Chapter 7
Connecting Algonquin Loomwork and Western Mathematics in a Grade 6 Math Class

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Abstract In this project we explored the connections between Algonquin ways of knowing and the Western mathematics that is represented in the current Ontario provincial mathematics curriculum. Using an ethnomathematics framework, we worked with community members from the Algonquins of Pikwakanagan First Nation to co-design and co-teach a Grade 6 lesson sequence based on Algonquin loom beading. As a research team made up of Algonquin and non-Native educators, we documented the mathematical thinking and cultural connections that emerged. Results indicate that the activity was both mathematically rigorous and culturally responsive. Creating and analyzing looming patterns supported students' algebraic, proportional, and spatial reasoning. Community members made connections between the environment created in the classroom, which was based on trust, humor, and proximity to available experts, and the safe learning contexts they had experienced as children. They also indicated that this type of experience supported students' pride in the Algonquin identity and strengthened their relationships with non-Native peers. This project illustrates the potential of co-designing and co-teaching mathematics instruction as a first step to creating meaningful community and classroom interactions.

Introduction

Ministries of Education across Canada have recognized the need to explicitly incorporate Indigenous content to support identity building and appreciation of Indigenous perspectives and values. There is a need in contemporary education to understand how to provide Indigenous students with meaningful connections to their learning. In recent years, work has been undertaken to incorporate First Nations, Metis, and Inuit perspectives in curriculum subjects such as social studies, but it is our belief that connections to Indigenous content should permeate all

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curriculum content, including mathematics. This project explored connections between the mathematical content knowledge required of the Ontario curriculum expectations and the mathematics inherent in Indigenous cultural practices.

The work outlined here was conducted in a Grade 6 classroom at a small public school near Pembroke, Ontario. The school population comprises approximately 20% Algonquin students from the nearby Algonquins of Pikwakanagan First Nation and 80% non-Native students. In this work, we brought together community and school in support of mathematics learning, with a long-term goal of transforming school-based education from a colonial past into a form that respects both Western and Indigenous traditions.

Theoretical Framework

We drew upon ideas from ethnomathematics research and culturally responsive education. In our education system, the dominant Eurocentric culture is manifest in the content of educational curricula, including mathematics curricula (Battiste & Henderson, 2000; Lipka, Mohatt, & the Ciulistet Group, 1998). Mathematics instruction, as reflected in the Ontario provincial curriculum, goes back to a Western European tradition of mathematical knowing (Bishop, 2002). Mathematics was, and still is to some degree, taught with the intention of scaffolding learners from elementary to more complex levels of mathematical thinking, through secondary school to university level. This comes from an historical tradition of educating the elite and using mathematics as a gatekeeper to higher education (D'Ambrosio, 1985). An elitist vision of mathematics education contributes to feelings of alienation that many students, particularly Indigenous students, feel toward mathematics (Barta, Jette, & Wiseman, 2003). This view does not allow students who may not wish to pursue higher-level mathematics to experience the beauty of mathematics for its own sake, nor does it allow them to develop a positive personal relationship with mathematics.

Ethnomathematics research includes a growing area of research about how Western mathematics curricula can and should connect to local culture (D'Ambrosio, 2006; Knijnik, 2002). Ethnomathematics has been thought of as reclaiming mathematics as part of Indigenous culture; however, previous researchers have had different interpretations about what mathematical reclamation entails (Barton, 1996). One interpretation of ethnomathematics has been 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, Powell, & Frankenstein, 2009). Another interpretation was based on generating mathematical thinking from combining traditional Indigenous sources and conventional mathematical thinking, what Gerdes (1988) termed "unfreezing" the mathematics from cultural artifacts or activities. The idea of unfreezing the mathematics referred to those who analyze an activity or artifact and identified the "hidden" mathematics. Barton (1996) defined ethnomathematics as creating a bridge between mathematical thinking and the practices of other cultures, with the aim of both reconceptualizing cultural activities through a lens of mathematical interpretation and highlighting new ways of conceiving mathematical concepts. What these interpretations had in common was that the mathematical thinking identified in different cultural contexts, or in various cultural artifacts, was deemed to be mathematical because of its alignment with Western mathematical thinking.

Mathematical thinking is not, however, simply about participating in an activity. Also needed is a context within which students can reflect on the mathematical relationships embedded within the activity. Mathematizing is a way of articulating or highlighting the mathematical aspects of an activity by translating the material into mathematical terminology or relating it to existing mathematical concepts (Ascher, 1991). The mathematics inherent in the activity can be identified and extended to a creative, mathematical investigation. Looming is an activity that can be undertaken without consciously or explicitly focusing on mathematics. We were interested to explore, however, the consequences of having community members, teachers, and students explicitly mathematize an activity in order to explore the connections between Algonquin looming and mathematics and to create an opportunity for Algonquin students to see their culture reflected in mathematics instruction.

Culturally responsive mathematics education refers to efforts to make mathematics education more meaningful by aligning instruction with the cultural paradigms and lived experience of students (Castagno & Brayboy, 2008). Making connections between math instruction and Indigenous culture has had beneficial effects on students' abilities to learn mathematics (Cajete, 1994; Lipka, 1994; Lipka, Sharp, Adams, & Sharp, 2007). Long-term studies by Lipka (2002), Brenner (1998) and Doherty, Hilbert, Epaloose, and Thar (2002) found that culturally responsive education in mathematics had statistically significant results in terms of student achievement. Recent researchers have also explored the insights Indigenous epistemologies and practices provide for understanding ways of teaching mathematics (Barta & Barkley, 2001; Barta et al., 2003; Battiste, 2002, 2004; Hampton, 1995; Leavitt, 1995; Nielson, Nicol, & Owuor, 2008). While these studies suggested that Indigenous pedagogical approaches benefitted both Indigenous and non-Native students' mathematics learning, few studies have focused specifically on connecting Anishinaabe and Western mathematical perspectives. This is an important connection to make because Anishinaabe communities comprise one of the largest Indigenous groups in Canada.

Cultural knowledge can be defined as knowledge derived from settings outside of school, such as in the home or in the community. As outlined below, practices such as looming were (and are still) taught informally in students' homes, along with some of the historical significance and importance of these practices. In the Algonquins of Pikwakanagan First Nation, activities like looming were part of community teachings passed down from elders and were retained by some community members even during the time that other aspects of culture, such as language and ceremonies, were forbidden. The culture of the Algonquins of Pikwakanagan First Nation, as it pertains to this study, encompasses the community's emphasis on rediscovering and revitalizing cultural practices and language.

Most ethnomathematics studies have focused on the mathematical thinking of diverse cultures to make connections between Indigenous cultural activities and Western mathematics in contexts where local cultures are less influenced by

Westernized mathematics textbooks and pedagogy. We were interested in investigating the potential of cultural activities to support mathematical instruction for Indigenous students who live in an Algonquin community, who are educated in a publicly funded provincial school and are familiar with Western mathematics, but whose culture is not incorporated in their classroom experience.

Methods

One concern working as non-Native researchers within Indigenous cultures is the risk of appropriating culture. Cultural appropriation is the taking of Indigenous knowledge to use within a different cultural context, without truly understanding the cultural significance of the knowledge. Our core research team for this project, therefore, included cultural insiders and outsiders. The team was made up of two Algonquin teachers, including Jody Alexander, along with the operations manager of the Algonquins of Pikwakanagan Cultural Centre, Christina Ruddy, who is an expert loomer. The team also included three non-Native teachers from the school, including the Grade 6 teacher, Mike Fitzmaurice, in whose classroom the study took place. We followed a cyclical approach (consult, plan, teach, reflect, share) in the project to insure that we continually cycled back to members of the Algonquins of Pikwakanagan community for guidance and feedback. The cycle included a consultation phase during which we met with community leaders from Pikwakanagan, who were invited to share their insights and provide guidance.

A key theme raised by community members was the importance of revitalizing Algonquin culture. As one community member stated, "From the outside it's perceived that we have all the culture. We don't. Culture was taken from us. We are actually in the process of learning our culture again." Like most Indigenous communities in Canada, the Algonquins of Pikwakanagan were forced to abandon many cultural practices, which they are now in the process of reviving. One focus of this cultural revitalization has been beadwork, including loomwork, which has always had significance for this community. This focus on cultural revitalization in the community was something the advisors believed should be reflected in students' experiences in the classroom. They also spoke about the importance of engendering pride in identity by supporting students to navigate Algonquin and Western cultural perspectives.

Another key message was the importance of making mathematics instruction meaningful for the children, because mathematical understanding is important for effectively participating in Canadian society. Community members articulated a desire to afford their children the opportunity to find meaning in, and develop positive relationships with, mathematics by "seeing themselves in the math classroom," because these students had not had a chance to explore mathematical thinking in a way that reflected priorities and experiences that are important in their community. Community members also identified the difficulty many students have learning mathematics, particularly those who struggle with pedagogical approaches that prioritize memorization.

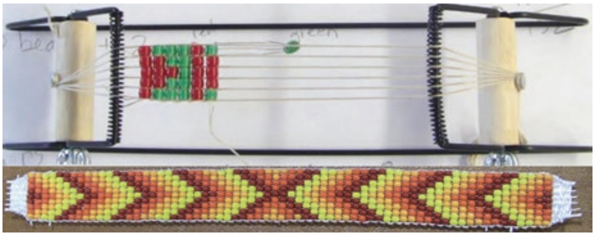


Fig. 7.1 Loom beading

Howard: Some kids still memorize times tables but there are other ways of attaching meaning to it and kids will remember because there is meaning to it. Rote memory is okay if your brain can do that but for some kids they can't. But if it is something that's meaningful for them they will be able to remember it, and it's maybe a longer process but they will be able to do it. So those are the kinds of things that we are looking at. How do we reach those kids?

Shirley: I think its hands on! They need to see and do!

This aligns well with current approaches to mathematics teaching, which emphasize the development of conceptual understanding in meaningful contexts rather than rote memorization and symbol manipulation (National Council of Teachers of Mathematics [NCTM], 2000).

For this study, we co-planned a unit of instruction based on Algonquin looming. Looming is a type of beading that is done on a loom and involves stringing beads onto vertical weft threads and weaving them through horizontal warp threads (see Fig. 7.1).

During the co-planning phase, Christina taught the rest of the research team how to loom and shared her insights about some of the inherent mathematics of looming:

> When you're deciding the width of the loomwork you count your beads, how long and how wide you want it. So, how long determines the number of columns and how wide determines the number of rows. There's a lot of counting. When you take your design and put it on the loom then you need one extra thread on the loom for every count of beads that you do. For example, a bracelet that is 9 beads wide will need 10 warp threads on the loom. Then you have to measure your wrist and decide how long your bracelet needs to be.

The team co-designed a sequence of lessons centered on looming. This study focused on approaches to mathematics instruction based on Indigenous activities, and the lesson designs prioritized exploration. Lessons were structured in terms of the sequence of looming patterns Christina introduced to the students. However, the processes to engage in mathematical thinking were generative; we had no predetermined paths of investigation for students to follow. Instead, teachers and students co-constructed avenues of inquiry, delving into mathematical ideas as they naturally arose during the activities.

The team also arranged for Albert Owl, a fluent speaker of The Language, to teach some Algonquin Language during the lessons. Ten to twenty minutes at the beginning of every lesson was devoted to teaching students Algonquin words and phrases related to the activity of beading. As Mr. Owl taught students words, he also explained some of the meaning behind the words. The word for bead, manidominens, comes from the word Manido, Creator or spirit, and minens, meaning small piece, so a bead is a small piece of the Creator, or a small spirit. Mr. Owl deconstructed The Language so students learned, for example, the suffix “tig” means that an object is made out of wood. The word for loom, mazinàbido-iganàtig, and pencil, ojibìhiganàtig, both end with this suffix. Mr. Owl also shared stories and some teachings about beading, including the teaching that if you drop a bead, it is important to pick it up because by doing this you show respect for the bead and the activity of beading. Introducing Algonquin Language through the activity of looming helped students develop a meaningful connection to The Language.

Data Collection

Mike and Christina co-taught the lessons over 2 weeks in a Grade 6 classroom. One-third of the 27 students in the class were from the community of Pikwakanagan and two-thirds were non-Native. All lessons were videotaped and field notes were completed each day by the author. These notes included an overview of the sequence of activities and a summary of the mathematical thinking evidenced either through students’ verbal answers or their written work. All student work, including patterns drawn on paper and beadwork, was photographed. We videotaped Christina’s and Jody’s reflections at the end of each of the 2 weeks to capture the cultural connections they perceived. Given that both are members of the Algonquins of Pikwakanagan First Nation, we wanted to ensure we honored their voices during the project.

Lessons were shared with community members at community meetings during which we showed compilation videotapes to give community members an overview of the activities in which we had engaged and examples of students’ mathematical thinking. Attendees spoke about the fact that, from watching the mathematical thinking of students, “everyone can learn math, really complicated math” and that “everyone has a mathematical voice.” One of the attendees, a band councilor whose grandchildren attend the school, stated that what she saw was “an awakening of a spirit of mathematics” and was proud that this awakening had come through the process of Algonquin looming.

Data Analysis

Lesson video was edited into segments that related to a specific learning episode generated from the looming activity, and those segments were transcribed. For example, when one student in the class posed the question, “What would the column before column 1 look like in a chevron pattern?” the ensuing discussion was edited into a segment that was then transcribed and analyzed for mathematical thinking. The video segments evidencing mathematical thinking, transcripts of those segments, field notes, and student artifacts were analyzed by the research team using a framework to identify mathematical thinking. The framework for identifying mathematical thinking consisted of the following areas:

Unitizing

- Working with a unit simultaneously as one unit and the number of elements that make up the unit
- Identifying and working with different sizes of units including the pattern core (unit of repeat), the pattern core made up of *n* columns, the pattern core made up of *n* beads, the template made up of *n* pattern cores, a bracelet made up of *n* templates

Algebraic Reasoning

- Identifying the unit of repeat in a two-dimensional pattern
- Identifying the covariation between the numbered columns and the beads within each column and the relationship of the numbered columns to the unit of repeat in a repeating pattern, to make predictions further down the sequence (e.g., the 64th column)
- Creating generalizations

Proportional Reasoning

- Using multiplicative relationships to compare quantities and to predict the value of one quantity based on the values of another. For example, comparing the number of columns in a pattern to predict the number of centimeters in beadwork

Spatial Reasoning

- Understanding relationships within and between spatial structures
- Understanding the relationship between visual and numeric representations of quantity
- Decomposing, for example, decomposing a pattern into identifiable units of repeat
- Mental rotation and transformation

Coding was carried out by the author. Each learning episode could receive more than one code, particularly since the concepts are intertwined. The author then developed brief case accounts describing each learning episode. The team then reviewed video segments and written case accounts and discussed each to reach consensus about the students' demonstrated mathematical thinking.

Results

Results focus on the mathematical thinking documented from week 1 of the lesson sequence, which focused on pattern design. In addition, some of the reflections from the Algonquin members of the research team are presented in which they identify aspects of the project that they found culturally relevant. We begin by providing an overview of the context in which this learning occurred.

Designing Patterns in the Classroom

During co-teaching, Christina taught the art of looming to the students and introduced them to the design process. Mike facilitated class discussions about the mathematical content of the work by asking students, for example, to identify the unit of repeat of different patterns. Inevitably, although the Indigenous members of the research team identified the need for authenticity in teaching the activity, the resulting experiences were both culturally authentic and inauthentic. We strove to create the kinds of learning experiences community members remembered from their own childhoods, when they learned beading techniques from community elders around kitchen tables. Our goal was also, however, to bring out mathematical thinking, and to this end we facilitated the exploration of mathematical ideas as they arose. For example, the template we created for students to use as they designed their patterns was based on the kinds of drawings Christina and others in the community created prior to looming. Some of the inquiries students engaged in, for example, calculating the numbers of beads needed for different designs, were questions that students asked during the course of the investigation but are not areas on which traditional loomers would necessarily focus. Christina told us that most beaders estimate the numbers of beads they require and that this focus on exact numbers seemed to her more of a Western idea.

Christina explained to the students that looming is a traditional Algonquin activity that pre-dates the arrival of Europeans to North America. Historically, sinew and porcupine quills and shells would have been used, but currently looming is done with nylon thread and plastic or glass beads. The pattern for each looming project is created on graph paper (see Fig. 7.2). The first step in creating a design is to define the space to be used. Based on Christina's work, we created a design template of 20 columns and 7 rows. The columns represent the weft threads, on which beads are threaded and woven onto the warp threads. The number of columns corresponds to the horizontal length of the beadwork. The rows represent the spaces between the warp threads, where the beads sit when they are woven into the work. The number of rows corresponds to the width of the beadwork.

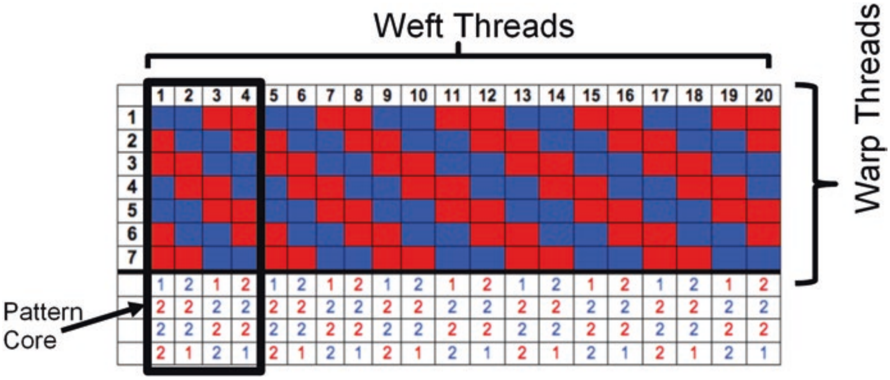


Fig. 7.2 Diagonal loom pattern

The rows and columns of the design space are numbered. Below each column, the number of each color of bead is entered (with the number representing the color of the beads, in this case blue numbers for blue beads and red numbers for red beads). This helps the beader know the order for stringing beads for each column, or line of beads on the weft thread. Each column should add to the total number of beads on each weft thread (so in the example in Fig. 7.2, each column should add up to 7).

Students were taught to copy and extend two patterns, the "diagonal" and the "chevron," which reflect the geometric nature of early Algonquin designs. Students explored these and other patterns through a series of investigations outlined below. Finally, students were invited to design their own pattern, which was then used to create their beadwork.

Diagonal Pattern Christina introduced the diagonal pattern using an interactive whiteboard as a way of orientating students to the columns and rows of the grid and to demonstrate the conventions of planning a pattern using a template. Christina filled in the template up to the 10th column, and students were asked to copy and extend the pattern to the 20th column. They were then asked to identify the section of the pattern that repeats (which was termed the "core" of the pattern). Identifying the unit of repeat in this pattern required students to analyze the visual and numeric structure of the pattern. The students identified the first four columns as the unit of repeat and had various ways of justifying their thinking. Some students looked at the numeric patterns and identified that number pattern for columns 1–4 repeated every four columns (see Fig. 7.2). Other students looked at the visual pattern of the first four columns and predicted that this four-column structure, when rotated 180 degrees, would be congruent. The first four columns represented the fewest number of columns for which this was true and so were identified as the core (e.g., the same is true if you rotate a core made up of columns 1–8, but this can be broken into two groups of four columns). Students tested their theory by copying the four-column structure on the interactive whiteboard and rotating the core. Still other students used "occluders" (strips of paper) to isolate different parts of the pattern to determine the unit of repeat and through visual trial and error identified the first four columns as the core of the pattern (see Fig. 7.3).

Christina then introduced students to a pattern of chevrons that were two beads wide and created using two alternating colors: a two-color two-bead chevron pattern

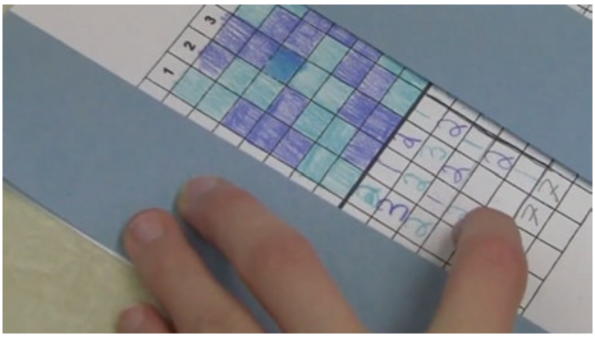


Fig. 7.3 Using "occluders" to find the unit of repeat exploring chevron patterns

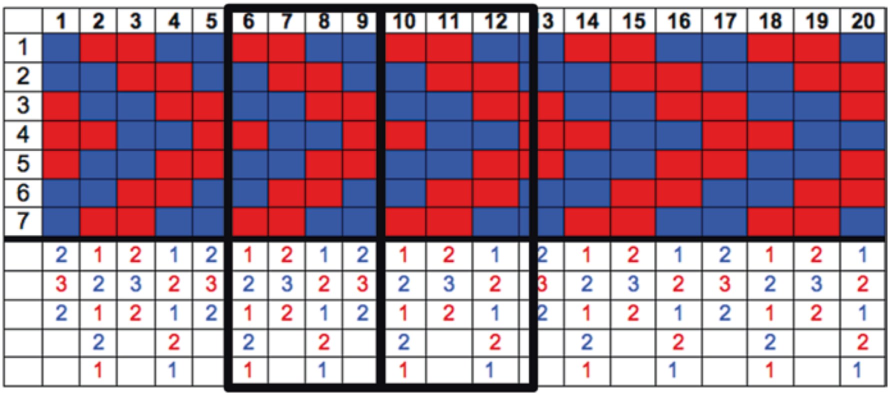


Fig. 7.4 Two-color two-bead chevron loom pattern

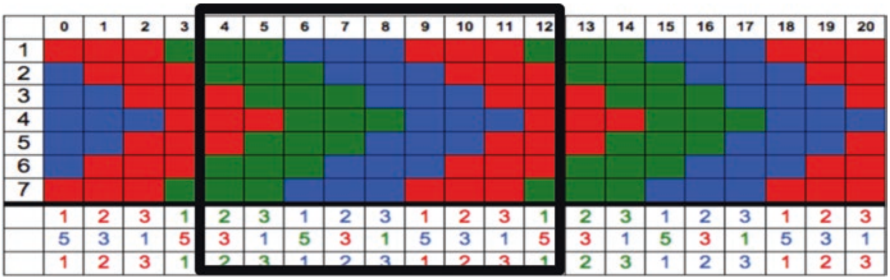


Fig. 7.5 Three-color three-bead chevron with column 0

(see Fig. 7.4). Students were asked to find the core of the pattern. Some students focused on the numeric pattern and noted that even though the numbers repeated after the second column, the colors were different, so the first four columns made up the core. Other students identified the visual pattern of the first four columns and described the central blue chevron surrounded by parts of red chevrons on either side.

Next, students were taught to create a three-color three-bead chevron (see Fig. 7.5). Students identified the core by finding the columns that were the same (either visually or numerically). Students found that column 10 was identical to column 1 and reasoned that the core comprised columns 1–9. Students described imagining superimposing the first nine columns onto the next nine columns to see if they "matched." They then used the interactive white board to copy the core and overlay it onto columns 10 to 18. Noticing that the pattern seemed to begin with a partial chevron, a few students wondered what would happen if they added a column "before" (to the left of) column 1 on the pattern (which they referred to as "column 0") and whether this would change the pattern core. The rest of the class then explored this line of inquiry. They discovered that if a column was added to the left of the core, and the new column was considered the beginning of the core, then the whole core "shifted" to the left by one column and comprised columns 0–8 (see Fig. 7.5). They continued to add columns to the left of column 1 and noticed the core shifted by as many columns as were added. They also

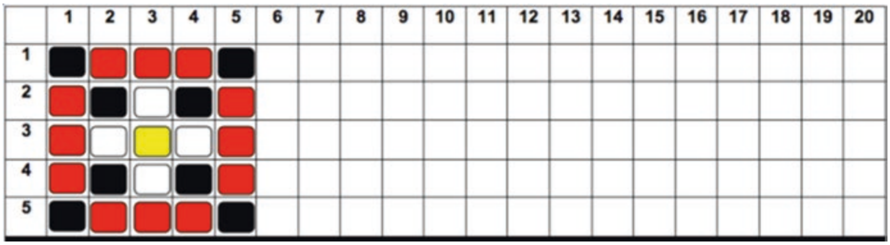


Fig. 7.6 Flower pattern

noticed, however, that the number of columns in the core did not vary. For a three-color three-bead chevron pattern, the core was always made up of nine columns.

The students identified that any nine consecutive columns in the pattern could be considered the core and that identifying the first nine columns as the core was arbitrary since the pattern could extend to the left as well as the right of the initial given element; the width of the core did not vary. This prompted a student-generated inquiry about whether it would be possible to predict the width of the core for any chevron pattern. Each student was asked to create a chevron pattern made up of any size chevron and any number of colors. Students then analyzed different chevron patterns to identify the core. They reviewed a two-color two-bead chevron with a core of four columns and a three-color three-bead pattern with a core of nine columns. Next they considered a two-bead four-color chevron and found the core was eight columns and a two-bead five-color chevron with a core of ten columns. Based on these experiences, the students generalized to predict the number of columns in the pattern core of any chevron pattern. They found that the width of the core was determined by a multiplicative relationship between the width of the chevron (the number of beads that made up the chevron) and the number of colors. To test this theory, they created a three-bead five-color chevron that they accurately predicted would have a core comprised of 15 columns. Students also discovered that their theory worked for the diagonal pattern as well, because when the top three rows of a seven-row diagonal pattern are reflected vertically, the diagonal pattern becomes a chevron pattern.

Other Patterns The students were then introduced to other patterns, like the flower pattern (see Fig. 7.6).

As they worked to determine the unit of repeat, students initially identified the core as column 1 to 5 and predicted that column 6 would be the same as column 1. They also argued, however, that the core might be considered as extending from column 1 to 4, and that column 6 would, therefore, look the same as column 2. Mike added some beads to the pattern so students could judge which of their conjectures were accurate (see Fig. 7.7). The students agreed the core was four columns.

They were then asked to make predictions about columns in the pattern further down the sequence, for example, what the 64th column would look like. Students had a few ways to solve this. Sylvie said, “I think it’s column 4 because you just need to times 20 by 3 and that’s 60 and go 4.” Underlying this answer is Sylvie’s understanding that the 20th column would be the same as the 4th column, and three full templates plus four more columns (or one pattern core) would be the 64th column.

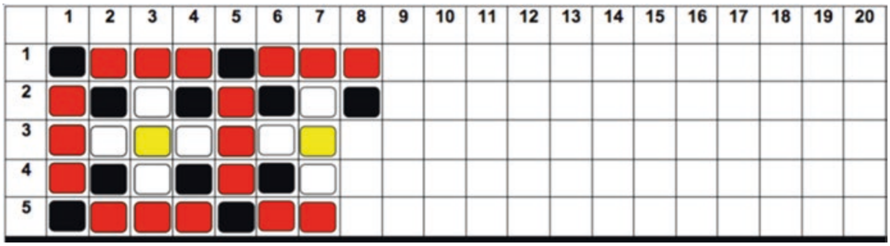


Fig. 7.7 Extended flower pattern

Adam stated, "It would be column 4 because 4 is a direct multiple of 64 and it would come around to be a full pattern core." This reasoning shows an integration of both the numeric relationships and the visual aspects of the pattern, since Adam justified his thinking both through stating a multiplication fact and an understanding that the 64th column would be the last column of a core. Mike then asked the students how many repetitions of the core would be included up to column 64. Again, explanations from students demonstrated an integration of numeric and visual reasoning. For example, Jonah's first explanation was grounded in multiplication facts. "It would repeat 16 times because 10 times 4 is 40 and 6 times 4 is 24 and add them together, it's 64." His response was challenged by Sam.

Sam: Sixty. You were thinking of 16 as 60. But there's one extra one, so 64, that would actually be 17.
Adam: One extra what?
Sam: One extra pattern core.
Jonah: No it's not, because 5 times 4 equals 20, which would make it 60, so that's 15. Then when you add one more it would be 16 to make it 64.
Sam: Oh, yea, ok.

Implicit in this argument is the understanding that the 20-column template will contain 5 repetitions of the 4-column core. Sam argued 16 repeats of the core would only reach column 60, and so one more core would be needed to get to column 64. Jonah, however, responded that "5 times 4 equals 20," meaning there will be 5 repetitions of the core in one 20-column template, "so that's 15" meaning for 3 full templates, there would be 15 cores, and adding one more pattern core would add 4 columns to 60 to end at column 64.

Individual Bracelet Designs At the end of the first week, the students designed their own pattern to use as the basis of their bead creations. By measuring some sample bracelets Christina had brought into the classroom, they discovered that five columns on the pattern template equaled 1 cm of beadwork. Students measured their wrists and then used the relationship of 5 columns = 1 cm to calculate how many columns long their bracelets would need to be in order to fit. They also calculated how many beads in total they would need and how many beads of each color they would require. Some students, like Ella, designed a pattern with a five-column core and reasoned that the number of repeats of the core would equal the size of her wrist in centimeters (see Fig. 7.8). Ella measured her wrist at 15 cm, so she would need 15 repeats of her core. Since each core comprised 35 beads, she calculated that

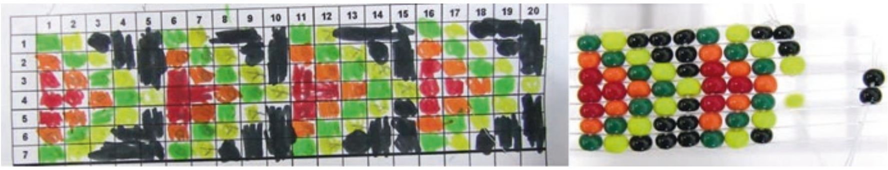


Fig. 7.8 Ella's five-column pattern core

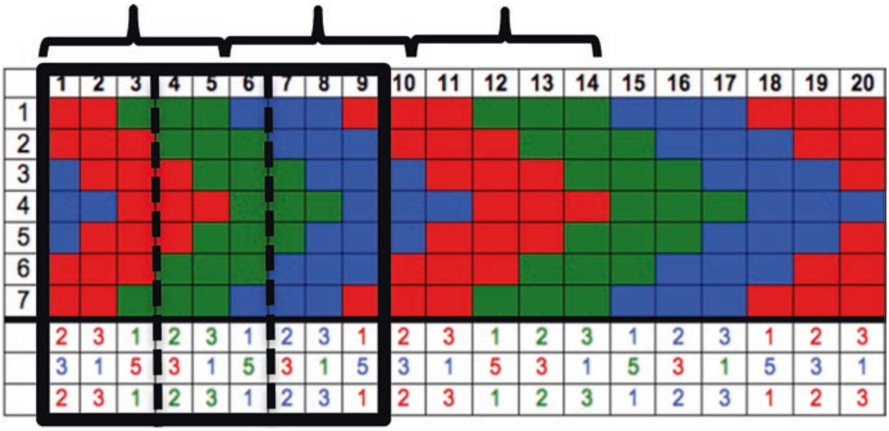


Fig. 7.9 Three "sub-cores" in a nine-column pattern core

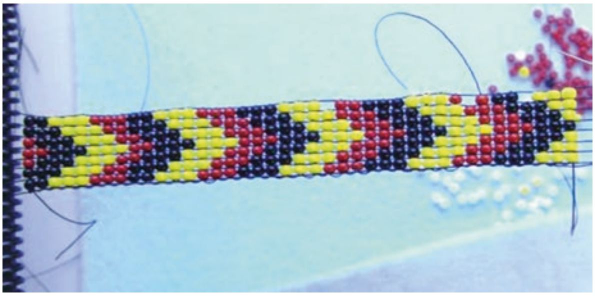
the total number of beads she would need would be 35 times 10 (350) plus 35 times 5 (175), for a total of 525 beads. She double-checked the total by calculating the number of columns (75) and multiplying that by the number of rows (7).

Many students, though, designed patterns that were not based on a five-column core. Julia, for example, measured her wrist at 15 cm and knew her final bracelet would need to be 75 columns in length. She found a numeric pattern in her three-color three-bead chevron that repeated every three columns; however, she saw that visually the core was nine columns wide, which could be broken down into three different "sub-cores" (see Fig. 7.9). She calculated the number of sub-cores that would fit into her 75 columns and determined that sub-core 1 would repeat nine times and sub-cores 2 and 3 would repeat eight times each. She then counted the number of different colored beads in each sub-core and multiplied that by the number of times the sub-core repeated. Sub-core 1 had 15 red, 4 blue, and 2 green, each of which was multiplied by 9. Sub-core 2 had 15 green, 4 red, and 2 blue, multiplied 8 times. Sub-core 3 had 15 blue, 4 green, and 2 red, multiplied 8 times. This resulted in a total of 525 beads.

Luke designed a patchwork design and found his pattern core was nine columns (see Fig. 7.10). His wrist measured 18 cm, so his design needed to be 90 columns with ten repeats of the pattern core. The design consisted of an overall 9 × 9 array, made up of smaller 3 × 3 arrays. Since he used only three colors, each color required 27 beads, so the total number for each color bead was 27 times 10 (units of repeat) for a sub-total of 270 beads. He then multiplied 270

Fig. 7.10 9 × 9 Luke's array pattern core

Fig. 7.11 Jack's chevron



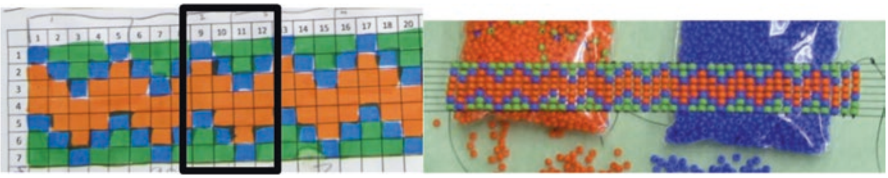


Fig. 7.12 Wyhatt's four-column pattern core

times 3 to figure out that he would need a total of 810 beads. He confirmed this by calculating the total number of beads in the 9 × 9 pattern core and multiplying the answer, 81, by the ten repeats of the pattern core.

Jack also needed 90 columns for his 3-color 3-bead chevron (see Fig. 7.11). He counted 14 beads in each chevron. He drew his pattern to the 90th column and found there were 15 yellow, 14 black, and 14 red chevrons. He then realized that each partial black and red chevron at the beginning and end of the pattern would, if put together, create a full chevron, so there were 15 chevrons of each color. He multiplied the number of chevrons by the number of beads per chevron to get 210 beads of each color, which multiplied by 3 meant 630 total beads.

Finally, Wyhatt's pattern core had four columns (see Fig. 7.12). He calculated that 5 pattern core units = 20 columns, or 4 cm; that 10 pattern core units = 40 columns, or 8 cm; that 20 pattern core units = 80 columns, or 16 cm; and that he would need one more core, plus a column, to reach 85 columns, or 17 cm.

The work of this project adheres to four components necessary for culturally responsive math education: (1) focus on important mathematics, (2) relevant content, (3) incorporate student identities, and (4) shared power (Averill et al., 2009). The mathematics the students explored was rigorous and complex. The content was relevant for students, both for those from the community and also for non-Native students who were equally interested and engaged in the activities and mathematical discussions. The Algonquin students saw their culture reflected in math instruction, and through our process of inquiry and discovery, all students contributed to the mathematical knowledge building – every student's ideas were important and acknowledged.

Mathematical Thinking

This sequence of lessons contributed to students' understanding of a number of key mathematical concepts inherent in beading, including identifying complex patterns, algebraic reasoning, proportional reasoning, and spatial thinking.

Patterning and Algebra Research has suggested that an important part of developing algebraic reasoning is the ability to identify the mathematical structure of a repeating pattern and to use that structure to make predictions about the pattern far down the sequence, which is an early form of constructing a mathematical generalization (e.g., Mulligan & Mitchelmore, 2009; Mulligan, Prescott, & Mitchelmore, 2004). Most of the visual patterns students typically encounter in elementary classrooms are created horizontally, with an emphasis placed on finding the pattern core and finding "what comes next" (i.e., to the right) of the given elements (McGarvey, 2013). In this project, students considered patterns that extended in two dimensions and were far more complex than a series of shapes or numbers. Copying, designing, and creating these patterns supported students to analyze this complex structure. We found that students were able to shift their focus to consider four different levels of the pattern: (1) the beads within each column, (2) the core of the pattern made up of a specific number of columns, (3) the number of beads in a core, and (4) the overall design of the pattern.

The idea of a "shifting" pattern core seemed to be a new idea for these students, as they would likely have never been previously prompted to consider that a pattern can extend to the left as well as the right of the given elements. This allowed them to recognize that the core of a pattern is not necessarily defined by the first set of elements and that what remains constant is the size of the core (in this case, the number of columns). This discovery prompted the students to capture the relationship between the size of the chevron and the number of colors to create a generalization in order to predict the size of the pattern core (bead × color = core width).

The students were also able to make predictions far down the sequence of different patterns, for example, predicting that the 64th column for a 4-column pattern would look like the 4th column because 64 is a multiple of 4, and the 64th column represents the final column of the 16th repetition of the core. These predictions were based on recognizing the covariation between the numbered columns and the elements in the unit of repeat (the beads in each column) and the number of columns comprising the core. What was interesting was how students justified their predictions using both their knowledge of multiplication (i.e., that 64 is a multiple of 4) and the structure of the pattern and its relation to the template, that is, describing the 64th column in terms of 3 completed 20-column templates (or 15 pattern cores) plus one more core.

Proportional Reasoning In this study, students used proportional reasoning to estimate the total length of their finished bracelets using a fixed ratio of 1 cm = 5 columns. Students whose pattern cores were also 5 columns were able to translate the size of their wrist in centimeters directly into the number of pattern cores required. Other students, however, used other units in their reasoning. For example, Wyhatt's reasoning used a composite unit: the 20-column template represented 5 pattern core units and 4 cm simultaneously. Students exhibited an ability to use single or composite units as the basis for multiplicative thinking and could make decisions about which unit to use for their calculations (e.g., using the unit of 5 columns for 1 cm, or using the unit of the pattern core of 4 columns related to an understanding that 20 columns = 5 cores *and* 4 cm). Many proportional reasoning activities found in elementary mathematics curricula are designed to encourage students to apply a memorized rule or algorithm; however, the application of memorized rules does not mean students are reasoning proportionally (Lamon, 1993). The problems posed during this unit were practical and engaging because the teachers needed to know how many beads to order and of what color. As one student put it, "we needed to figure out the number of beads pretty accurately, because if we didn't order enough beads we wouldn't be able to finish off our bracelets!" The students had not been taught specific strategies for reasoning proportionally but were able to do so because they understood the context of the problem.

Spatial Reasoning Numerous studies have suggested that spatial reasoning skills, including mental manipulation and spatial visualization, are linked to mathematical achievement (Gunderson, Ramirez, Beilock, & Levine, 2012; Mathewson, 1999). Here, we found that designing two-dimensional patterns on a grid, and identifying components of the pattern (like the pattern core), provided an opportunity for students to engage in visuospatial thinking. As they worked to discern the columns that made up the core of the pattern, the students were able to mentally visualize isolating the pattern core and rotating it, or superimposing one core onto the next to determine whether it "matched." These mental processes were then checked using the interactive whiteboard. In addition, the planning of patterns (and subsequent beading) required students to consider spatial relationships on many different levels: the relationship of the beads within a column, the relationship of a column to surrounding columns, the relationship of the columns representing the "core" to the bracelet as a whole, and the relationship of beads and columns with respect to the overall design of the piece. All of these relationships were considered within a two-dimensional grid (the paper designs) or in three dimensions on the loom.

Engagement and Mathematical Thinking

After reviewing transcripts of students' experiences in these lessons, we found that integrating a traditional cultural practice as the basis for mathematical instruction seemed to suggest enjoyment and engagement for all students, as well as high levels of mathematical thinking, which Christina believed were intertwined: "The thing that impressed me most about the videos of student learning is that they were *proud* of what they did. It wasn't hard for them to talk about the math because they enjoyed it so much." Although the lessons supported students to engage with complex concepts such as algebraic and proportional reasoning, the means of facilitating this learning was through the process of designing and constructing beaded bracelets. Students spent up to 3 hours at a time in the classroom not only working on designs but also solving mathematical problems that emerged from the activities, reflecting Howard and Shirley's advice to make the content meaningful and hands on.

The method of instruction also played a role in student success. For some looming lessons, Christina used direct instruction to teach students how to use a grid template to design their patterns and how to create certain designs. For a majority of the time, though, the classroom was more informal. Students designed their own bracelets and tackled the mathematical problems that arose naturally from the activity. They worked with Christina, or in small groups or individually, to find solutions. Jody likened this to her experiences as a child growing up in Pikwakanagan and learning how to bead from community members:

> Christina was sitting at the front table that was set up for the students. She was working with a group of girls, and it reminded me of when I was growing up. I must have been about 8, and my cousins and I went to an elder's house, and we did beading. I recall that there was a big wooden kitchen table, and we had beadwork all over the table. Christina working with the students just reminded me of that because we were just sitting, we were chatting, we were laughing. There was no worry about making mistakes; there was just, we were all learning together. And you were sitting in close proximity to someone who you trusted to teach you whatever it was you were doing. You know, a lot of humor and laughing among us, and it was a safe place, and I think that's the part that reminded me of when Christina created that environment in the classroom. Quite often we think of classrooms in schools as institutional, but I think that the community feeling was created in that classroom.

This feeling of safety, humor, and community provided an opportunity for students to begin to develop a positive, personal relationship with mathematics. Rather than focusing on the acquisition of math concepts as stepping-stones to even more complex mathematics, the students were able to explore the mathematical ideas inherent in the process of design as interesting lines of inquiry, rather than as sequences of memorized steps. Indigenous pedagogy is holistic, in that it emphasizes the need to address the intellectual, physical, emotional, and spiritual development of the student (Barnhardt & Kawagley, 2005; Cajete, 1994). We created an environment where students learned complex math by being active participants in activities that they seemed to care about and through which they made connections to Algonquin culture.

Importance of Indigenous Community Members in the Mathematics Classroom

Another aspect of the experience highlighted by the team was the importance of all students learning from community members who came into the classroom to teach and seeing that the knowledge brought by those members was honored and respected. Jody spoke about her excitement: "I'm excited to see more culture. The students really wanted to hear what Christina said and they wanted her help and I think that's an important part too – the value of our own people bringing in their understandings." Christina also spoke about the impact of this experience for Algonquin students and how this experience supported students' pride in their identity and strengthened relationships with non-Native peers:

> I think it's important for a First Nations person to teach First Nations skills. What are we doing this for if it's not cultural? If it doesn't have some kind of cultural significance then what are we doing this for, is it just to teach math? No. Not when you see the changes in the First Nations students. Seeing them more confident, and the pride in talking with their peers about their lives, their regalia and stuff like that. And it's nice to be able to share with your best friend who might not be Native a little bit more about your life that they might not know about because they only ever see you in a school setting.

Bringing community members into the classroom expanded the students' conceptions of "who does mathematics." As Hatfield, Edwards, Bitter, and Morrow (2007) state, "pride and a sense of hope, rather than learned helplessness, are education's goals for students who previously would never have considered mathematics as a viable option in their lives." (p. 70).

Revisiting Ethnomathematics

As previously stated, one aspect of an ethnomathematics approach to Indigenous mathematics instruction has been the "extraction" of mathematics from Indigenous cultural activities. And while this stance has, for our study, yielded rich mathematical thinking that aligned with community goals to have Algonquin students become more proficient in "school math," the fact is that this work is still framed by a Western perspective of what it means to think mathematically. The Algonquin activity of looming was, in effect, dominated by Western mathematical perspectives. Given that so much of the Indigenous mathematics teachings and language of the community had been taken, we found it difficult to determine what genuine "Algonquin mathematics" might look like. One of the goals of community members was for their students to become proficient in "school math," and this goal was met within the context of a learning community that mirrored the childhood experiences of community members.

This study is aligned with an understanding of ethnomathematics as "interpretive mathematizing;" that is, identifying and developing the mathematics implied in the activity (Ascher, 1991; Barton, 1996). This contextualization of mathematical ideas meant students could connect with school math ideas through the process of engaging with a traditional Algonquin activity. Conversely, after instruction, Christina explained how she began to view her looming through more of a mathematical lens: "It's easier to design patterns once you understand there are numbers there, not just beads. I've started looking at it from a totally different perspective. Numbers, colors, and shapes in space."

Conclusion

Although this project represents an initial introduction of bringing together Algonquin community members and non-Native educators, we have been able to document the inclusion of mathematics content knowledge (informed by the Western perspectives and the mathematics inherent in the cultural activities explored), pedagogical knowledge (particularly the pedagogical practices brought to the experience by Christina), and contextual knowledge (connecting the school to the community of the Algonquins of Pikwakanagan First Nation). Co-designing and co-teaching units of math instruction are the first steps to creating classroom and community interactions in the hopes that mathematical and pedagogical knowledge will connect school and community contexts. Students learned techniques of looming and engaged in classroom discussions focused on selected ideas and concepts so that the mathematics was revealed.

One way of framing the results of this study is to consider it a "third space" (Gutiérrez, Rymes, & Larson, 1995; Haig-Brown, 2008). We attempted to create this space by documenting the Western mathematical thinking that is inherent in a traditional Algonquin activity and by explicitly privileging Algonquin content and pedagogical approaches alongside Western pedagogy and mathematical content. The resulting learning experiences were considered by the research team to represent a hybrid of Algonquin and Western cultural content and pedagogical approaches.

It was important that all students had an opportunity to learn from community members who came into the classroom to teach and to see that the knowledge brought by those members was honored and respected. Christina emphasized the cultural importance of the activity, which provided an opportunity for students from Pikwakanagan to connect to their own cultural heritage and to develop a sense of their mathematical identity through culture. This project was also important for the non-Native students who gained greater insights into the culture of their classmates and who extended their own mathematical thinking.

The focus of this project was specifically on integrating Algonquin culture and mathematics instruction, and it responds to the Canadian Truth and Reconciliation Commission's call to action to "develop culturally appropriate curricula" (*Canadian Truth and Reconciliation Commission: Calls to Action*, 2015, p. 2). We believe, however, that it also addresses the Commission's call to action outlined as "building student capacity for intercultural understanding, empathy, and mutual respect" (p. 7). Highlighting the teachings of the community members in the classroom gave students an opportunity to participate in knowledge systems that were valued on the same level as Western curricula. This experience can, we hope, form the foundation for lifelong intercultural learning and respect.

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