree expression back into English. That's called "back translation". Then you take a look at it to see how close you can get. Here's an example: the Cree word for circumference, in the English language, is 'running around a small stone'. Do you notice it's a verb? [In] Mohawk, […] it's 'where two lines come from'. And that's a long word, that's what happens in Indigenous languages they speak in sentences longer than in single words. So, the idea of incorporating language, that's superior […] the language is a window into the culture. And running around a small stone is a lot better than some noun that someone has made up (2021).*

Thus, Indigenous language enables students to visualize and comprehend abstract concepts in ways that are culturally-relevant to them. Moreover, many Indigenous languages are verb-based, which necessitates that math content is taught through correspondingly action-based activities in classrooms (Aikenhead 2021). This exemplifies the intertwined nature of Indigenous-centred math content with Indigenous approaches to teaching math (see Section 4.4).

Not only is it important to incorporate Indigenous language in math content for the benefit of Indigenous students' mathematics learning journey, but it is also important to incorporate language in order to give Indigenous communities the power to decide what to focus their math education on (Lipka 1994). A key question for schools and programs to consider is the level at which language will be included and incorporated. Is the math curriculum an immersion program focusing on language acquisition, or is language used to supplement existing math content and make meaning for students to engage with content? Regardless, which math concepts should be taught, and the degree to which language plays a role in this, can be primarily achieved by supporting the active involvement of local Indigenous communities in designing math content.

4.2.3 Centering Community Involvement in Curricula

The involvement of Elders and knowledge holders is essential in the development of Indigenous math curricula and programs (Aikenhead 2021; Jungic 2021; Sajo 2021). This is important because collaborating with local Indigenous group(s) in their traditional territories, where the cyclical nature of place, inquiry and relationships inform each other, can ensure that math curriculum captures these relational dynamics (e.g., connections to traditional territories) (Garcia-Olp, Nelson and Saiz 2019, 691). Community involvement also ensures that culturally responsive curriculum (CRC) is developed. According to Stephens (2000), CRC integrates culture holistically throughout curriculum (rather than adding it as a separate module), and respects learners' unique culture and lived experiences. Community involvement means the exchange of information and perspectives become the foundation from which educators

understand what community members value, thereby providing an opportunity to create authentically culturally responsive curriculum (Stephens 2000).

Moreover, community involvement creates connections between students and the content that is taught in schools (FNESC 2020). It both generates meaningful connections between student's math skills and math content, and also between learners and community members, particularly when community steers, guides, and assists in implementing curricula and programming. Czuy argues that:

> *Bringing in community allows students to again see themselves in the content, validating the community worldview and creating a strong sense of cultural identity (Borden, 2015; Marin & Bang, 2005), while supporting those personal narratives of "if they can do that so can I!" Marin and Bang (2005) noticed that students did better in mathematics when their identities and worldviews aligned with those of the teachers (2020, 198).*

Sustaining these relationships and accountability with community members creates opportunities to build Indigenous-centred math curricula that is meaningful to individual learners and helps them succeed. In particular, a focus on who is involved and collaborating is important, not only in the initial relationship building process, but throughout the development and implementation of math curricula and programs (Martinez 2020; Stephens 2000). Relationship-building with Elders, knowledge-keepers, and community members is required in order to incorporate the culture, knowledge, worldview, pedagogy, and relationality that are at the heart of Indigeneity. Only then can curriculum and education be mobilized to revitalize and sustain Indigenous ways of knowing and being, with the aim to create successful Indigenous students in their math endeavours. Including teachers in a focused discussion with community knowledge keepers about appropriate methods of culturally relevant and experientially focused math programming is a critical approach in ensuring a that Indigenous perspectives are reflected.

Lastly, authentic, locally specific, community involvement in designing math content can prevent the homogenization and tokenization of curricula. Involving knowledge-keepers can help to holistically weave Indigenous culture *throughout* math and science learning:

> *…This is also where I see greater impact. As long as they don't feel that it's a token thing, that it's part of the whole thing, I think that's what really works the best. (Alvarez 2021)*

For example, developing curricula and programming which is rooted in local place and based on relationality, prevents appropriation, homogenization, or tokenism. Instead, educators and teachers can develop local lesson plans with community members that speak to the local sense of place, relationship to that place, and how this cultural knowledge relates to mathematical concepts.

4.3 Finding Math in Everyday Environments

Developing Indigenous-centred math content is closely related to the concept of focusing on math in everyday environments. This notion was underscored by interviewees and the literature, particularly as 'everyday' math often pertains to Indigenous cultural practices.

Furthermore, everyday activities allow Indigenous knowledge to be focused on in ways that are relevant to the lives of students (see also Section 4.5).

4.3.1 Math in Everyday and Cultural Activities

Indigenous peoples practice math in diverse ways through kayak building, sewing patterns in regalia, astrological navigation, or practicing probability through moccasin games, to name a few examples (Lika, Webster and Yanez 2005; Ezeife 2011, 37). Engineering can also be found in Indigenous communities – in the building of tipis or longhouses, fish weirs, fish wheels, carving canoes and bentwood boxes, and weaving baskets or wool (Lipka, Webster and Yanez 2005; Jungic 2021; Gail Sajo; Strong 2021; Neel 2008). Neel shares that in the West Coast,

> *the artist who draws different geometric shapes such as Ovoids and U-shapes has the intuitive knowledge as to what the final piece of art will look like. Somehow the artist has a sense as to what shape will be the most appealing to the eye of an observer. The art may integrate mathematical concepts such as symmetry, congruency, and transformations without the artist implicitly or intentionally knowing that they are doing it. Mathematical thinking seems to be inherent with the artist (2008, 249).*

Thus, there are many 'everyday', cultural, mediums through which mathematical concepts can be utilized and be taught. If educators, teachers, and community members can focus on the everyday life experiences of Indigenous students when developing and implementing math curricula, Indigenous learners can be engaged, motivated, and empowered in knowing that they are, and can be, mathematicians.

"Ethnomathematics" is one related theoretical construct in which mathematics is

> *embedded in cultural activities, in the workplace, home, community, and in aspects of everyday tasks to solve problems…Ethnomathematics seeks to identify the diverse ways in which cultural groups quantify, compare, classify, measure, and explain day-to-day phenomena in their own environment. (Neel 2008, 82-82; 24)*

There are multiple ways in which math is utilized in daily life, from building complex structures and creating art as noted above, or even paying for groceries at a store. These are examples of learning and teaching mediums through which community members, educators, and teachers can find, problematize, and teach math concepts meaningfully.

Acknowledging ethnomathematics in everyday activities is critical because while math is used by Indigenous peoples in indirect and subtle, yet impactful ways, it is vastly different than western, eurocentric notions of math (Neel 2008). Whereas math is approached from a theoretical perspective in western pedagogy, math is utilized from an observational and tactile perspective for many Indigenous communities, where abstract thinking and problem solving are key.

Making connections between math and everyday activities is also pivotal for Indigenous learners' success. As argued previously, Indigenous peoples have always incorporated math into their daily lives, and the challenge facing educators is to acknowledge the cultural activity, recognize the embedded numeracy in these activities, and apply this pedagogy to teach mathematics in school (Neel 2008, 50). This is crucial because some learners may find it difficult to recognize the links between mainstream math ideas learned at school, and the math concepts embedded in the everyday cultural practices in their communities (Hawera and Taylor 2011, 343). Neel points out that by showing Indigenous students how traditional and contemporary cultural activities have many mathematical concepts embedded within them, they can be motivated to learn (2008). Thus, connection to everyday environments and Indigenous cultural practices is key for learners to succeed in the acquisition of math skills.

4.3.2 Math in Place-Based Environments

Lastly, a key approach to finding math in everyday environments is to ground learning math in place (Sterenberg 2013; Aikenead 2017; Garcia-Olp, Nelson and Saiz 2019). 'Learning from place' not only recognizes the intimate relationship that Indigenous peoples have with the land, but it also continues to be a valid and meaningful method of interpreting and understanding the world, including math (Sterenberg 2013). For example, tactile, cultural practices which involve mathematical thinking may occur on the land, such as skinning a hide. Moreover, Sterenberg found that learning from place had a significant impact on student learning and student achievement (2013, 27). Being grounded in place creates a foundation in which Indigenous math curricula can be built, where learning occurs in, and through, everyday environments.

4.4 Grounding Math Teaching Strategies in Indigenous Approaches

While it is paramount to ensure math curricula is relevant for Indigenous learners, the pedagogical approaches used to teach math concepts are equally important for student success. Indigenous methods of teaching are unique to each community, however common trends include approaches which favour observation, hands-on learning, and relationality. Teaching strategies based on Indigenous approaches and pedagogy are to be developed with the students in mind, and grounded in the local community's teachings. By developing purposeful relationships with community members, educators can get to the heart of excellent Indigenous instruction strategies (see also Section 4.2.3 on Centering Community Involvement).

4.4.1 Localizing Teaching Methods

One example of an Indigenous math teaching method shared by an interviewee demonstrates how difficult concepts, such as fractions, can be better taught through local, cultural methods. Using a traditional drumming approach that was tactile provided the necessary context for learning that made math lessons more approachable:

> *The hand drumming for grade five's, the problem they were given to solve was: count the number of beats in a complete song […]. There's an Indigenous drummer*

> *whose teaching them about that, and they're learning an awful lot about the culture because that's what he taught them. Two students realized as they were going through that, that they didn't have to count all the beats, they just had to count the beats in one refrain that's repeated. They just had to count the repeated ones and multiply. [So] they memorized multiplying by grade five…and as soon as they told the others that, everyone caught on. (Aikenhead 2021)*

Quilting is another example of a hands-on approach to teaching math, as explained by Sajo:

> *Some of the projects that were trying to propel, one of the things that I would love to see is a quilting project that is started in the beginning of the school year and grows over the time, until the spring or the summer. It would be wonderful to set projects like that up within a school, so the kids are learning about important math concepts. So they'd be learning about measurement, they'd be learning about addition, subtraction, multiplication, division, they'd be learning about scope, they'd be learning about all kinds of things and it would all come into the point of putting a quilt together that comes with pieces from their individual backgrounds, and becomes part of, I think a living representation of who this group of people is. (Sajo, 2021)*

Teaching through hands-on learning means students can learn about their personal backgrounds and culture, and also math concepts (e.g., multiplication and division).

4.4.2 Teaching with Language in Mind

If educators and curricula are to create successful Indigenous learners, research suggests that both math language (i.e., words for terms and concepts) and Indigenous local language, should be the focus of instruction.

As previously discussed in Section 4.2.2, language-based strategies are promising for supporting Mi'kmaw, Cree, Mohawk, and other students in learning math (Borden 2016; Aikenhead 2021). It is also beneficial to have Indigenous teachers teach math content, as they may be fluent, or aiming to become fluent, speakers in their language and may have an inside perspective for how students learn. This can intuitively engage and motivate students (Parkins 2021). This is particularly true for Indigenous groups that use their language in their daily lives, as language continues to be an important component in gaining knowledge and understanding the world. Moreover, Indigenous language can convey culturally-appropriate interactions and exchange between educators and students.

Sajo points out that when teachers breakdown math language, it helps students to understand math content and concepts, particularly when math is taught in a non-Indigenous language:

> *[…] understanding how to read questions, and that's one of the things that we've been working away at for the last couple of years […]. Teaching kids how to approach a mathematical problem, in a way that strips away the stuff that they don't need and works at the stuff that they do need in order to get to an answer. (Sajo, 2021)*

Sajo also shared instances where language is employed by Indigenous educators in instrumental ways, including teaching on land:

> *I had one Indigenous, a Cree teacher actually […] and she's using what she learned as a math teacher to propel her kids in some really interesting projects that are stretching their traditional languages, and stretching their knowledge in making the application, so that the pieces fit together. And in the high school we have a couple of […] just fantastic language people over there […] and they too are embracing what we can offer and are finding ways of pulling the pieces together. They take the kids out on the land frequently and are doing a lot of math with them with their teachers out there. (Sajo 2021)*

Going one step further, research by Ruef et al. aimed to bridge math terms and concepts from English to Ichishkíin, and from Ichishkíin to English (2020, 314). Their goal was to develop a math curriculum written in Ichishkíin with an organized set of tasks and supports for teachers to implement in instruction when teaching math (Ruef et al. 2020, 314). Regardless of how educators choose to incorporate language in teaching math, research has shown that using language and cultural content in math supports students' overall knowledge and academic success (Borden 2016, 39).

4.4.3 Teaching through Relationships

Relationality and relationships are integral to a learner's journey, especially when math is involved, as math can be alienating in and of itself if students are not set up for success. If math is presented by a teacher in a complex manner, with no connections made to the learner, a student may not want to engage with math at all. Therefore, a student's relationship with math may be affected by their relationship with their teacher (Jungic 2021; Aikenhead 2017; Martinez 2019; Hawera and Taylor 2011). Teachers have the agency to make math content approachable and relevant, rather than intimidating. Borden states that,

> *[w]ithin culturally responsive education, teacher and student relationships are open, caring, and reciprocal. In this relationship, students and teacher can communicate what they are thinking and how they are feeling without being criticized or judged (2010, 50).*

Navigating socio-cultural environments through strong relationships between educator and learner are critical as Indigenous learners may hold different ways of thinking and absorbing information, and thus may respond better to different styles of communication (Borden 2010; Aikenhead 2017).

Notably, a student must feel comfortable in a math classroom, with ample opportunities for growth, and space to make mistakes in a guided learning process. For example, in Walpole Island First Nation, emphasis is placed on learn-as-you-do math and in-class demonstrations. This mirrors the long-standing 'apprenticeship system' of skill acquisition common among certain Indigenous cultures (Ezeife 2011, 26).

Community collectivism can also be a successful approach to teaching math, where learning is

> *rooted in relationality in which the inclusion of family, self, peers, community, school settings, and [E]lders all inform our Indigenous students' development and outcome. (Garcia-Olp, Nelson & Saiz 2019, 694).*

In particular, as highlighted by Hawera and Taylor, a key element in Indigenous education is the notion of actively promoting a close relationship between kura (school) and the community, which is important for supporting students' learning in math (2011, 341). Teaching through strong relationships between educator and learner, and supporting relationships which extend beyond the classroom to the community, is vital to ensuring success in learning math.

4.4.4 Scaffolding Learning

Lastly, building on a student's prior knowledge is an effective way to 'scaffold' learning math. Scaffolding learning refers to various teaching approaches where educators provide individualized supports to students when they are learning a concept (e.g., by modeling a math problem, or providing an outline), which stands in contrast to autonomous learning, where students are expected to figure out concepts independently. Scaffolding is critical in learning math terminology and concepts, as students' Indigenous knowledge or ways of doing can be utilized and applied to understanding new content. One example of an Indigenous teaching approach to scaffolding learning is to teach math on the land or through hands-on activities (Hawera & Taylor 2011). Various methods of scaffolding learning are inherently supportive and accepting of individuals, which directly relates to the key finding that math should be student-centered, as elaborated in the next section (4.5).

4.5 CENTERING AND SUPPORTING INDIGENOUS STUDENTS

Acknowledging, honouring and incorporating Indigenous practices in math learning inherently centres and supports Indigenous students (Ruef, Jacob, Walker & Beavert 2020, 315-6). When math is embedded in Indigenous ways of being, and is approached in positive and non-intimidating ways, students see that they are already doing mathematics, and that they can be mathematicians – they just need culturally-safe support to actively engage with math learning. For example, Ruef, Jacob, Walker and Beavert (2020) explain how their math curriculum revitalizes Ichishkiinn language and cultural teachings in order to connect learners to their 'sense of place' and respect for their culture. Their hope is that through this connection, the curriculum not only teaches math, but also acts as a mirror which reflects cultural knowledge back to learners, building their confidence. With this confidence in themselves and their culture, Indigenous students can develop positive relationships with learning and academia overall. This can be achieved when Indigenous students are the central focus of *all* math content, learning, and teaching.

4.5.1 Engaging Indigenous Learners

Ensuring Indigenous students are engaged in math is a key aspect of supporting learner-centered education. Engagement was also cited as a key factor in Indigenous-specific math program success and effectiveness (Jungic 2021). Math education that is based on meaningful content (see Section 4.2) creates positive outcomes and success for Indigenous learners by centering their learning processes and growth as the utmost goal. Further, engaging and empowering students can have the same outwards ripple effect to the surrounding local community.

Methods of engaging students in math while centering their learning can include tools such as games and other technologies. In order to continually keep students engaged, teachers need to keep up with what engages learners, including new technology to help them understand math in alternative ways (Hawera & Taylor 2011, 341). Learning through play and through hands-on activities are also effective strategies that make learning fun and engaging. For example, Indigenous games are a great way to engage students, as there are many skills that can be developed through fun, alternative methods, including strategy, probability, and problem solving. In 2019, Bernard and Gamble published "Indigenous Logic Games", which is math resource for educators for Grades 8 to 11. This resource is a compilation of logic and strategy games played by Indigenous people all over North America. They can be used as a stand-alone unit or as part of a lesson to incorporate Indigenous worldviews and perspectives into the math curriculum (2019, 2).

Engaging students in math can also take the form of promoting Indigenous identity. Promoting culture and language in math lessons sustains the identity of Indigenous students, further connecting them to who they are as Indigenous people, including mathematicians (Meaney, Trinick, & Fairhall 2013). Developing math curricula and programs that are infused with Indigenous practices and knowledges can engage and create success for Indigenous students who struggle or are not interested in math, while also supporting and revitalizing cultural identity.

4.5.2 Employing Positive, Strengths-based Measures of Success

Many Indigenous students have received and experienced negative feedback during math learning from teachers, which can also create a challenge for future teachers and educators in engaging and teaching those students. A deficit model of learning assessment focuses on what students do not know, rather than celebrating what they do know, which can create alienation and shame in a child's learning journey (Jorgensen 2020). Jungic shared an anecdote from a student who he was teaching in the Simon Fraser University Preparation University Program:

> *One of the reasons I have been running this Math Catchers Program is to try to give a positive experience in mathematics to young learners, because talking to my students I learned that almost each of them had a bad experience, had some kind of mathematical scar. One [student], she later volunteered with my program. She's from one of the big Nations in the north. She's Tlingit. She's probably one of the most intelligent people that I ever met. I asked her what was she doing in this Aboriginal University Preparation Program. She was just an incredibly intelligent*

> *young woman. She said that when she was in grade five or six, her math teachers called her mother and told her she should give up on mathematics. And that story it is equally tragic and incredible that somebody was willing to make that kind of damage to a child. (Jungic 2021)*

Despite this negative experience, with adequate support, this student went on to volunteer and succeed in math. In order to avoid – and heal from – these 'math scars', it is crucial to center trust, and validate Indigenous students' learning through positively encouraging participation and curiosity in math concepts. In contrast to deficit-models, culturally responsive education or curricula (CRE and CRC), as developed and exemplified by the Yu'pik communities' Math in a Cultural Context program for example, require culturally valid assessments (Lipka, Webster and Yanez 2005). Aikenhead has also found that culturally valid assessments are a factor which positively impacts Indigenous students' achievement in math (2017).

While overall education systems need to be revised to reflect Indigenous ways of knowing in assessment practices, many Indigenous math programs are employing promising alternative approaches to assessing math learning which are truly supportive for Indigenous students. For example, Aikenhead explains how teachers can tailor assessments to be specific to individual learners whom they already have a relationship with, generally through any activities that 'show what you know' in math:

> *The best assessment instrument is the teacher's mind. They know the students, they know what the students have been doing, and the assessment should not be "here the questions, what are the right answers?" The philosophy of the testing should be, I believe, 'show me what you know' and give students an opportunity to do that: to show what you know. There are some standard techniques related to that, but you can tap into student's creativity. (2021)*

Similarly, on-the-land learning can be assessed through 'exit slips' based on context and student-specific outcomes educators wish their students to achieve from the activity:

> *in our modules we have exit slips for lots of different things. And they're so adaptable that they can be used just about anywhere. That's how they would then be assessed. If we're going in a pre-discussion, what the teachers and whoever their guides might be on the land, [they] sit down and have a conversation about what it is that we want the kids to come away from this experience […]. So, in the pre-planning of it, teachers can start to pull together from what we have in the modules, questions, concepts, outcomes that they would like to see happen when they get the kids out there. And that can be assessed. It can be assessed visually, it can be assessed by taking photographs and videos […]. And the documentation doesn't necessarily mean written down. It can be visual, it can be some kind of artifact that the kids bring back with them if they've been out on the land. If they've been doing games, like stick games – there's evidence that the kids have been figuring it out and they'll say 'oh I just did it in my head'. But if push comes to shove and you really sit and ask 'so how did you determine what you needed to do here?' They will start talking to you about it. But that takes time. Time and a feeling of - the foundational relationships of trust are there. (Sajo 2021)*

As explained by Sajo, this kind of math 'assessment' truly centres the individual student and is dependent on supporting that student through a trusting relationship (see also Section 4.4.3). Alvarez (2021) similarly explained how they encourage students to continue trying, and to build off of learners' previous knowledge (see also Section 4.4.4 on Scaffolding Learning). These assessments are ongoing and reflect a student's learning journey in a non-competitive way.

Supporting Indigenous students' learning through effective math assessments can also take the form of inherently strengths-based exercises which do not rank learners against one another.

> *In line with the early cultural socialization experiences of Aboriginal learners, end-of-unit quizzes were administered as consolidating exercises aimed at diagnosing learners' strengths and weaknesses, instead of competitive, ranking-oriented school examinations. (Ezeife 2011, 26)*

In Maori communities in New Zealand, culturally responsive curricula, as well as a consistent use of Maori language, are cited as key factors that support positive assessment outcomes. Mathematics lessons are taught in *te reo* Maori (Maori language), and students generally achieve good results, both on the end-of-high-school assessments and other assessments, even compared to students in English-medium schools (Meaney, Trinick & Fairhall 2013, 240). Clearly, when Indigenous students are centred and supported in math education and assessments, improvements in learning and outcomes follow, ensuring that academic success in math is possible.

4.5.3 Upholding Lifelong Learner Success

Overall, if Indigenous learners are supported and engaged in math, and are assessed from a strengths-based perspective which contributes to their achievement, they are in an excellent position to be supported and successful in their future endeavours. Moreover, math can provide transferrable life skills which are important to Indigenous learners' overall educational trajectory. As explained by the Alaska Native Knowledge Network (1999), the underlying purpose of math is to use pattern recognition skills to solve problems. Students should be supported in learning various problem-solving strategies, so that they can perform complex math reasoning by extending the logic from simple models, to more complex situations. Hence, students should be able to apply math concepts and processes to situations within and outside of school, because as mentioned earlier, math encompasses our everyday daily lives (Neel 2008). When students are the central focus of learning math, they can understand the value in engaging in math concepts and can be successful in achieving both math concepts and valuable life skills (Czuy 2020).

4.6 Building Skilled and Competent Educators

It is imperative to ensure that Indigenous-centered math curricula is taught meaningfully by skilled, competent, and supportive educators. Teachers also need to feel supported in their teaching journey. This can occur through providing culturally-appropriate professional development opportunities, support and encouragement to foster relationship-building, and leadership at the school district level. During Sajo's interview, she stated that,

> *Teachers are key to the whole thing. It's about the relationships they build with their kids, the relationships they build with their communities, that's really important. And how they can kind of contextualize that relationship that the kids have with their environment and how to pull those pieces together with a more Western or European style, which is the way that many have been brought up with. But always paying very careful attention to honouring and respecting the kids that they are working with and their families. And the traditions that are so important and critical if we're going to keep things moving along (2021).*

Additionally, Aikenhead points out that when developing math curricula, and teaching math, both the "head" and the "heart" need to be involved together:

> *The mind is an intellectual organ, and to make up lesson plans for curricula it's all intellectual. That doesn't work. The brain needs the heart. You just don't get it. You're just going through the motions if your heart hasn't been led in whatever way (Aikenhead 2021).*

An educators' openness, support, and understanding is imperative. Teachers must have the capacity to consider students' experiences and culture (e.g., through learner-centered teaching, or scaffolding learning as described in Section 4.5 and 4.4), to teach culturally-relevant math content (as described in Section 4.2), and to shape 'everyday' math experiences (as described in Section 4.3).

Professional development training can be a space where educators build cultural competency and awareness as they learn about the culture and community in which they are teaching math (Nicol et al. 2020; Sajo 2021). While this is especially critical for educators who are external to the local community, even teachers from the local community can benefit from engaging with their relations as they can learn to build cultural responsivity into math education (Nicol et al. 2020, 27). One example is the professional development support provided for math teachers working with Indigenous students in Haida Gwaii as described through Nicol et al.'s research (2020). Space was created to discuss culturally responsive math education and what this means in the context of Haida Gwaii, to build interpersonal relationships with the community, and to participate in activities in cultural literacy (Nicol et al. 2020). It takes time to develop an approach to pedagogy that connects math, culture, and community. Regular meetings, trainings, or activities for teachers allowed the space and learning for educators to question, explore, and examine their teaching for effective math education (Nicol et al. 2010). Crucially, cultural engagement with the local community proved to be an asset that contributed to math teachers' professional learning (see also Section 4.2.3) (Nicol et al 2020).

In addition to providing professional development in cultural competency and engagement, some successful Indigenous math programs bolster teachers' math concepts through intensive trainings. Alvarez, who collaborated and worked with Veselin Jungic, shared that she and other staff from the UBC offer summer camps for both students and teachers. She stressed the point that teachers also need to comprehend math in-depth in order to become effective teachers:

> *Something else that we have, is summer camp for elementary school teachers. And this is a four-week summer camp. And actually, our priority are teachers that are mainly working at Indigenous schools. We invited teachers from there, and so we do four weeks of training. These are for in-service teachers. So, teachers who feel that they are not quite as comfortable in how they teach math, or they would like to learn a little bit more about that. (Alvarez 2021)*

Alvarez also underscores that teacher support is crucial because she finds that many teachers are not adequately prepared to teach math in elementary schools. Moreover, in remote communities where access or transportation is limited, there is often a lack of professional learning opportunities for educators. The more that educators, administration, and support staff are included in professional learning and development, the more that education in general can become equipped with the content that will form the basis of successful math education for Indigenous students. One of the elements of the South Slave approach to math education recognizes that many teachers who teach math are on their own journey. The staff are supported by infrastructure including a Math Coach and ongoing collegial support to challenge about how teachers can continually work toward being responsive to the needs of their students. The question of how to support the ongoing learning of teachers on their journey of becoming effective math educators needs to be considered. Thus, additional and continual support and professional development is necessary to make a difference in math learning for Indigenous students (Alvarez 2021).

District level, and school level, leadership and support is also pivotal for building competent math educators (Nicol et al. 2020, 38). This could include for example, district-level changes in hiring practices to ensure that math teacher candidates express their visions for culturally responsive education (which has occurred in some Haida communities) (Nicol et al. 2020, 39). Additionally, this same Haida school ensures that culturally responsive education is constantly an agenda item for all school staff meetings and district meetings, so that teachers and report and receive feedback on their approaches to teaching (Nicol et al. 2020, 39).

Grounding math education in Indigenous culture and knowledge is a long-term commitment. For this reason, professional development for math educators in the forms of cultural awareness training, in-depth math training, and discussions surrounding culturally responsive education need to be actioned. This strong professional development in math also needs to be supported by district, ministry and school leadership. Nicole et al. (2020) determines that there needs to be ongoing professional learning and development where leadership in education is championed, in order to mobilize Indigenous knowledges as an integral aspect of teaching.

5. CASE STUDIES

The literature scan and interviews revealed a number of promising practices relating to Indigenous math programs. The following cases include practical resources for educators and promising practices for administrators, and outline the types of collaborative and contextual approaches used to establish successful programs for Indigenous students.

5.1 MATH IN A CULTURAL CONTEXT

https://www.uaf.edu/mcc/

Math in a Cultural Context (MCC) is an ethnomathematics program co-developed by Yup'ik Elders, mathematicians, math educators, educational researchers, and school districts over the course of 30 years. MCC is a culturally-based math program which contextualizes and localizes math by choosing a cultural activity, using an interactional style of teacher-student observation and demonstration, and emphasizing the importance of the activity to community and kin (Likpa and Andrew-Ihrke, n.d.).

For example, in the module *Picking Berries: Connections Between Data Collection, Graphing, and Measuring* (Grades 2–3), students engage in a "series of hands-on activities that help them explore data, graphic representation and linear measuring. Students gather data related to the berry harvest to build and analyze tables and graphs, and they learn to read thermometers and measure the length of their shadows" (MCC, 2021). This is one of the many modules developed for elementary school grades (grades K-7) available on the MCC website free for download under a Creative Commons Attribution License, in addition to other resources (i.e., videos, storybooks).

A key strength of this program is that MCC conducted many rigorous studies on student outcomes, with clear efficacy results. MCC has been delivered to a number of schools across Alaska for many years, and 15 independent studies have shown improvement in student performance and demonstrated the program's effectiveness. MCC's work is ongoing and collaboration with new stakeholders – including recent partnerships with Greenlandic Inuit, Sami, and Pacific Islanders – means that the MCC curricula is routinely updated.

5.2 MATH FIRST PEOPLES: TEACHER RESOURCE GUIDE

http://www.fnesc.ca/math-first-peoples/

The *Math First Peoples: Teacher Resource Guide* is a comprehensive tool developed by the First Nations Education Steering Committee (FNESC), and informed by Elders, educators, and community leaders. The guide, created for math teachers in British Columbia, recognizes that students will have better outcomes if teaching approaches and content are more inclusive and engaging, but that educators, particularly non-Indigenous educators, may not be equipped to integrate Indigenous knowledges and approaches into their lesson plans. Therefore, FNESC created this guide to support teachers in building understanding of Indigenous knowledge and approaches and including these into the curriculum in respectful and non-appropriative ways.

The guide provides guidance on choosing and developing local Indigenous teaching and learning resources by identifying criteria to assesses curricula:

- *Indigenous Voice:* What cultural experts can contribute to the unit development and implementation?
- *Indigenous Languages:* How can the local First Nations languages be included in the lessons?
- *Diversity of Indigenous Groups:* Do the lessons recognize the diversity of First Nations? Can the unit be shared and adapted to other groups?
- *Protocol:* What protocols need to be followed during the implementation of the unit?
- Relationship with the Land: How can the unit reinforce the importance of the land, plants and animals to Indigenous people?
- *Ways of Learning, Ways of Teaching*: Are traditional ways of learning included? Are activities student centered? Is evaluation formative?

The guide provides key principles and concepts as well as sample multi-grade thematic units. For example, the unit *Playing and Learning from Lahal*, provides a context-setting introduction, followed by activities that enable students to build an understanding of experimental probability. The unit demonstrate how to use this traditional Indigenous game to teach probability and other math concepts – like collecting, displaying, and analysing data – and how to assess student learning. While the guide was developed for teachers and schools in based in BC, it can serve as a framework for other regions.

5.3 South Slave Divisional Education Council Math Education Approach

The South Slave Divisional Education Council (SSDEC) serves the needs of eight schools in the Northwest Territories, totalling approximately 1,500 primarily Indigenous students from K-12. Each SSDEC school has a dedicated Numeracy Lead, as well as a regional coordinator and contracted math consultant who assist in providing professional training, and supporting teachers in achieving numeracy outcomes (Government of Northwest Territories, 2018-2019).

SSDEC's approach to math promotes creative solution strategies and intuitive reasoning. They encourage students to develop their own solution strategies to mathematical problems, with adequate teacher support, and close teacher observation of progress. When discussing their approach to math, the SSDEC numeracy coordinator identified that they needed to have numeracy coaches to work with students in the classroom. They stated that it is crucial to have these numeracy leads help keep the program on track and have teachers be supported. This is especially beneficial as numeracy leads do not have any other job duties (unlike a classroom teacher) and can focus their efforts entirely on math learning.

Enhancing Indigenous language is also a core component of the SSDEC, and they offer classes and materials in Slavey, Chıpewyan, and Cree. In an interview, the numeracy coordinator for SSDEC explained that their language teachers have helped connect what the students are learning in math with what they are learning in culture and language classes, and this has proved very beneficial. SSDEC's approach to math also engages families by having

community events where math games are played so that parents can understand that the subject can be fun and approachable.

It is important to note that SSDEC has a comprehensive and extensive data collection and data tracking system for math learning outcomes. Teachers assess and track student learning frequently in their teaching of math concepts (often weekly) in order to make adjustments to teaching methods daily. For example, this may mean grouping students by certain abilities together for one math lesson, or adjusting group sizes, in a continually flexible way. Student data is colour-coded in a master spreadsheet, so that teachers know right away which students have grasped concepts (green), which students need support (yellow), and which students have not yet acquired understanding (red) (Sajo, personal correspondence November 4, 2021).

These spreadsheets are shared annually between grade levels, so that receiving teachers can see their students' learning journeys and know where their understanding is at in relation to the curriculum. This data is gathered and monitored consistently from school to school, teacher to teacher, and grade to grade, allowing students to be supported and gaps to be addressed (Sajo, personal correspondence November 4, 2021).

Overall, improving numeracy has been a successful Council priority since 2007. In the 2018-2019 school year, results indicated that 71% of SSDEC students are at or above the Canadian average in math, exemplifying that SSDEC's approach to math is meeting the needs of Indigenous learners (Government of Northwest Territories, 2018-2019, 15).

5.4 Transforming Education for Aboriginal Mathematics – Learning (TEAM-Learning)

https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.664.4716&rep=rep1&type=pdf

The Transforming Education for Aboriginal Mathematics – Learning (TEAM-Learning) is a community-based action research project that worked with students, parents, teachers, and community members to improve math teaching and learning for Indigenous students through culturally responsive mathematics education (CRmE), developed using participatory action research and Indigenous methodology. As stated in the report, CRmE may provide a framework for transforming mathematics education that "facilitates critical consciousness, engenders respect for diversity and acknowledges the importance of relationships, while honouring, building on, and drawing from the culture, knowledge, and language of students, teachers, and local community" (Nicol, Archibald & Baker 2010, 4).

This report provides details and examples of how teachers conceptualized a vision of CRmE, and actualized it within their classroom settings. Through this project, teachers transformed their views of mathematics, examined their own cultural identities, validated cultural practices from a mathematical perspective, and learned to be responsive to students' cultural backgrounds. "The educational significance of [the] research focuses on how teachers become aware of and responsive to Indigenous ways of knowing, students' culture and experiences, and mathematical thinking to develop their own curriculum and instruction" (Nicol, Archibald & Baker 2010, 7). According to the research team, a key part of supporting teachers to create

more culturally responsive curriculum involves opportunities for professional development for teachers to question and learn in collaborative and collective spaces.

The project findings provide a community-based model for developing culturally responsive approaches to mathematics teaching that draws upon and is rooted in Indigenous knowledges and methodology. Therefore, the report is a useful framework for enacting and living CRmE in a rural context.

5.5 INDIGENOUS LOGIX: MATHEMATICS, CULTURE, ENVIRONMENT (INDIGILOGIX)

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Grounded in the notion that Indigenous Knowledge has Always Been Mathematics Education (IK-HABME), a collective of Indigenous women in Denver (USA), alongside Elders, youth and community members, co-developed the *IndigiLogix* program to increase interest, access and outcomes of Indigenous students in math and sciences. The program teaches math from an Indigenous lens to ensure relevancy for Indigenous students "while carving out a space that [allows students] to be unapologetically Indigenous in the area of mathematics and in the academy" (Garcia-Olp, Nelson & Saiz 2019, 690). The curriculum is rooted in community and relationality, with the aim of decentering western notions of mathematics.

Garcia-Olp, Nelson, and Saiz (2019) describes key aspects of the STEM program, like the importance of tying Indigenous knowledge and histories to location and place. Through *IndigiLogix*, Indigenous Elders, educators and community members work with Indigenous youth to demonstrate how math concepts are tied to Indigenous practices – such as bean sorting, hunting and drum making. Moreover, key concepts like reciprocity are integrated into the program, where students were taught to make an offering when collecting pinecones for a teaching on math (Garcia-Olp et al. 2020). In order to explain spirals, sequences and the Fibonacci sequence, the *IndigiLogix* educators took their students to observe these spirals and sequences in nature. Before the students examined the spirals more closely, a teacher modeled giving water back to the earth before the pinecones were collected.

The creators of this place-based, culturally-specific program urge other educators wishing to engage in decolonizing math projects to adapt the program to best meet the needs and expectations of their own students, Elders and communities. According to the creators, the engagement process to adapt and develop relevant programming "is not a single event, but consultation should occur in different spaces, including individuals from different tribal affiliations, various ages, and roles held in the community" (Garcia-Olp, Nelson & Saiz 2019, 701).

6. Potential Implementation Outcomes

Based on the findings in Section 4, supplemented by the tangible case studies presented in Section 5, this section draws together potential positive outcomes which could arise from implementing Indigenous mathematics curriculum and approaches in the Yukon context. While each community and each classroom is unique, these broader trends are likely to be present in schools and programs which take a committed approach to decolonizing math learning.

6.1 Increased Student and Community Engagement

If Indigenous math curriculum is centred in community-based mathematics knowledge and history, students will be better engaged in math learning. Moreover, the literature and interviews showed that this engagement extends beyond math learning, and students come to feel valued and meaningfully involved in the overall school environment.

When Indigenous students' knowledge – and community knowledge – is present and valued, learners can truly engage in educational content. For example, the Mathematics in Indigenous Contexts (MIC) program enabled the Aboriginal history of the community to be upheld and applied in the program. MIC therefore enriched the involvement of Aboriginal students in their mathematics learning, created space for community-based mathematics teaching strategies, and increased the capacity of the community to engage in effective mathematics curriculum reform (Perry & Howard 2008).

Similarly, centring local Indigenous approaches to conceptualizing math also creates opportunities and space for greater community engagement in math learning. For instance, offering math games and numeracy activities during gatherings and family nights demonstrates to caregivers and families that math can be lots of fun. Sajo (2021) highlights examples of numeracy nights where families were very engaged in math concepts with their children, exemplifying that math is present outside the classroom, and in community.

6.2 Higher Academic Achievement Levels

If Indigenous students are assessed for math learning outcomes in ways that are relevant to their culture and lived experiences, they perform exceptionally well. When educators are cognisant of learners' strengths, this reduces bias in assessment practices (Nelson-Barber & Trumbull 2007). Culturally-appropriate assessment tools can help students to "show what they know and can do", by demonstrating skills and knowledge which are grounded in local Indigenous values (Aikenhead 2017). Thus, if assessing learning in mathematics measures the acquisition of mathematics knowledge in a cultural context, it is more likely that Indigenous students will see positive assessment outcomes.

When standardized results are assessed, it is typical for Indigenous students to outperform comparable control group students who use their regular math curriculum. In Alaska's Math in a Cultural Context (MCC) program, second grade students in Indigenous math programming in both rural and urban districts outperformed their control group counterparts on key outcomes such as measuring, graphing and tables, grouping, and place value. This reform-oriented math curriculum is one of the few curricula that has been extensively studied, and one of few

projects for Alaska Native and American Indian students that shows such powerful results (MCC Website (n.d.)). This trend repeats in other communities, where results showed that students from Walpole Island First Nation who were taught culturally-relevant curriculum performed significantly better than their counterparts taught the existing mainstream provincial curriculum (Ezeife 2011).

While improvement on standardized tests for Indigenous students went up dramatically, it is important to note that non-Indigenous students' enrolled in Indigenous math programs also performed better. "Not only do Indigenous students' mathematics scores rise dramatically (e.g., Lipka and Adams 2004; U.S. Congress HRSECESE 2008), but non-Indigenous students' average achievement increases noticeably (e.g., Furuto 2014; Nelson-Barber & Lipka 2008; Richards et al. 2008; Rickard 2005). Such research studies expose serious shortcomings in conventional school mathematics'' (Aikenhead 2017). These measures of increased achievement in assessment and testing – whether culturally-appropriate assessment, or standardized assessment of learning – indicate that closing the educational gap is possible with a decolonizing approach to education.

6.3 Improvements in Students' Overall Learning and Cultural Competencies

In addition to improvements in test scores and demonstrating mathematical knowledge acquisition, Indigenous mathematics can support students' overall learning and growth in a holistic manner. Learning and applying math is a transferable skill, and when math learning is not siloed to a subject discipline, it can support student growth (Sajo 2021). Interviewees explained that this occurred when students' talents are explored and developed through Indigenized math curriculum (Jungic 2021).

For example, when learners demonstrate their competencies in culturally-relevant ways (e.g., stretching hide), their artistic and cultural skills can flourish alongside their math skills (Sajo 2021). This outcome is achieved when holistic community-based and culture-based activities are used to teach math, because these activities value and support other skills meaningful to Indigenous ways of being.

6.4 Improvements in Educators' Overall Teaching Skills and Quality

Culturally responsive pedagogies in mathematics have shown to improve educators' overall teaching practices, which can not only better serve Indigenous students, but all students. When teachers are properly trained and supported to teach math in culturally-relevant ways (see Section 4.6), their professional skills as educators are bolstered, which in turn facilitates student learning (Rigney et al. 2020). For example, when educators effectively employ Indigenous mathematics methods through using hands-on and tactile activities, this accommodates all learners, especially diverse learners, in a classroom (Aikenhead 2017).

Fostering and supporting skilled and competent educators positively contributes to the overall school environment and quality of teaching in other subjects, as well as the relationship between educators and learners outside the classroom. Further, increasing cultural-safety skills ensures that educators can create a space free of racism and discrimination, where Indigenous students feel safe and supported.

6.5 Accurate and Timely Assessment and Data Collection

When accurate data about students' math learning is collected (preferably through alternative or Indigenous assessments), comprehension can be monitored throughout the school year and help educators respond to students' needs in a learner-centred paradigm. Assessment data collection should be frequent and ongoing so that math curriculum and approaches to teaching can remain flexible and relevant for Indigenous students. For example, weekly or daily spreadsheets can track math outcome comprehension, and sheets can be constantly updated as well as shared annually between teachers, as per the SSDEC's current practices.

In this way, assessment data can act as a guiding framework for schools, highlighting where gaps should be addressed, where students should be upheld and supported, or where educators may need more professional support. Accurate data can help educators understand and meet a student where they are at, ensuring their individual progress and success in math learning.

7. CONCLUSION

This *Environmental Scan of Indigenous Math Education and Tools* provides an overview of math education for Indigenous students, in an effort to gain a better understanding of potential options for improving math literacy in Yukon. The findings highlight how Indigenous communities have not been well-served by western educational systems which has resulted in gaps in learning outcomes, high school graduation rates, post-secondary enrollment, and an underrepresentation of Indigenous peoples in STEM. Yet, the study has also found that Indigenous cultures have always had their own complex and intricate math systems, and Indigenous knowledge 'has always been mathematics education,' (Garcia-Olp, Nelson and Saiz 2019). Still, mainstream math education continues to dismiss and exclude Indigenous knowledge and pedagogies, making math less accessible, relevant and meaningful to Indigenous students.

Based on this context, as well as the literature and key informant interviews, findings point to common positive trends which are moving away from western approaches, towards decolonizing math education; creating curricular content in centred in Indigenous culture and environments; implementing Indigenous pedagogies; and supporting both Indigenous students, as well as educators, in the learning process. The case studies detailed in this report exemplify that these trends have, and do, occur in different contexts and regions globally. Students who participate in these programs perform better in math, and importantly, feel more supported in a way that upholds their inherent experiences, capacities, and gifts. Other potential outcomes of implementing these findings can include increased student and community engagement in math, improvements in student's overall learning and cultural competencies, and improvement in educators' overall teaching skills.

It is important to acknowledge and honour Indigenous ways of knowing and being as part of math education, as Indigenous learners themselves already have math embedded within them. By demonstrating to students the ways in which their ancestors were mathematicians and scientists, students will feel a stronger sense of belonging, and math will have a better sense of meaning. Importantly, by supporting Indigenous peoples to study and work in STEM, the world may also be awakened to different, more holistic and comprehensive ways of understanding and applying math, to the benefit of all.

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APPENDIX A: INTERVIEW GUIDE

YUKON FIRST NATION EDUCATION DIRECTORATE

INTERVIEW GUIDE FOR THE ENVIRONMENTAL SCAN OF INDIGENOUS MATH EDUCATION AND TOOLS

1. Pre-Interview

Before formally beginning the interview, ensure the following has been completed:

1. Introductions
    - Introduce yourself and the research team, who you work for, who you were hired by, and who you report to.
2. Give the participant an overview of the project and goals of the research. Read the following:
    - The Yukon First Nation Education Directorate (YFNED) was launched in response to the need for First Nations leadership and involvement in education. YFNED is focused on capacity-building, systems and resource development, second-level educational program and service enhancement, and learner supports. YFNED advances First Nation decision-making and aspirations for greater control over education by providing technical support, research, advice, and advocating for First Nation student success.
    - This project (the Environmental Scan of Indigenous Math Education and Tools) aims to gain a better understanding of potential options for improving math literacy in Yukon, especially in rural and remote Indigenous contexts, to inform development of a pilot mathematics program.
    - The purpose of this research is to support YFNED in their ongoing work and research towards identifying:
        a) Innovative mathematics approaches and tools that are already implemented and proven to be successful for First Nations or Indigenous students elsewhere in Canada and internationally;
        b) Recognized strengths and weakness of existing and available mathematics approaches and tools for Indigenous contexts;
        c) Pilot mathematics approaches that been created, adapted, or tailored for use with Indigenous populations, best practices in the delivery of these programs for Indigenous students, and accountability measures and indicators for success in these approaches; and
        d) How YFNED can learn from the above to create, adapt, or customize their own pilot mathematics approach for use in the Yukon with First Nation students.

- From this, Firelight will be preparing a report for YFNED that provides an environmental scan and status assessment with respect to the above listed focus areas.

3. Explain the outline of the interview process.

4. Provide an opportunity for the participant to ask questions.
   - Providing accurate answers to participants' questions is an important aspect of free, prior and informed consent.
5. Review the consent form.
   - Read the consent form aloud to the participant if requested.
   - Ask the participant if they have any questions.
   - Once the participant's questions have been answered, review the consent form before beginning the interview. For obtaining verbal consent, ensure that the audio recorders are on, read through the consent form, and have the participant provide their verbal consent for the recording.
   - If the participant does not provide recorded or written consent, **do not continue with the interview.**

2. Introduction

Read the text below with AUDIO RECORDERS ON at the start of each interview.

Today is [date]. We are interviewing [participant name] for the YFNED Indigenous Math Education and Tools Project. Thank you for your time today.

My name is [name] and my co-researcher is [name]. [Participant name] has provided verbal consent, and I have explained the purpose of the study and interview.

3. Background and Experience

1. What is your current position (including position title, affiliations, etc.)?

2. What is your experience and involvement in math education for Indigenous students (past or current)?

   a. Which location or community does this program/curriculum/tool/approach serve?

   b. What is the target age groups for this program/curriculum/tool?

3. Can you tell us about how the Indigenous math education program/curriculum/tool/approach was developed?

a. What was the process, and who was involved? [*prompts: were Elders, leaders, parents, community members or education specialists brought in to steer the program/curriculum development?]*

b. Was it based on an existing model?

4. Can you tell us about the administration of the program? *[prompts: staffing/HR]*

    a. Can you share anything with us about the funding model of the program?

    b. Are there any funding barriers and challenges?

4. Core Components of Programs

Content and Curriculum

5. How did you know that there was an issue with math results for Indigenous students? How did you define the problem?

    a. Which particular areas of math were your Indigenous students struggling with, and how did you know?

6. What did you decide to change about your approach to math, and what data lead you to make this decision?

7. Is your current approach compatible with the provincial/territorial curriculum/program? Please elaborate.

8. Is Indigenous knowledge, culture, languages, histories and worldviews integrated into the curriculum? If yes, how?

9. Are there any other important or unique features of the program/curriculum/tool that we haven't discussed?

Methods of Teaching

10. Can you speak about the key elements of your program that you feel are critical to its success?

    a. How are teachers supported in the delivery of this approach?

    b. Does the program incorporate Indigenous pedagogy in teaching? If yes, how? *[prompts: experiential learning, land-based learning, etc.]*

    c. Does the program offer student mentorship or peer-to-peer support and learning, or other student supports?

    d. How do these methods accommodate for different learners?

11. Does the program utilize any specific technology to support student learning? [*prompts: computers, tablets, videos, mapping]*

Learning Environments

12. Can you tell us about the places your students learn math? [*prompts: in a classroom, in the community, on the land?]*

13. Is the program tied to any wider community supports or programs? *[prompts: integration with special needs or allied health supports?]*

Effectiveness

14. How do you monitor and measure students' performance? Do you use any specific assessment tools?

15. What are the key quality indicators that you use for your Indigenous math education approach?

16. If they participate, how do students perform on standardized math tests or other measures, both before and after your intervention?

17. Has student engagement in math class changed as a result of your intervention, and how do you know?

5. Best Practices and Opportunities

18. Are you aware of examples of *other* Indigenous math education programs that are success stories for Indigenous learners?

    a. Do you have further recommendations for who to speak to about our research?

    b. Do you have any suggestions of resources or tools we should explore?

19. What is the main lesson that you learned from your approach?

20. Do you have any final comments you would like to share?

6. Conclusion

Thank you for taking the time to speak with us today to share your knowledge.

Read with audio recorders on after every session.

Today is [date]. We have just finished interviewing [participant name] for the YFNED Environmental Scan of Indigenous Math Education and Tools.

My name is [name]. Notes are recorded in/on [notebook/computer]. This interview has taken approximately [#] hours [#] minutes.

APPENDIX B: CONSENT FORM

I (name) _____, on this day (complete date) _____, consent to participate in a key informant interview regarding the Yukon First Nation Education Directorate (YFNED) Environmental Scan of Indigenous Mathematics Curriculums and Tools.

I understand that this study is being conducted by the YFNED, with the support of The Firelight Group. The purpose of this interview is to identify innovative and successful Indigenous-led mathematics approaches, with a particular focus on best practices for improving math literacy in rural and remote Indigenous contexts. Additionally, this interview seeks to identify indicators for success that can support YFNED to improve mathematics curriculum in the Yukon First Nation context.

Participants will have the opportunity to review the notes and transcriptions from their interview in order to make additions or clarifications to collected information, if requested.

By signing below or verbally acknowledging the following, I indicate my understanding that:

a) I consent to have my words and responses recorded via audio recorder and notes.
b) I am free to NOT respond to questions that may be asked, and I am free to end the interview at any time.
c) I will have the opportunity to review the information collected following this interview to make additions or clarifications to the information I provided, if I request to do so.
d) I grant YFNED the right to use any intellectual property that I choose to share as a participant in the study, for purposes specific to the study and not beyond that. YFNED will ask for my consent for any additional use beyond those purposes.

For more information, please contact Lindsay Moore, Education Analyst YFNED at Lindsay.moore@yfned.ca or 867.667.6962 ext. 105.

I would like my quotes included in reports: ☐ **yes** ☐ **no**

I am willing to have my name included in reports**:** ☐ **yes** ☐ **no**

Signature of participant/verify oral consent _____