Considering Indigenous Perspectives in the Teaching and Learning of Mathematics: A Review of Literature

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Abstract: As part of the journey toward reconciliation for education, teachers are exploring how Indigenous perspectives might be considered within the teaching and learning of mathematics. This literature review synthesizes research from articles, theoretical frameworks, book chapters, a previous literature review and a dissertation to provide guidance for mathematics teachers. Previous beliefs about mathematics as culturally-neutral have given way to the understanding that mathematics is, in fact, connected to culture. Research suggests teachers consider the important connectedness between mathematics, people, place, and land. These findings are significant to teachers who are tasked with new curricular outcomes with specific Indigenous components to ensure respect of Indigenous ways of being, knowing and doing. Future research is suggested to support teacher professional learning in culturally responsive mathematics and expand our understanding of mathematics itself, beyond our Western/Eurocentric definitions.

Keywords: Indigenous Pedagogy, Elementary Mathematics Education, Culturally Responsive Mathematics, Mathematics Curriculum

Acknowledging the Land

As a non-Indigenous person living in the Treaty 7 region, it is important I situate myself in relation to the knowledge and learning I have experienced through the process of this literature review. I gratefully acknowledge the Blackfoot Nations, which includes the Siksika, the Piikani, and the Kainai. I would also like to acknowledge the Tsuut'ina and Stoney Nakoda First Nations and the Métis. I am grateful for all who make their homes in the Treaty 7 region of Southern Alberta. Additionally, I would like to acknowledge the Indigenous communities around the world who shared their ways of knowing, doing and being with the scholars included in this literature review. I am thankful for the opportunities I have to learn, and I commit to continued reconciliation through education.

Introduction & Rationale

In 2015, the Truth and Reconciliation Commission of Canada (TRC) released its ninety-four *Calls to Action* to engage all Canadians on a journey of reconciliation. Particular calls are significant in reconciliation for education, including: "developing culturally appropriate curricula" (TRC, 2015, 10-iii), and "developing and implementing kindergarten to grade twelve curriculum and learning resources on Aboriginal peoples in Canadian history, and the history and legacy of residential schools" (TRC, 2015, 63-i). These have a direct impact on teaching and learning. Perhaps in response to these *Calls to Action*, the Alberta government released specific Indigenous learning outcomes in its new kindergarten to grade six mathematics curriculum. Below are some examples:

> Kindergarten (knowledge) - First Nations, Métis, and Inuit relate specific shapes to those found in nature;
> Grade Two (skills & procedures) - Investigate First Nations, Métis, or Inuit use of the land in estimations of length;
> Grade Four (skills & procedures) - Recognize the rearrangement of area in First Nations, Métis, or Inuit design. (Alberta Education, 2022, mathematics curriculum)

Alberta elementary mathematics teachers need to find ways to authentically incorporate these outcomes in our teaching and learning, while avoiding cultural appropriation and tokenism. While traditionally mathematics has been positioned as culturally neutral (Aikenhead, 2017), these outcomes highlight a need to reconsider the significant role culture plays in mathematics. Examining culturally responsive pedagogy and its impact on mathematics education supports an understanding of how this learning is "grounded in place, connected to cultural stories, focused on relationships, inquiry-based, and requiring personal and collective agency" (Nicol et al., 2013, p. 82). We have a responsibility to our students to provide meaningful learning experiences, but an equally important responsibility to Indigenous peoples to engage in this content with hearts and minds open. How might teachers meaningfully consider Indigenous perspectives in the teaching and learning of mathematics?

Research Methods

The articles for this literature review were collected with searches in the Education Multi-Database (ProQuest), ERIC (EBSCOHost) and the University of Alberta libraries search tool. Search terms included: '*culturally relevant pedagogy*,' '*mathematics education*,' '*Indigenous pedagogy and mathematics*,' and '*ethnomathematics*.' The ProQuest Dissertations and Theses database was searched using the terms '*ethnomathematics*,' '*Indigenous ethnomathematics*,' and '*Indigenous pedagogy and mathematics*.' Numerous articles located through these searches also were used to search further using backward citation chaining. The query '*What does it mean to practice culturally responsive mathematics pedagogy*?' was used in the AI tool, Elicit (Elicit, 2024). Additionally, the AI tool Litmaps (Litmaps, 2024) was used to create a seed map from Lunney Borden & Wiseman (2016) to locate additional resources. Articles located from the aforementioned searches were eliminated based on the lack of empirical research, not being peer-reviewed, or not targeting the guiding question with enough specificity. Twenty academic articles or chapters and one dissertation are included in this literature review. In addition, three supporting theoretical frameworks and one literature review are referenced.

An important consideration was the presence of the voices of Elders and other Indigenous community members in the research studies included in this literature review, and evidence of decolonizing methodology. This represents a shift from considering "Indigenous people as the objects of investigation…to a focus on mutual benefit between the researcher and the studied Indigenous community" (Warren & Miller, 2013, p. 158). Indigenist research methodologies ensure Indigenous voices are prioritized (Lunney Borden, 2013) and research exists within relationships (Sterenberg, 2013a). When involving Indigenous communities or Indigenous stories, research should reflect Indigenous ways of knowing, being and doing, which demonstrates respect for those involved and for the knowledge shared.

Literature Review

Culturally Responsive Mathematics Pedagogy

Culturally responsive pedagogy (CRP) is a framework initially suggested by Ladson-Billings (1995) based on her research with teachers and African American students in the United States. This framework guides the pedagogical practice of teachers in confirming the critical importance of sharing expertise between stakeholders (i.e., students, Elders, community members, and teachers), and acknowledging the importance of community as curriculum (Ladson-Billings, 1995). While not specific to mathematics education, Ladson-Billings highlights the significance of culture in teaching and learning.

When considering mathematics through a culturally responsive framework, a critical point is the historic belief of mathematics being 'culture-free' (Bishop, 1988). Mathematics is not culture-free (Martinez, 2019) and in fact, is closely connected to cultural identity (Abdulrahim & Orosco, 2020). Knowledge is shaped by the values and the beliefs of a culture. For example, Meeran et al. (2022) worked with local South African Elders to locate the mathematics within traditional Indigenous games. Culturally relevant mathematics (CRM) invites a shift in the voice of mathematical authority; where culture finds space alongside our traditional understanding of mathematics (Lunney Borden et al., 2019). Nicol et al. (2013) suggest a framework for culturally responsive mathematics education, based on their work with educators and community members (both Indigenous and non-Indigenous) in an Indigenous Nation in British Columbia. This framework reflects the pedagogical practices for CRM and includes five elements: grounded in place, inquiry-based, focused on storywork, centered in relationships, and involving agency and action (Nicol et al., 2013).

The relational protocols of respect, relevance, reciprocity, and responsibility (Kirkness & Barnhardt, 1991) are used in the following section to explore Indigenous perspectives in mathematics pedagogy in further detail.

Indigenous Perspectives in Mathematics Pedagogy

Respect. Integrating Indigenous mathematics knowledge into pedagogical practice demonstrates respect for the traditional ways of knowing, being, and doing of Indigenous communities. Indigenous mathematical knowledge lives as a continuing process, emerging from generations of a community's experiences (Sterenberg, 2013a). It is embedded

in the relationships between people, place, and land (Robinson et al., 2023). This represents a different view of knowledge from non-Indigenous mathematics (school-based mathematics), which often asks students to learn from abstract concepts, disconnected from personal knowledge and experience. In his research alongside Yup'ik Elders and community members in Alaska, Lipka (1994) explored various Indigenous mathematics knowledges (e.g., coordinate geometry in basket weaving) to contextualize mathematics within Indigenous culture. Lunney Borden (2013), working with Mi'kmaw community members in Eastern Canada, revealed the critical importance language plays in culturally relevant mathematics. For example, there is no translation for the word 'flat' in Mi'kmaw (Lunney Borden, 2013), which may invite teachers to reconsider how language is used within non-Indigenous (Western/school-based) mathematics. Developing a respectful pedagogy includes bringing place, language and diverse mathematics knowledges to the centre of teaching and learning.

Relevance. The concept of relevance in Indigenous mathematics returns to the importance of place in learning. According to Ewing et al. (2010), mathematics learning is often presented as discrete concepts, with little connection to the lives of students. Mathematics, however, is socially constructed (Lipka, 1994); and understanding is developed through interactions between people and place. Adams et al. (2005) describe the process of relating mathematics to place in a star navigation and angle measurement project with Yup'ik Elder, Frederick George. The mathematical knowledge shared in this project is relevant particularly to those living in Alaska. The researchers, teacher, and Yup'ik community members all described a sense of harmony when observing the students "contruct (ing) their own path" (Opbroek, in Adams et al., 2005, p. 76), as students developed a deeper understanding of the mathematical concepts. Meaningful experiences for students create a sense of relevance, and this happens when mathematics reflects a local context.

Reciprocity. Reciprocity lies within relationships, where Indigenous and non-Indigenous community members, teachers, and students are "walking side-by-side" (Martinez, 2019, p. 65). Relationships between students and teachers are part of a strong pedagogical practice. However, relationships within Indigenous CRM extend beyond the classroom, to involve the community in developing the mathematical understanding of students (Lunney Borden et al., 2019). In this way, teachers and students have the honour of learning from community members, and community members have the opportunity to have their voices considered as authentic funds of mathematical knowledge. Indigenous Elders are critically involved in this process; as holders of mathematical knowledge, and trusted members of Indigenous communities (Adams et al., 2005; Beatty & Blair, 2015; Lipka, 1994; Lunney Borden et al., 2019; Martinez, 2019; Meeran et al., 2022; Nicol et al., 2013; Robinson et al., 2023; Sterenberg, 2013a). Beatty & Blair (2015) co-constructed mathematics lessons for grade two students in Algonquin looming and emphasized the importance of Elders in the project through iterative conversations throughout the research process. The reciprocal nature of Indigenous perspective in mathematics pedagogy inspires a shared relationship between Indigenous and non-Indigenous teachers, students, Elders, community members, all woven together by mathematics.

Responsibility. Cree Elder and scholar Willie Ermine (2007) invites us to consider the theory of 'ethical space'; that is, "the notion of a meeting place, or initial thinking about a neutral zone between entities or cultures" (p. 202). Teachers, leaders, and policy makers are accountable for negotiating both Indigenous and non-Indigenous mathematical knowledges in this ethical space. One does not precede the other; each is held in its own regard. Indigenous mathematics should not be considered additional to non-Indigenous mathematics; nor should ideas be oversimplified outside of their context (Lunney Borden, 2013). Within this ethical space, conversations occur to explore how each knowledge exists separately, but also to inform the other (Robinson et al., 2023). Sterenberg (2013b) provides a visual representation for the ethical space as "an intertwined image where Indigenous and Western mathematics encircle one another as they embrace, twist, or wrap each other. This implies that each type of mathematics is preserved, and the twisting together adds tensile strength to the learning" (p. 94). This is our responsibility when considering Indigenous perspectives in mathematics.

Limitations

In describing the rationale for their research, several scholars recognized a gap in mathematics achievement in Indigenous learners (Adams et al., 2005; Ewing et al., 2010; Warren & Miller, 2013). Additional research projects began by recognizing the difficulties students have in negotiating different knowledge systems and learning to 'fit' within what is constructed at schools (Ladson-Billings, 1995; Tate, 1995). This marginalization of Indigenous students in mathematics leads to disengagement because of the lack of inclusion or recognition of culture in mathematics (Lunney Borden, 2013). The success and engagement for Indigenous students is critical, and the research tries to

further understand how culturally relevant mathematics pedagogy and intentional recognition of Indigenous knowledges positively impacts this group of students. However, the intent of this literature review is to draw on research to support the pedagogical practice of teachers when implementing aspects of new curriculum related Indigenous perspectives in mathematics for all students. As such, the literature included less explicit pedagogical recommendations when considering how to guide teachers.

Recommendations for Future Research

Building on the identified limitations, many researchers recommended additional research areas related to teacher professional learning. There is an identified need to support teacher growth in understanding various aspects of culturally relevant mathematics (Adams et al., 2005; Harding-DeKam, 2014; Lunney Borden et al., 2019). Bishop (1988) remarks "teacher education is the key to cultural preservation and development" (p. 190). Further to this, exploring a model or reflective tool for teachers based on the identified features of culturally responsive mathematics is recommended (Bonner & Adams, 2012; Nicol et al., 2013).

A second key area of research identified through this literature review is our understanding of mathematics education itself. Lunney Borden et al. (2019) suggest bringing together teachers, Indigenous Elders, researchers, and mathematicians to explore mathematics concepts embedded within cultural knowledge. In her dissertation, Graham (2020) reveals how further research through/with Indigenous knowledges might serve to redefine our Euro-western view of mathematics. Additional exploration of mathematics knowledge existing within Indigenous culture, community and daily practices is needed (Lunney Borden, 2013). While numerous studies examined mathematics embedded within specific Indigenous cultures (i.e., the Yup'ik people of Alaska [Lipka, 1994]), it is important to recognize how community-specific this mathematics knowledge can be. Further research, guided by Elders and Indigenous communities, would be beneficial to teacher-researchers seeking specific knowledge connected to *their* place of teaching and learning.

Implications for Teaching & Learning

In relation to the findings from this literature review, one of the most significant implications for teaching and learning is connecting Indigenous knowledges to place and community. As Robinson et al. (2023) share, "you need to take time to come to know and understand a place, to hear the language it speaks, to hear the stories it tells, and what it might be teaching" (p. 1064). Connections to the community can be made by engaging children through their experiences at home (Beatty & Blair, 2015), which would develop the relationship between home and school (Ladson-Billings, 1995). These are important in strengthening the foundations on which learners build their mathematical knowledge. While considering the local cultural knowledge of a community and students is key (Bonner & Adams, 2012), Bishop (1988) suggests six mathematical practices evident in all cultures: counting, locating (spatially), measuring, designing, playing, and explaining. These six practices might be a starting point for teachers seeking ways to explore local Indigenous community mathematical knowledge. However, caution is offered in trying to 'Indigenise' mathematics, if the purpose is still to learn Eurocentric mathematics and be assessed against Eurocentric standards (Stavrou & Murphy, 2022).

Teachers must also consider how Indigenous knowledges work in relation with non-Indigenous mathematics knowledge, found in the curriculum. Aikenhead (2017) cautions "teachers cannot be guided by a curriculum hypothetically envisioned by its writers who lack the experience of introducing Indigenous perspectives into their own mathematics classrooms" (p. 79). What reveals itself often in the literature is the importance of how the relation between these two knowledges exist. Ewing et al. (2010) advocate for a blending of aspects from each cultural system, but not having one subjugating the other. In describing the experiences of a Blackfoot teacher, Sterenberg (2013a) explains the teacher was unsuccessful when trying to integrate Indigenous perspective after beginning with Western mathematics. The teacher tried again, beginning first with Blackfoot knowledge, and then relating Western mathematics, with much more authenticity. Each perspective brings with it strengths in the teaching and learning of mathematics (Beatty & Blair, 2015), and students should have the opportunity to interact with both knowledge systems (Sterenberg, 2013b). Teachers have a critical responsibility to ensure Indigenous mathematics knowledge is not an 'add-on' (Lunney-Borden et al., 2019), especially when tasked with the new outcomes for elementary mathematics in Alberta.

It may be worthwhile to consider how the province of British Columbia has integrated Indigenous ways of knowing, being and doing in their mathematics curriculum. It is guided by *The First Peoples Principles of Learning* (FNESC, n.d.), a document for educators created by Indigenous Elders, scholars, and Knowledge Keepers. This mathematics curriculum aligns with numerous findings from this literature review, including inviting Indigenous voices to be a part of the learning process and ensuring learning is relevant to place (Government of British Columbia, n.d.).

A final consideration is pedagogical style. A tenant of culturally responsive mathematics is ensuring topics of inquiry are not predetermined by the teacher (Enyedy et al., 2011). Therefore, the teacher must enter this learning with an openness, and accept this pedagogy as "unpredictable, always in the process of becoming" (Ladson-Billings, 1995, p. 478). The teacher takes on the role of facilitator, which lends itself to a problem-centered and inquiry-based learning approach (Adams et al., 2005; Lunney Borden et al., 2019).

Conclusion

This literature review is intended to guide Alberta elementary teachers in considering new Indigenous mathematics curriculum outcomes in authentic and meaningful ways. While teachers are often seeking practical solutions to challenging questions, there is no one way or formula to follow when engaging students in Indigenous mathematics (Martinez, 2019; Robinson et al., 2023). It is also not about merging Indigenous and Western mathematics concepts, but rather considering each in their own right (Sterenberg 2013a). The TRC advocates for "building student capacity for intercultural understanding, empathy, and mutual respect" (TRC, 2015, 63-iii). As such, a critical point is the pride Indigenous students develop when Indigenous mathematics is valued alongside non-Indigenous mathematics, but equally important is the respect non-Indigenous students develop through these learning experiences (Martinez, 2019). When considering Indigenous perspectives in mathematics, the most important reminder for teachers is to ensure Indigenous voices, and their ways of knowing, being and doing, are at the heart of teaching and learning.

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