CHAPTER 10

Relationships and Reciprocity in Mathematics Education

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INTRODUCTION

This chapter explores the importance of creating and maintaining reciprocal relationships with Indigenous community partners for the teaching and learning of mathematics. As part of the First Nations and Métis Math Voices research study, 13 teams across Ontario comprising Indigenous leaders, artists, educators, and non-Indigenous educators worked together to explore connections between Anishinaabe or Métis cultural practices and the mathematics inherent within these practices. The projects have taken place in different community settings that varied in terms of contexts and participants. Each individual project was at the local grassroots level and driven by the views, opinions, resources, and interests of participating communities. Project sites included federal schools each within a First Nation, and provincially funded public schools. In rural settings schools had ties to and tuition agreements with a specific First Nation. In urban settings community research team members were invited via the board's Indigenous Education Advisory Committee and so did not represent one specific First Nation, but rather urban Indigenous communities that created themselves as "intimate, human, and self-defined spaces" (Smith, 2012, p. 127). For this chapter we have included projects led by an Anishinaabe artist from the Chippewas of Nawash First Nation, an Anishinaabe artist from the Algonquins of Pikwakanagan First Nation, two community leaders from Matachawan First Nation, and two Métis educators and artists who are descendants of the Red River Métis and now living in Ontario (one a former senator and one the former president of the Grand River Métis Council). The activities included different kinds of beading (loom, medallion, and peyote stitch), birch bark basket making, moccasin making, and Métis finger weaving.

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A focus of this work was reclaiming mathematics as part of Indigenous cultures, with the view that school mathematics is one of many diverse mathematical practices and is no more or less important than mathematical practices that have originated in other cultures and societies (Mukhopadhyay et al., 2009). Instruction was designed to generate mathematical thinking by combining traditional Indigenous practices and conventional mathematics. Our goal was to make math meaningful and relevant to First Nations and Métis students by making an explicit connection to their communities, and to provide an opportunity for all students to experience culturally sustaining mathematics instruction.

We followed a cyclical process that began in each community with an initial consultation to ensure the work was grounded in local circumstances and responsive to the community's educational goals. Project team members then co-planned and co-taught a particular form of technology and/or artistry chosen by the community based on either their own priorities for cultural revitalization or the funds of knowledge of participating artists. Cultural teachings were shared by artists through the process as they saw fit. Woven into the cyclical process of relationality were accountability measures of respect, reciprocity, and responsibility (Kirkness & Barnhardt, 1991; Wilson, 2008).

Each team included a member who acted as the "translator," the person who can speak in a way understood by both school systems and staffs, and communities and community partners, to guide the navigation of the project. In most projects this role was carried out by the school board's Indigenous Education lead. All of the leads we worked with were Anishinaabe and provincially certified teachers; consequently, they were in a unique position to explain the work using a Eurocentric educational perspective so that it was intelligible to non-Indigenous school board administrators and colleagues and, importantly, could also connect with community partners to describe the work using an Indigenous lens.

This chapter presents examples of projects that integrated mathematics instruction into an Indigenous cultural framework. The chapter also highlights the outcomes of this work including its impact on students, community partners, and non-Indigenous educational allies.

LOOM BEADING

We have facilitated loom beading and mathematics investigations in many different classrooms with students from grades 2 through 8. When exploring loom beading, the students learned about the cultural background of the artists and the history of beadwork including pre-contact materials (sinew, porcupine quills,

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shells). The artists introduced principles of design, and inspired students with their design processes. The students also received important cultural teachings—for example, why and how to respect materials, and the importance of holding good thoughts while engaging in the work.

Students were then taught how to create their patterns using a square grid template (figure 10.1), in which the rows represent the spaces between the horizontal warp threads, and the columns represent the vertical weft threads onto which the beads are strung.

Students copied, extended, and analyzed patterns that the artists created, and then had the opportunity to create their own designs. Once their designs were complete, they were taught how to string a loom, and create their beadwork.

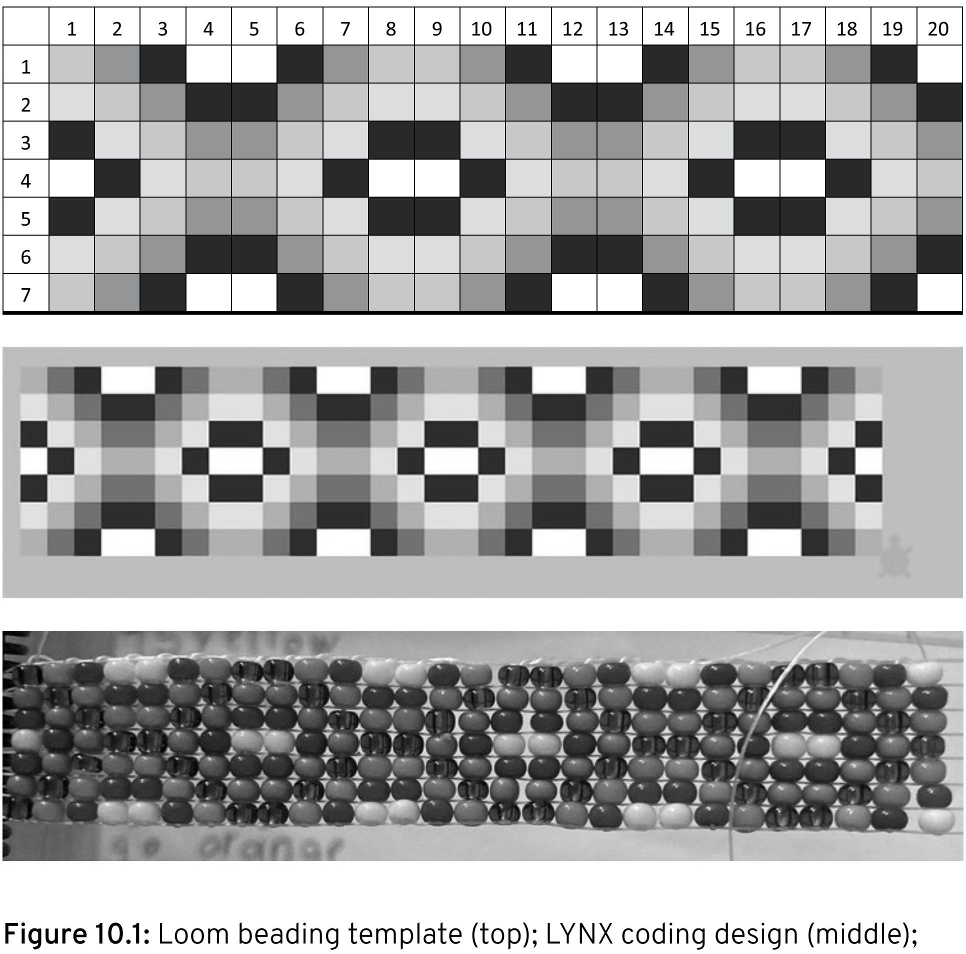

Figure 10.1: Loom beading template (top); LYNX coding design (middle); loom beadwork (bottom)

Source: Template created by C. Ruddy. LYNX design and beadwork created by a grade 6 student.

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Many mathematical concepts emerged as students engaged in the planning and execution of this cultural practice.

Exploration One: Analyzing Bead Designs to Develop Multiplicative Thinking

For these projects the students primarily worked with repeating patterns for their bracelets. Through creating and identifying the pattern core (unit of repeat) for each design, they developed the concept of unitizing (Lamon, 1996), which is the ability to perceive and consider a unit simultaneously as one unit and as the collection of elements creating the unit. In this case, students considered and moved flexibly between different units, such as the whole 20-column template, the pattern core made up of a particular number of columns, and individual columns of beads. For example, students calculated that if one full template represented 100 beads, and that each template represented 5 pattern cores (20 beads per core), that for a bracelet that had 10 pattern cores they would require two full templates (200 beads) plus two additional cores (40 beads) for a total of 240 beads.

Exploration Two: Making Predictions to Develop Algebraic Reasoning

Students began to consider the fact that repeating patterns can also be thought of as growing patterns since each additional pattern core extends the pattern and increases the number of columns in the design (and the number of beads in the bracelet). They used the structure of the repeated core to make predictions far down the sequence of the design. For example, they investigated how to determine what the 805th column of a pattern would look like based on the number of columns in the pattern core (e.g., if a pattern has a 4-column core, knowing that 201 repetitions of the unit of repeat would be the 804th column, which would look like column four, then the 805th column would be the start of a new pattern core and so would look like column 1).

Exploration Three: Making Their Bracelet Fit to Develop Proportional Reasoning

Naturally the students wanted to design bracelets that would fit their wrists. Students measured the circumference of their wrists, and then determined how many columns they would require for a wrist of *n* centimetres if 4 columns on the template represents 1 centimetre of beadwork. From this they were able to

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determine how many times the core of their design would repeat, and also how many total beads they would require.

Exploration Four: Reflecting and Rotating the Core to Develop Spatial Reasoning

There are geometric transformations in many examples of Anishinaabe beadwork. For this investigation the students incorporated two-dimensional transformations in their designs to explore the outcome when their pattern core was rotated or reflected. We asked them to first visualize what a reflection or rotation would look like, colour what they imagined the transformation would look like on the template, and then use the LYNX coding software to determine if their transformations were correct.

Exploration Five: Incorporating Coding

We integrated the LYNX coding program in order to convert the design process from colouring a static paper template to creating a dynamic representation of looming patterns. LYNX is a text-based program based on the LOGO turtle-geometry programming language created by Seymore Papert (1980). We taught students how to create coding procedures and carried out investigations of how to program the "turtle" by writing procedures to create beads, columns, and pattern cores.

This foray into 21st-century instructional tools resulted in the students engaging in problem solving through iteratively creating, reusing, remixing, debugging, and generalizing code. They developed an understanding of the logic of writing procedures and created multiple connections among different representations of beadwork including concrete (beads), visual (templates/LYNX patterns), and abstract (code).

EXPLORING THE MATH OF CIRCULAR MEDALLIONS

In these projects, which took place in a grade 6, a grade 7, and a grade 10 classroom, students had the opportunity to work with renowned beadwork artists who shared an extensive history of beadwork in Anishinaabe culture. The artists taught the students how to make circular beaded medallions (figure 10.2).

Students were taught how to use a circular template on which to create their designs, and how to bead in concentric rings from an initial centre bead (figure 10.3).

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Figure 10.2: Circular beaded medallion

Source: Created by a grade 7 student.

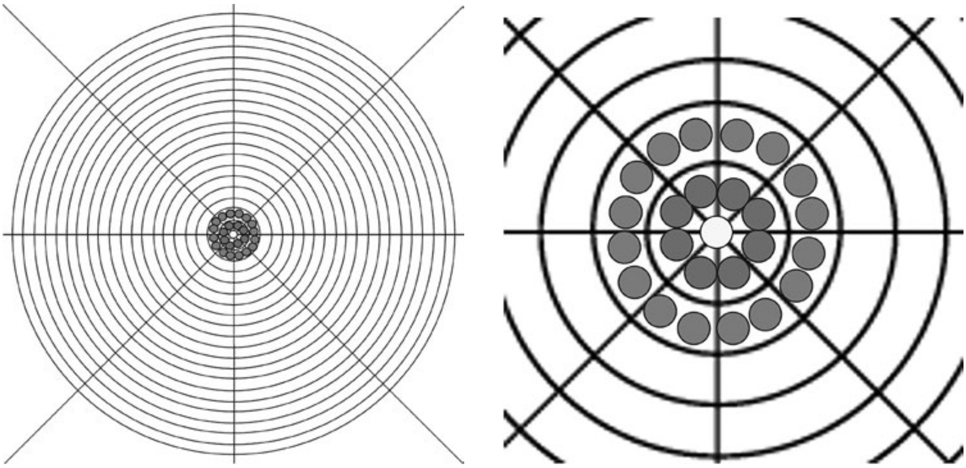

Figure 10.3: Medallion template illustrating the placement of beads

Source: The template was created by Anishinaabe artist N. S. for the project. The bead illustration was created by R. Beatty based on student investigations.

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Through the planning and execution of their beadwork, some interesting mathematics emerged. Prior to beading, students were asked to estimate how many beads they would need for their medallions. The artists indicated that they typically do not estimate how many beads they will need; however, they felt this was an important task when working with large groups of students so that the students would be able to approximate how many beads they would need and would respect the materials by not taking too many beads. The students found it difficult to accurately estimate quantities of small seed beads: most students estimated that 1/4 teaspoon of size-eight beads would contain 30 to 45 beads, when the reality is approximately 85 beads. Using the planning template, the students discovered that if they started with a centre bead, each successive ring held one (more) bead per section (8 beads for ring one, 16 beads for ring two, etc.). Using this information, students were asked to find how many beads they would need for a 20-ring medallion, and to find a rule (generalization) that would allow them to accurately predict the number of beads needed for any size medallion.

Exploration One: Estimating for a 20-Ring Medallion

Estimation is a critical component of computational fluency, and the ability to determine the "reasonableness" of quantity. Below are examples of two different approaches (the grade 6, grade 7, and grade 10 students used similar kinds of thinking). One approach was to relate each 1/8 wedge of the medallion to a triangle and use the formula for a triangle to determine that there would be about 200 beads per wedge (20 rings by 20 beads in the outer edge, divided by 2), and then multiply that by 8 wedges for a total of 1,600 beads (figure 10.4).

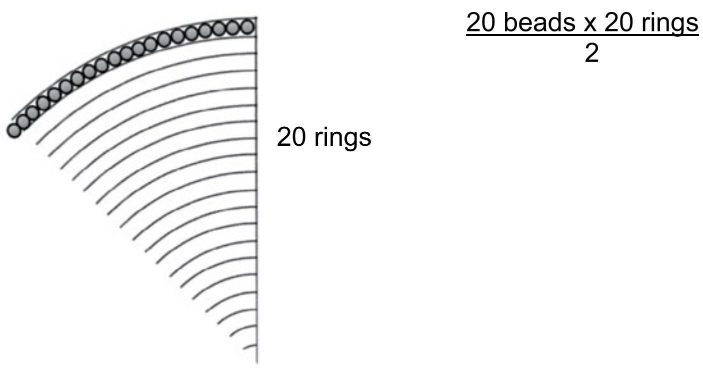

Figure 10.4: Estimating the number of beads using the formula for the area of a triangle

Source: Created by R. Beatty based on grade 6 and grade 7 student reasoning.

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Another approach was to find an efficient strategy to add consecutive numbers from 1 to 20, since the number of beads increased by one bead per ring per section. Students created groups of 20, adding up 1+19, 2+18, and so on to create 10 groups of 20, plus the extra 10 for a total of 210 beads per wedge, or 1,680 beads per medallion. This was a student-generated idea similar to Gauss's sum of an arithmetic sequence. The discrepancy between estimations produced by the first and second strategies was explained by the fact that the "wedge" was not actually a triangle, and the "bulge" of the wedge contained 10 extra beads.

Exploration Two: Finding a Generalization

Students then determined a rule, or generalization (algebraic expression), that would allow them to predict the number of beads that would be needed for any size medallion. In all three classrooms, students identified two different kinds of growth as they documented the increase in beads per ring and total beads each time the size of a medallion increased by one ring. Students determined that the centre bead could be referred to as "ring zero" and that each subsequent ring grew by multiples of eight. They identified this as linear growth and identified the proportional relationship between ring number and beads in each ring: "You keep adding groups of eight, so as the ring number goes up by one, the beads in the ring goes up by another group of eight." They recorded the following patterns:

In grades 6 and 7, students noticed that the total number of beads comprised consecutive odd square numbers. In order to more fully understand the reason behind the sequence, they explored visual representations of increasing odd squares to identify the growth. One rule they came up with was (ring number + next ring number) x (ring number + next ring number). They illustrated this rule as follows (figure 10.5):

Table 10.1: Numeric patterns found in circular medallions

Ring Number	Beads in Ring	Total Beads in Medallion
0	1	1
1	8	9
2	16	25
3	24	49
4	32	81
5	40	121

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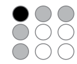
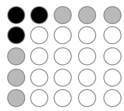
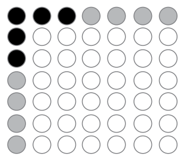
Numeric Representation	Visual Representation
(0+1) x (0+1), 0+1=1, 1x1=1	
(1+2) x (1+2), 1+2=3, 3x3=9	
(2+3) x (2+3), 2+3=5, 5x5=25	
(3+4) x (3+4), 3+4=7, 7x7=49	

Figure 10.5: Numeric and visual representations of the grade 6 medallion generalizations

Source: Created by R. Beatty based on grade 6 and grade 7 student thinking.

In grade 10, students also noticed the pattern of consecutive odd square numbers, and most students identified the generalization $(2n+1)^2$, where n represented ring number. Some students also came up with the expression $4x^2+4x+1$. The students initially were unsure how the two expressions represented the growth of beads in the medallion, or how the expressions related to each other. They explored the expressions by creating vertical lines of circular counters to compare the total number of beads of different sizes of medallions, and used these to construct a graphical representation, which demonstrated that the growth was exponential because the rate of growth accelerated with each ring (Lloyd et al., 2010). They also created consecutive odd squares using tiles in order to decompose the squares to see the different parts of both expressions and find connections between the two (figure 10.6).

Although these strategies provided powerful predictions of bead totals for different sizes of medallions, the community members stated that these specific numbers were still estimates because beads are not always uniform, and so during the process of beading each ring may contain more or fewer beads than predicted.

EXPLORING THE MATH OF MÉTIS FINGER WEAVING

During these projects students explored the mathematics of the design and creation of Métis finger weaving (figure 10.7) with an emphasis on working with repeating patterns and creating coded representations of weaving.

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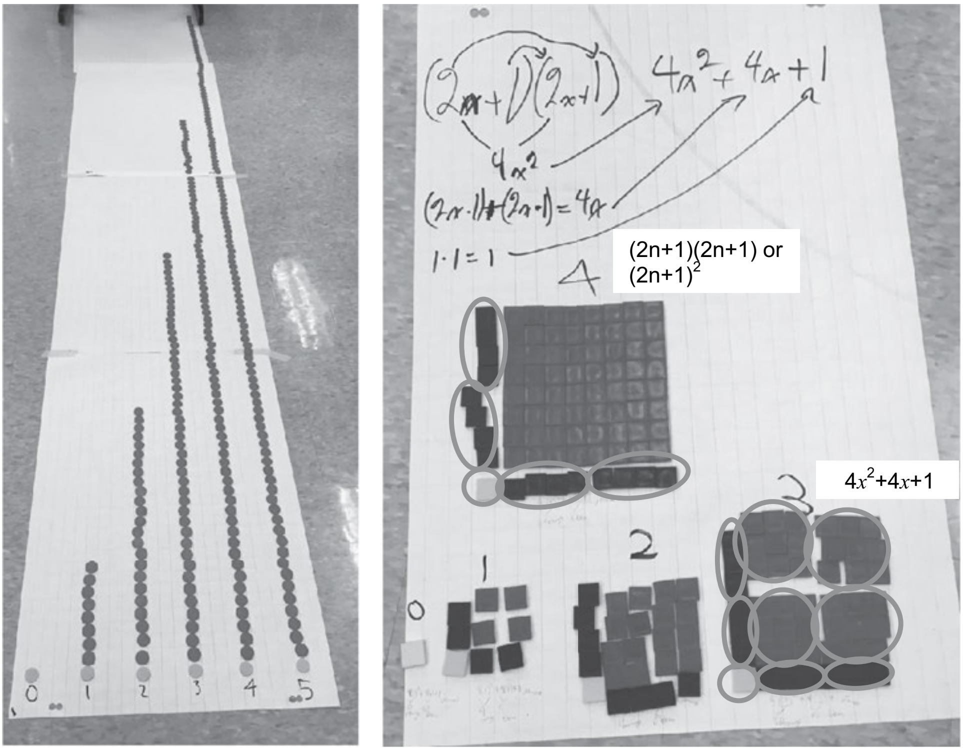

Figure 10.6: Visual representations of grade 10 students' quadratic expressions

Source: Created by grade 10 students.

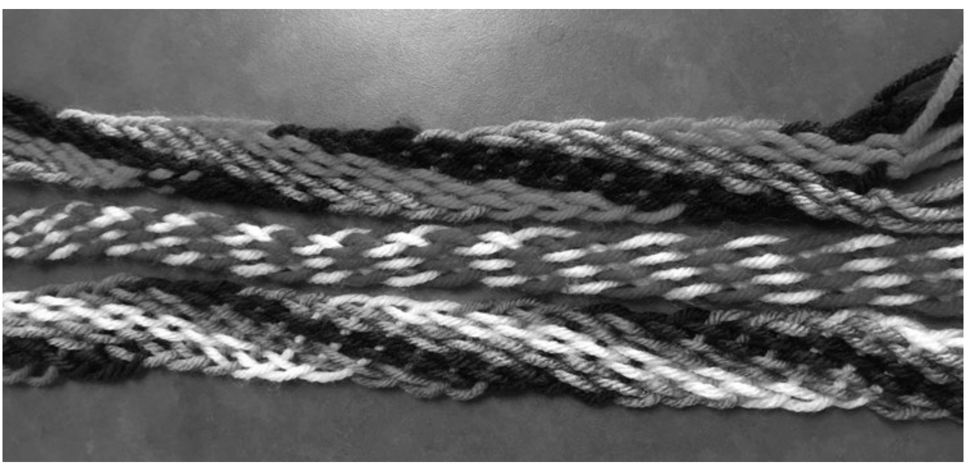

Figure 10.7: Examples of students' Métis finger weaving

Source: Created by grade 5 students.

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Two Métis artists and educators, both Red River Métis living in Ontario, began by introducing students to the history of the Métis people, who are one of the distinct Aboriginal Peoples of Canada whose family lines can be traced to the historic Métis Nation homelands in west-central North America.[1] Although finger weaving is common in many cultures globally, the focus of this instruction was the connection of weaving to the Métis sash. The artists explained the importance of the sash in Métis culture, and how it was both an important multi-use tool and a means of identifying familial and other affiliations. In these investigations students created mini-sashes.

Students were first taught to weave an 8-string pattern made up of alternating red and white yarn. To weave, they were taught to lift the left-hand string and every alternate string (all the same colour as the left string) and then bring the right string (the other colour) to the left of the bundle (under the lifted strings). Students repeated this move until the weave was complete. They were then asked to represent the patterns of the weave mathematically.

The second project the students tackled was a three-colour, 12-string bundle with the bundles laid out in three groups of four strings. They used the same weaving technique as the previous project, but without the support of colour to assist with picking up alternating strings, which made the weave more challenging. Again, they were asked to represent the weave mathematically.

Finally, based on their experiences, students were asked to design and create their own sash pattern.

Exploration One: Representing an 8-String and 12-String Sash

Our first question to students, once they had learned the 8-string weave, was how they would represent the process (repetition of movement) and the product of weaving (the woven sash) mathematically. Initially students drew diagrams, but then as they worked to capture the movement of the strings mathematically, they created a numeric grid/array showing the movement of the numbered strings. The number in the eighth column of each row moves to the first column in the next row, and the rest of the numbers shift over one column. Other students created representations that blended diagrams and numbers and included labelled lines to show the movement of the strings (figure 10.8). Although the pattern repeated, it was at first difficult for students to determine the unit of repeat, or pattern core, for the weaving pattern.

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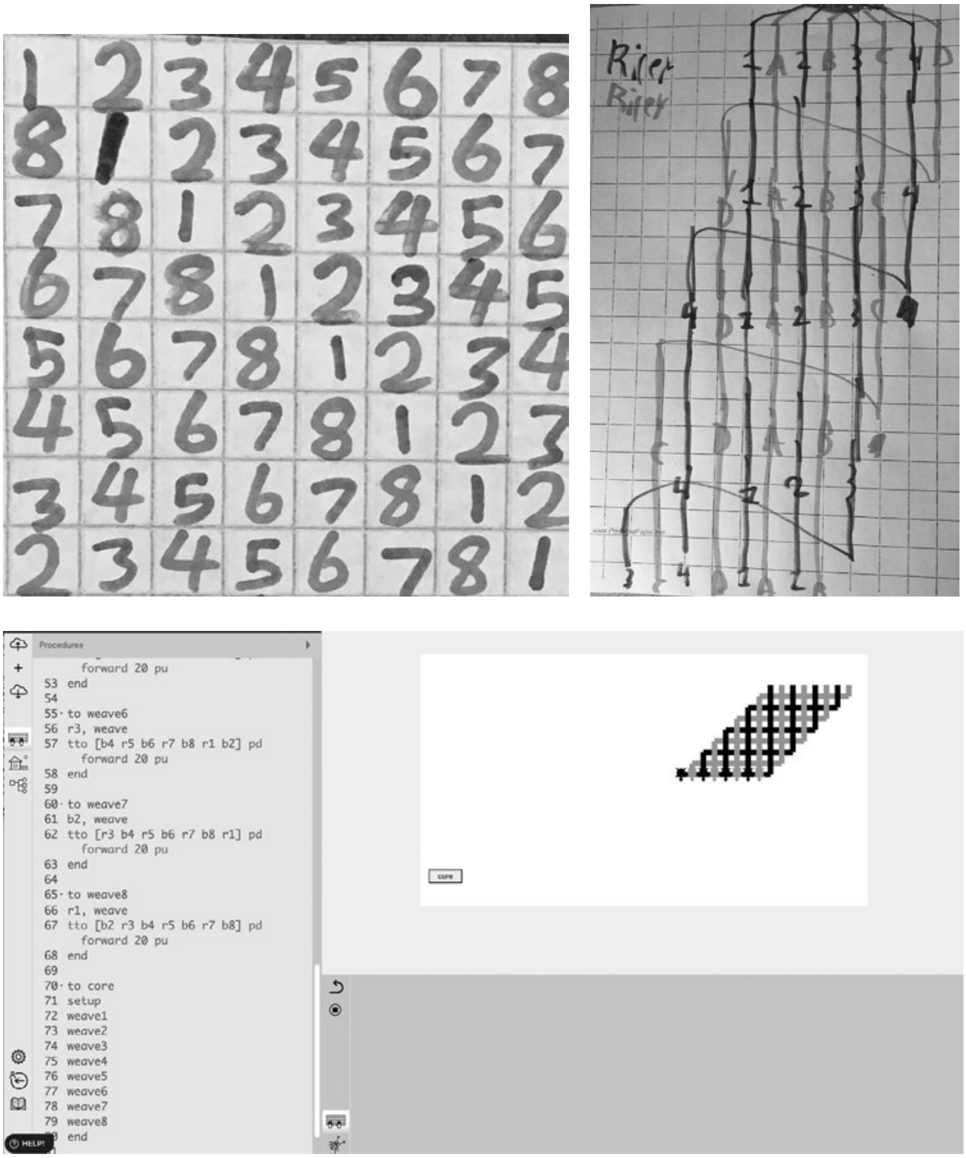

Figure 10.8: Numeric grid representation of the repeating pattern of a two-colour 8-string weave and a representation that also captures the movement of the strings. Below these is a series of eight weaving procedures to create a two-colour 8-string weave in LYNX.

Source: Created by grade 5 students.

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Exploration Two: Representing an 8-String and 12-String Sash Using Coding

The next challenge was to represent the sashes using LYNX coding, which involved combining both the numeric grid representation of the weave, and the diagram of the movement of the strings from right to left. Students created eight "turtles" and wrote procedures to name them, and to colour half one colour and half another. To weave, the students worked collaboratively as a class to write procedures so that each turtle would weave in turn. Each procedure, labelled "weave1" up to "weave8," was directed at the turtle at the end of the row.

S1: Write a procedure called "to weave1."
S2: He needs to go right. You have to talk to that turtle, so talk to B4 (the turtle's name) turn right 90.
T: Okay next?
S2: He needs to go forward. 160 [pixels] maybe? Because each turtle is 20 pixels wide.
S3: Then left turn 90 to face down like everyone else.
S4: Yeah, then everyone forward 20.

The procedure was repeated seven more times for the remaining turtles (figure 10.8). Students then realized they could group each individual turtle weave procedure into a super procedure called "weave core." The result was an animated representation of the weaving process, with each turtle mimicking the movement of the strings as they wove together and leaving behind lines that tracked their movements and created a stylized version of the sash. The process of creating eight weave movements supported students to realize the unit of repeat for the 8-string weave, since a ninth weave procedure would be identical to the first weave procedure. The students then wrote procedures to create the 12-string sash (and determine that the unit of repeat for this sash had 12 weaves).

To design their own patterns, students decided how many colours and strings (either 8 or 12) to use and chose whether to design their weave using the numeric grid representation, or to code their designs before weaving.

Repeating patterns are typically taught in the early elementary grades (kindergarten to grade 2). Most patterns are presented in a linear configuration and children are asked to copy the pattern and extend the pattern from right to left. Working with patterns is a precursor to generalizing mathematics, and fundamental to this is the ability to discern the structure of the pattern. Past research

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has shown that even adolescent students tend to see patterns as rhythmic chants of alternating elements but fail to identify that the pattern consists of repeating units, and thus fail to generalize the pattern structure (Threlfall, 1999; Mulligan, 2011). Representing the dynamic process of repetitive string movements and analyzing these movements through both a mathematical and computer coding lens supported students to develop a sophisticated understanding of the nature of repeating patterns with respect to finding the unit of repeat. Through a combination of weaving, creating a variety of visual/numeric models, and engaging in writing LYNX coding procedures, the students refined their thinking about what constitutes a pattern.

DISCUSSION

In each project, not only was the mathematics content derived from cultural activities, but the way that the lessons were taught also aligned with community practices. Indigenous pedagogy is holistic in that it emphasizes the need to address the intellectual, physical, emotional, and spiritual development of the person (Lunney Borden & Wiseman, 2016: Barnhardt & Kawagley, 2005: Cajete, 1994). We created environments in which students learned complex mathematics by participating in activities that they cared about, and through which they made connections to First Nations and Métis culture, to the members of the research teams, and to each other. The emphasis on co-planning and co-teaching led to the introduction of traditional cultural pedagogical patterns including a mentor/apprentice model of instruction, placing students in close proximity to experts, an emphasis on modelling and observation, and the creation of a community of learners based on trust, safety, and humour into Western mathematics classrooms. In transforming mathematics instruction into a form that acknowledges and respects Indigenous and Western perspectives, we were paying close attention to the differences in pedagogies. We soon realized that the heart of this work was lifting up Indigenous knowledges and shifting educational practices toward an emphasis on ethical relationality (Donald, 2012). Donald (2012) defines ethical relationality as "an ecological curricular and pedagogical imperative that calls for more ethical understandings of Aboriginal-Canadian relations. Sustained attentiveness to Aboriginal-Canadian relations and willingness to hold differing philosophies and worldviews in tension creates the possibility for more meaningful talk on shared educational interests and initiatives" (p. 45).

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PARTICIPANT OUTCOMES

Student Experiences

These projects have had a profound effect on everyone who has been involved. Students have expressed the importance of learning from community to make cultural connections, and the importance of learning math in context. First Nations and Métis students expressed their appreciation for working with community when learning math, the holistic approach taken, and the opportunity to learn more about their culture.

> I liked it because it was something different, not just plain old math. I got more involved because I like doing art, so it was good for me to take something I'm good at and interested in and incorporate it with something I wasn't as good at. I liked having caring adults pushing me to do something I wasn't good in. It made me feel better because I got it done, and I accomplished something that I thought I wouldn't be able to do. I liked seeing what other people could come up with in their designs and seeing different ways people have to think about math. I really liked learning more about my culture, and skills like looming and peyote stitching that I didn't know how to do. And the fact that we incorporated the language, learning different words … common words that we use daily. In a math class [laughs]! (Anishinaabe student interview, June 2018)

Non-Indigenous students also expressed an appreciation for learning math in context with community, which they stated helped them (some for the first time) to understand concepts that they had learned through rote memorization and symbolic manipulation but that they had not understood at a conceptual level.

> The Elders talked to us and got to know us individually—it was more one-on-one. And the math—it's a lot easier to understand, and a lot more engaging when we're able to feel the beads. It's a lot more hands-on and it's a lot more visual. It's not just equations being written on the board and us taking notes of the answers, it's trying to find the answer with your hands, and seeing it, and playing with the beads to get to the answer. (Grade 10 student interview, May 2019)

All of the students expressed an appreciation for the opportunity to develop relationships with community partners. Rather than experiencing Indigenous

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cultural teachings as a one-day session, students were learning from and with community for the duration of the two-week projects and, in many cases, during multiple projects throughout the year. Students were given responsibility by the community artists to share what they learned from the projects and, in some cases, to continue the activity on their own.

Community Partner Experiences

One thing that has been so powerful has been community partners' evolving perceptions of themselves as mathematical thinkers and teachers. For example, Christina Ruddy, who is an expert beader, came to the project with no concept of herself as a mathematical thinker. In a previous publication (Beatty & Clyne, 2020), we have documented how Christina was told that "Native people can't do math." Through this work she has realized that she is, in fact, a mathematician, which has become her motivation to do this work so that other Indigenous students can see themselves reflected in mathematical instruction and investigations. More devastatingly, she has also recounted the trepidation she had when first coming to join the project because it was taking place in the building where she herself had gone to school. As the only Indigenous student at the time, she had suffered through years of racist abuse from students and teachers. In this excerpt from a chapter she has written for a publication of Indigenous narratives and cultural expressions, she recounts her experiences of returning to the school, and what the impact of the project has been.

> I watched the students, both the Indigenous students and their non-Indigenous peers, embrace the culture. They had conversations about pow wow, community, regalia, family—we created a safe space for that to happen. We created a space where Indigenous students were safe to share who they are and their way of life where those conversations had not happened before. Growing up Indigenous sometimes means you have your home identity and your school and work identity. What I saw in that classroom is something I only dreamed of when I was young—that I could be myself in every space I was in. (Ruddy, 2022, pp. 206–208)

Christina has been part of the work since its inception, and since her first foray into the classroom has mentored other First Nations and Métis artists to work with non-Indigenous educators to continue to create safe spaces for students within the domain of mathematics education. She also regularly speaks with non-Indigenous

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teachers about her experiences and the importance of Indigenous representation in the mathematics classroom.

Similarly, L. M., an expert beader and Métis artisan, was apprehensive about the fact that the projects were about creating a different approach to teaching mathematics. Initially she was excited to work with students to teach them about Métis culture, design, and activities like beading and finger weaving, with the understanding that the math would be taught by the classroom teacher. However, during an interview after the first two projects she was involved with, L. M. was asked what she would be taking away from the experience and her answer surprised everyone.

> Math, definitely. I see it in a whole different light now. Well before, I just did beading, that's the way I was taught. I wasn't taught by anybody that it included math. And when they were breaking it down into the math components, even designing, I'm thinking, I do that, but I never knew I did it. I just didn't know the names. So, then I got really excited. Now I'm looking at my designing and everything else more so on the math side of it, rather than just designing. Like, it's amazing! At first, I didn't understand the math, but I was able to still help out, and then when I did get the math it was … okay … a whole new door's opened! I like beading more now! (Interview, April 2018)

In 2021, L. M. participated in LYNX coding investigations, and although she had never done any coding before—"I never even heard of coding!"—she embraced the opportunity to work with the students to learn how to write procedures for looming and finger weaving designs. By the end of the looming project, she described how she would use LYNX in the future as part of her design process.

> I think I will use it [LYNX] more because a lot of times I design and then make the bracelet and then I'll see that I don't like the beads in a certain spot, whereas this way I'd see the whole pattern without having to bead it and then take it apart to start over. (Interview, June 2022)

When asked to reflect on the impact the last five years have had on her, she spoke about how the experience has been transformational beyond learning mathematics.

> It's a great learning experience. I had a lot of great moments with the kids as I learned with them. I kind of got stronger in my own understanding and I

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> made relationships. And … I can't say enough about it because it has opened me up a lot. I'm not as shy as I was. It's been an overwhelmingly positive experience for me. I came out with a better understanding of myself, and I know that I brought knowledge and cheer to the students I worked with. (Interview, June 2022)

Over the past five years, L. M. has co-taught both the skill and the mathematics of beadwork and finger weaving in a number of elementary classrooms and has co-facilitated a number of workshops for teachers. She has presented to teachers at school board–level professional development sessions and during provincial Indigenous Knowledge and Education conferences.

Overall, the community research partners have built on their self-reflexive experiences and have become co-applicants on three successful Social Science and Humanities Research Council (SSHRC) grants. They co-planned an Indigenous Education and Mathematics Conference for two hundred participants in 2019 and a second virtual conference in 2022, and held a third, face-to-face conference in April 2023. They have co-authored book chapters and papers in conference proceedings and have co-presented at provincial, national, and international academic and practitioner conferences (including keynote sessions). This is the reciprocity; beyond paying the artists for their time working in schools, these projects support community partners and have created ethical spaces for them in schools and beyond.

Settler Educator Experiences

Participating non-Indigenous teachers shared the insights they gained about the importance of incorporating Indigenous pedagogies into their teaching, particularly an appreciation for teaching and learning beyond colonial settler norms. During an interview with two elementary teachers who have been involved in this work from its inception, both spoke about how this work has transformed their teaching practice from "standing at the front of the classroom teaching *at* students" to creating a learning community and being "part of the group of learners." They learned this from working with the Anishinaabe artist, Christina Ruddy, with whom they co-taught for years.

> That's something that we learned from Christina. When she comes in the classroom and when she's talking to students, she sits with them. It's not like the sage on the stage at the front. It's sitting down with the students

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> and teaching among them. Now I always try to sit, to share the experience, to share the voice, to be in it at the same level as the students. (Elementary teachers' interview, November 2022)

They also spoke about their move away from "traditional Western approaches" to teaching, which focus on data, timed student improvement, and teacher-controlled timetables and methods of assessment, to an approach more focused on building relationships to support students.

> In Western education we're so wrapped up with data. Then based on the data we collect we create these four- or six-week cycles to see if we can move the kids forward to the next level. Social emotional learning takes a back seat when those kinds of initiatives happen. In our project, there's time and space for everyone. That's what I learned from Christina too. If a student isn't ready to be assessed, or if they want to choose a different way to show their understanding, she'll say, okay, express yourself in a different way. It's more about supporting and developing student strengths, which we *talk* about in Western education, but in our project, we actually see it happening. I would say it's more about nurturing and less about pushing. (Elementary teachers' interview, November 2022)

There was a shift from teacher-led to student-led mathematical inquiries, where the teacher follows the students' lead. This aligns with Indigenous approaches where traditional teachers rarely give a direct answer but rather ask more and more questions to guide learners to answers.

> I used to overplan. I planned for the month, I planned for the week, and we had to cover everything I had planned. But with this work it's day to day, minute to minute because you never know what is going to come up, what questions students will have or where *they* want to take the learning. It's so much more student centred. It's constant pivoting—it's like just in time mathematics! It's following their lead, and being flexible, and taking chances to try something different. (Elementary teachers' interview, November 2022)

One of the biggest changes has been "an increase in humility" and an acceptance that teaching math is about creating opportunities for each student to

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contribute to the collective knowledge of the classroom, rather than relying on the teacher to be the expert.

> Christina said one time every child is a gift; every child has something to share. And I think about that a lot, how we have to share our space, and have all of these great conversations! Before, when I taught there were rows in my classroom and little student conversations, so there was very little sharing of ideas because I was the teacher, so it was my job to know everything. When we work with the project and C. comes in the class the students are all working together and there's a real buzz in the classroom! And now we value different kinds of mathematical thinking. Not just someone who can solve equations, but someone who creates beautiful works of art. I learned that you have to be willing to let go of whatever it is you think you know, because you don't! Now we highlight student thinking and create this rich environment where there's all this mathematics—it's a beehive of math! (Elementary teachers' interview, November 2022)

In another interview, a grade 6 teacher reflected on how learning from community and incorporating Indigenous pedagogies in the classroom with community guidance has led to more and better mathematics teaching and learning. Specifically, it has helped them expand their conceptions of good math instruction, which has resulted in better learning for all students, particularly those who may not have perceived themselves as mathematical thinkers.

> This project has opened my eyes. I have been teaching math for years, and this is some of the most complex, sophisticated, amazing mathematics I've ever explored. And the students love it. They love having the community partners come in and they love the work. The students are getting the math through the beading, and through having rich math talks that allow the mathematics to surface. In the past, some students over the years fell through the cracks—we lost them. But through this project they're finding a path because a part of who they are comes out through this work—particularly their artistry and their mathematical thinking. In a regular math class, these kids didn't have a place, but with this work the kids just come alive. To see the confidence in these students, and to see that confidence continue as they get older and continue to participate in the project—they're flourishing. (Grade 6 teacher interview, April 2018)

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CONCLUSION

One of the main goals of this work has been to transform mathematics education into a form that respects both Indigenous and Western ways of knowing, as part of a response to the colonized educational institutions and systems in which Indigenous students and educators have been forced to assimilate. With these projects we have broken apart traditional Western approaches to teaching math and have instead centred Indigenous knowledges and Indigenous Knowledge Keepers to the point where most of the mathematics education, as well as the cultural education, has been led by community partners. Our approach is so different that students often do not realize they are engaging in complex mathematical problem solving. We noted high levels of student engagement, and that students spent hours at a time working on their beadwork or weaving designs and on solving mathematical investigations that emerged from these activities.

In terms of mathematics learning, results of our study indicate that making connections between mathematics instruction and Indigenous culture has beneficial effects on all students' learning of mathematics (Beatty, 2018; Beatty & Blair, 2015; Beatty & Clyne, 2020; Beatty & Ruddy, 2019; Wiseman et al., 2020). We see these community-led action research projects as a small step toward decolonizing mathematics instruction through ethical relationality by engendering ongoing meaningful relationships and creating new ways of understanding, and as a model for Canadian relations in education in other content areas. All students learned to see mathematics as part of First Nations and Métis culture, and then were able to apply this mathematical lens to other cultural activities. It was important for the First Nations and Métis students to see community members leading mathematics learning, and for all students to experience Indigenous knowledge valued at the same level as Western knowledge. Paramount to the success of these projects were the respectful long-term reciprocal relationships created with community partners who made mathematics engaging and relevant for students.

CRITICAL THINKING QUESTIONS

1. How might you/your school develop relationships with Indigenous communities in your local context?

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2. What are some other curricular areas a project like this could extend into? In what ways might that extension be similar to and different from the math content described in this chapter?
3. In what ways is the ethical relationality that is at the core of this project similar or dissimilar to your experiences at your school/institution?
4. What conditions are necessary for a project like this to work effectively?

KEY TERMS

Culturally responsive mathematics: Education that centres math instruction within local cultural practices, with the aim of transforming mathematics education into one that respects and is grounded in Indigenous worldviews and knowledge systems.

Ethical relationality: Dwayne Donald (2012) defines ethical relationality as "an ecological curricular and pedagogical imperative that calls for more ethical understandings of Aboriginal-Canadian relations. Sustained attentiveness to Aboriginal-Canadian relations and willingness to hold differing philosophies and worldviews in tension creates the possibility for more meaningful talk on shared educational interests and initiatives" (p. 45).

Ethnomathematics: A research area concerned with the mathematics of local cultural practices. In part, it focuses on how Western mathematics curricula can and should connect to local culture because "school mathematics" is one of many diverse mathematical practices and is no more or less important than mathematical practices that have originated in other cultures and societies.

FURTHER READINGS AND RESOURCES

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NOTE

1. The Métis National Council General Assembly adopted the following "National Definition" in 2002: "Métis means a person who self-identifies as Métis, is distinct from other Aboriginal peoples, is of historic Métis Nation Ancestry and who is accepted by the Métis Nation." https://www.Metisnation.ca/about/citizenship

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