SETS OF, ROWS OF, JUMPS OF: VERBING MULTIPLICATION

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Prologue (Lisa) In 2011, I published my first sole-authored article in FLM, in issue **31**(3). It was called 'The verbification of mathematics' and I shared insights into how focusing more on action and process in mathematics teaching and learning could support Indigenous learners, and really all learners. I drew from my experiences working in Mi'kmaw communities in Nova Scotia, having come to learn about the Mi'kmaw language, which like all Indigenous languages in Canada, is a verb-based language. Reflecting upon the way I often heard my students turn nouns into verbs—"Broom the floor", "Off the light", "Camera me!"—I also noted that when I spoke more in verbs about mathematical processes, my students seem to connect with the mathematics better; in fact, speaking in too many nouns was deemed 'crazy talk'. Verbification had been a central focus of my doctoral research and continues to be a focus of my work.

I had chosen the word 'verbification' to stand in contrast to the nominalisation that is far too common in mathematics. At the time, some colleagues pointed out the irony of my using a noun to describe a process of speaking more in verbs. As a new academic, I was enamoured of the word 'verbification'—I got to invent a word and then write about what it means, how cool is that? Over time, however, I have come to appreciate the irony and have been gradually moving to the idea of *verbing* mathematics. I spend a considerable amount of my time thinking about verbing mathematics, designing tasks that focus students' attention on verbing mathematics, and trying to articulate the process of verbing in a way that becomes comprehensible for teachers, so that they too might take up the task of verbing mathematics. While typical approaches to addressing the needs of Indigenous children in mathematics learning tend to focus on cultural artefacts, verbing for me goes beyond that narrow approach. Verbing is about allowing Indigenous knowledge systems to enter and be valued in the mathematics classroom even with what looks like typical school-based mathematics.

This article captures aspects of this on-going exploration of verbing mathematics by exploring a series of lessons that my colleagues, Evan and Ellen, and I implemented in a Grade 3 classroom with Suzanna, the teacher, whom I had known for a long time. This is our story of verbing multiplication.

Introduction

What does it look like to verb mathematics? How does it play out in the classroom? How does a teacher design a task that is rooted in a verbing approach to learning mathematics? How do we explain verbing mathematics to others?

We believe that verbing mathematics is about an intentionality that goes beyond mere syntax. We seek to intentionally think about actions, processes, and motion that honour an epistemological approach that values movement and flux in the world. We also recognise that the affordances of English might ask us to name these processes as something that moves us away from verbing and so we try to resist labels, as mathematics and English pull us toward them. We live in this tension as we try to explain our work and to come to understand it more deeply ourselves. What we are sure about is that we recognise it when we see it and so we often examine specific examples to explain the process of verbing mathematics. We talk of joining and separating quantities as opposed to sums and differences. We consider how to get from one point on a line to the next by going over and going up or down rather than focusing on the rise and the run to determine the slope. We suggest that rather than talking about the vertical and horizontal shifts, vertical and horizontal stretches, and reflections, we can talk about how changes in the equation make the graph move up or down, left or right, be pulled outward or upward, or flipped over. We know examples of verbing, we can plan lessons that focus on verbing, and we can find tasks that allow teachers to see verbing in action, yet we still struggle to articulate a more general process of verbing mathematics. In this article we will explore a series of multiplication tasks done with a third-grade class as a specific example of verbing mathematics.

In more recent conversations we have been thinking deeply about playing with mathematical concepts in ways that allow students to structure these concepts both physically, with concrete models, and perceptually. We focus on task design that encourages active engagement with mathematical ideas. The tasks are generative in how they allow students to notice processes that are foundational to a concept, in ways that are rooted in cultural synthesis (Wagner & Lunney Borden, 2011) rather than cultural collision (Mallea & Young, 1984). We ask ourselves: How might one design a task to promote abstracting through concrete exploring? How might playing with quantities in particular lead to structuring of number and operation concepts? This has resulted in an exploration of the term 'structure' as both a noun and a verb.

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Structuring structure

Towers and Davis (2002) problematise our understanding of constructivism and encourage us to consider two definitions of 'structure'. First, in an architectural sense, structure denotes foundations, building blocks, order, rigidity, and permanence. Alternately, in a biological sense, structure conveys an organic, evolving fluidity, embodying, for example, the structure of living organisms or ecosystems. In living systems, we describe structure as continually unfolding rather than permanent.

Venkat, Askew, Watson and Mason (2019) described the architectural quality of structure involving "a spatial organisation formed by specific relationships that place some element or elements in particular configurations with another element or elements, rather than in random arrangements" (p. 14). This description resonates with the ways in which Mi'kmaq describe objects as 'forming' into an arrangement of a certain quantity or shape. In our verbing of mathematics, we draw upon this idea of architecturally structuring mathematical tasks through playfully engaging with concrete models that invite students to literally build multiplication, adhering to the idea of forming.

Biologically, Mulligan and Mitchelmore (2009) defined structure organically as "the way a mathematical pattern is organised" (p. 34) and proposed four actions strongly correlated to mathematical understanding: identifying, visualising, representing and replicating. Learners who develop mathematical structures in this organic sense, do so by taking action: recognising and organising ideas in relation to other ideas. Ellemor-Collins and Wright (2009) recalled Freudenthal who described 'doing mathematics' as "organising phenomena into increasingly formal or abstract structures" (p. 53), a process he termed 'structuring', and extended the organising to include "relating numbers to other numbers and constructing symmetries and patterns in numbers" (p. 53). As structures become knowledge, they allow for new structures to emerge thereby creating an evolving and iterative learning cycle. As Ellemor-Collins and Wright (2009) state, "such recursive level-raising is familiar in many characterisations of doing mathematics, for example Sfard's reification (1991), and Pirie and Kieren's folding back (1994)" (p. 54). In our verbing multiplication example, we also draw upon this organic definition of structuring to describe how the tasks allow for abstracting of mathematical ideas through the iterative engagement with varied architectural structuring experiences.

In conceptualising structuring, we embrace these two definitions and the complexity of this recursive process because they inform our observations of how children first play and engage with quantity (by holding mathematics in their hands) and then organise and identify specific spatial relationships (building sets of, rows of, jumps of) as they develop their understanding of multiplicative structures. Viewed through enactivism (Reid, 2014), we appreciate more fully how, through interactions of structuring architecturally and structuring organically, students create meaning. Given the attention to flux and movement in the Mi'kmaw language, we know this meaning making is less like static pictures and more like moving videos (Sable & Francis, 2012). As such, we seek to create experiences for students that allow them to see mathematics forming through actions and models. In doing mathematics with children, we acknowledge the specific actions taken by children that are associated with mathematical thinking and suggest the 'verbing' of mathematics fosters emerging structures that may remain in motion. How teachers structure activities is critical: too much diminishes students' thinking, too little and students struggle to connect concepts. Such is the teacher's dilemma: by telling students about a multiplicative structure (*e.g.,* multiplication means repeated addition), learners may perform the operation without understanding how this structure emerged. This tension requires just enough structure to open a learning space where possibilities flourish for students to make connections. In our experiences in schools, we find that following directions often dominates mathematics teaching (literally *in-structing*) more than playful exploration; knowing the rules constructs simplicity on the surface but inhibits a deeper complexity from unfolding through exploration, creative play and wonder.

Our challenge, restated, is to rethink how we might design mathematics tasks for students to embrace the tension and the necessary 'just right' structuring. We take inspiration from the 'Curriculum manifesto' (Whiteley & Davis, 2003) presented at an annual meeting of CMESG. This re-visioning of the mathematics curriculum argued that an "appropriate image of mathematics centers on the rich problems themselves with their relationships among concepts and highlights both multiple entrance points into topics and multiple directions for expanding one's practice" (p. 83). However, in our context, 'just right' must also consider Mi'kmaw knowledge systems, bringing attention to the actions made possible by a task so that students might recognize how mathematical concepts are forming. Such considerations push back against the cognitive imperialism of Eurocentric thought far too dominant in our education system (Battiste, 2013). Our instructional approach connects with students' informal methods of engaging with mathematical ideas from their own ways of knowing by first structuring and noticing specific mathematical relationships that may then lead to more general properties and ways of knowing in mathematics. Generalisations, "instantiated in particular situations as relationships between elements" (Mason, Stephens & Watson, 2009), arise in a playful space allowing students to abstract conceptual understanding by exploring non-abstract models. Our MATH Project aims to create this playful space.

The MATH Project

We are currently engaged in a variety of research activities that fall under the MATH Project, which is focused on helping teachers to understand what it looks like to centre teaching and learning in Mi'kmaw knowledge systems as they attempt to decolonize their pedagogy. MATH stands for Moving Achievement Together Holistically and draws from the holistic model for transforming mathematics teaching and learning that Lisa developed in her doctoral work (Lunney Borden, 2010). In this project we work alongside teachers and teacher leaders in Mi'kmaw Kina'matnewey (MK) and public schools providing both professional learning experiences and in-class support as we collectively consider the implications of the model. We employ the process of *mawikinutimatimk* (coming together to learn

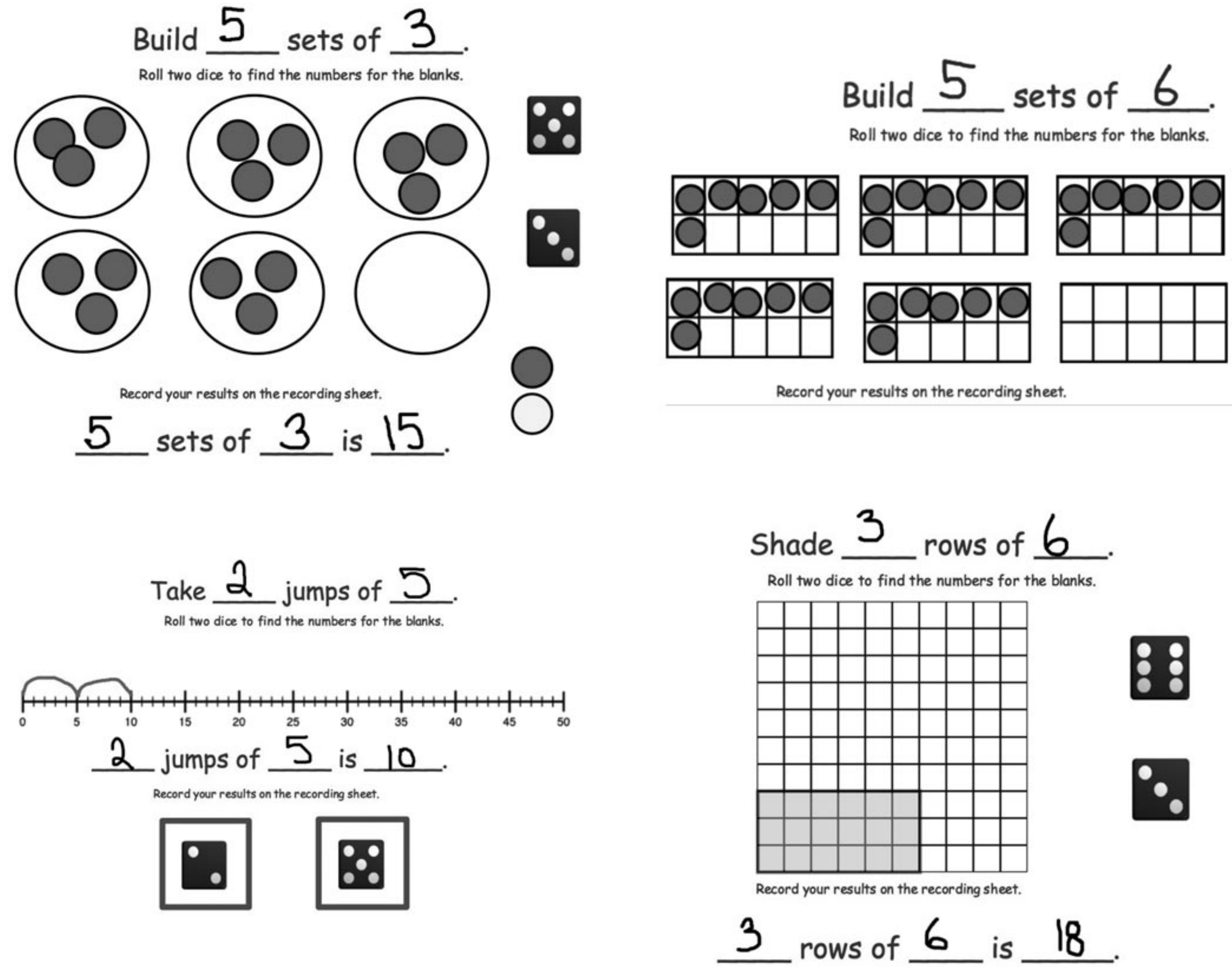

Figure 1. 'Sets of', 'rows of', 'jumps of' centre activities.

together) as we co-create an understanding of what it is to live out this decolonizing approach in the classroom. As stated in the prologue, typical work on Indigenous mathematics tends to focus on cultural artefacts and ethnomathematical investigations. The model we use to guide our work demonstrates that such practices are simply not enough to result in a more decolonized approach. While honouring the mathematical knowledge inherent in the Mi'kmaw cultural community is important and has been a part of a larger body of work we have engaged with through the Show Me Your Math Program (Lunney Borden, Wagner & Johnson, 2020), this current study moves away from artefacts and aims to build from Mi'kmaw ways of knowing or *L'nuita'simk*. Colonialism has tended to discount Indigenous knowledge systems and other them as 'culture', but it is the ways of knowing, being and doing in communities that have ensured survival in the face of attempted genocide, and these knowledge systems need to be valued in our school systems.

Within the aspect of the MATH Project described in this article, we specifically draw upon two ideas, using more verbs and integrating more spatial reasoning. This particular school is part of MK, a collective of Mi'kmaw schools that hold a self-governance agreement with the federal government in Canada. These schools are highly successful with respect to decolonizing education, supporting student learning and identity development, and have exceptional graduation rates (Paul, Lunney Borden, Orr, Orr & Tompkins, 2017). We have the privilege of visiting this class regularly, supporting the teacher with task design rooted in *L'nuita'simk* and drawing from enactivist approaches to learning that acknowledge collective knowing as being and doing in interaction with others. Collective knowing is characteristic of Indigenous ways of knowing, being and doing and inherent to *L'nuita'simk*, as is verbing. While our research shows that verbing mathematics benefits Mi'kmaw students, we believe it holds promise for all students and provides a way for non-Indigenous teachers to value and honour Indigenous knowledge systems.

Considering multiplication

During regular visits to the school, we observed the third-grade classroom and engaged with students learning multiplication. Often conceptualised as counting equal groups or repeated addition, children experience misunderstanding with multiplication when distinguishing numbers of sets from numbers within sets (Kouba, 1989). Watanabe (2003) suggested further difficulties for children stemming from different word choices (*e.g.,* 'multiplied by' or 'times') and structures designating the multiplier and multiplicand explicitly (*e.g.,* sets) or not (*e.g.,* rectangular arrays). Considering how students might model multiplication in different ways to foster emerging structure and conceptualise the operation became a focus for us.

Lu and Richardson (2018) described how students with no formal understanding in multiplication went about solving problems. They recognised that children often draw on visual, verbal and gestural ways of knowing to demonstrate understanding. Thompson and Saldanha (2003) found that knowing addition is not enough to conceptualise multiplication and encouraged visualising mathematical objects as equal-sized groups. Instructional factors promote misconceptions when teachers rely on multiplying tricks, overgeneralise strategies, or use imprecise language to describe multiplicative thinking. Drawing upon this literature, we are particularly interested in understanding more about prompting students to build their conceptual understanding of multiplication.

Verbing multiplication

When we think about what it looks like to teach mathematics with more verbs, we aim to unpack concepts to uncover core actions in which the understandings can emerge. With the lesson on multiplication, we begin with core actions that make multiplication necessary—making equal sets, taking equal jumps on a number line as a linear model, or building equal rows in an area model or array—rather than beginning with an explanation followed by activities to practice. We seek to design tasks with limited rules or terms, making them more accessible for all students. Our goal with language is that, like mathematicians, when we figure it out, we name it; we do not name it before we understand it.

To integrate spatial models, we think about ways that the concept can be explored concretely. With multiplication, three models—set, linear, and area models—provide an opportunity for us to consider which concrete materials we could use to help students hold the mathematics in their hands as they also develop visual-spatial models.

From these considerations, we developed a lesson we call 'sets of, rows of, jumps of' which highlights the various contexts in which we might use multiplication. We designed a series of four learning centres where students use dice to obtain two numbers which they then use to build multiplication facts as sets, rows or lengths. For example, at a 'sets of' centre, if a student rolled 3 and 5, they could choose to build 3 sets of 5 or 5 sets of 3. The language of the activity, rooted in action, compels students to choose the set size and the number of sets with awareness of each. We provided two variations of the set model—with and without a ten frame. The 'rows of' centre provided students with square colour tiles to build area models, *e.g.,* 4 rows of 6 or 6 rows of 4, and a blank grid to shade what they built. The 'jumps of' centre used number lines. The four tasks are given in Figure 1. Again, with rows of and jumps of, students can choose which number will indicate the number of rows or jumps and which will indicate the size of the row or jump. Students are not forced to unpack a multiplication sentence to determine which is the multiplier (number of) and which is the multiplicand (size of), rather they are working from an understanding of this concept as a starting point for building. The beauty of these tasks is that they require limited resources; one could use digit cards in lieu of dice and found objects to build sets and arrays.

Sets of, rows of, jumps of

While students worked in centres, Lisa and Suzanna circulated around the room engaging students in discussion about their thinking. Students reported finding this activity to be "So much fun!" and seemed to be on task the whole time. They also used reasoning skills to determine the totals. This provided us with opportunities to see how they were thinking about the quantities and observe calculation strategies. There were also opportunities to discuss if order matters. For example, "Would 3 sets of 5 give the same total as 5 sets of 3?" Figure 2 shows the expression on one student's face when, after bringing 5 sets of 2 into being with her hands, realized it was the same as 2 sets of 5.

Figure 2. Excitement in seeing that 2 sets of 5 is the same as 5 sets of 2.

In the lesson, students repeatedly used the language 'sets of, rows of, jumps of' as they were building concrete models which then brought their focus to the action associated with multiplication. Consider for example, one student who, when building 4 rows of 6, assembled the model, and then explained the model by gesturing to show the dimensions of the rectangle by moving his hand back and forth repeatedly, demonstrating how the array was forming (Figure 3). He then used a double-double strategy to find the total, adding 6 + 6 to make 12 and then doubling the 12 to get 24.

Another student working with the sets on ten-frames built 5 sets of 6 and noticed that it could be counted by counting the groups of five and then adding on the five ones. This observation lays the groundwork for future learning with the distributive property. Many students used skip counting strategies working with smaller subsets of quantities, but a few students would count items one at a time. All these observations gave the teacher and the research team insight into the quantity sense of the students which is useful in guiding future instruction.

The teacher continued working with these centres for a few days to deepen the students' understanding of building multiplication conceptually. We returned the next week with story problems that involved these concepts. We still had not introduced the students to the words 'multiplication' or 'times' as our intention was to focus on verbing by staying with the process of building equal quantities. Some examples are given in Figure 4. The problems provided a context for students to continue working with the same concept. While many students would have seen examples of multiplicative relationships in their daily lives—grouping beads or quills or the score marks on a loaf of fresh baked *luskinikn* creating an array of delicious biscuit bread—we were careful to not trivialise Mi'kmaw knowledge systems with contrived connections and instead stuck to ideas relating to everyday experiences of bagging candies or cookies for fundraisers or organising chairs into rows. They had a variety of materials to choose from to build their solutions and recorded their answers on large format paper.

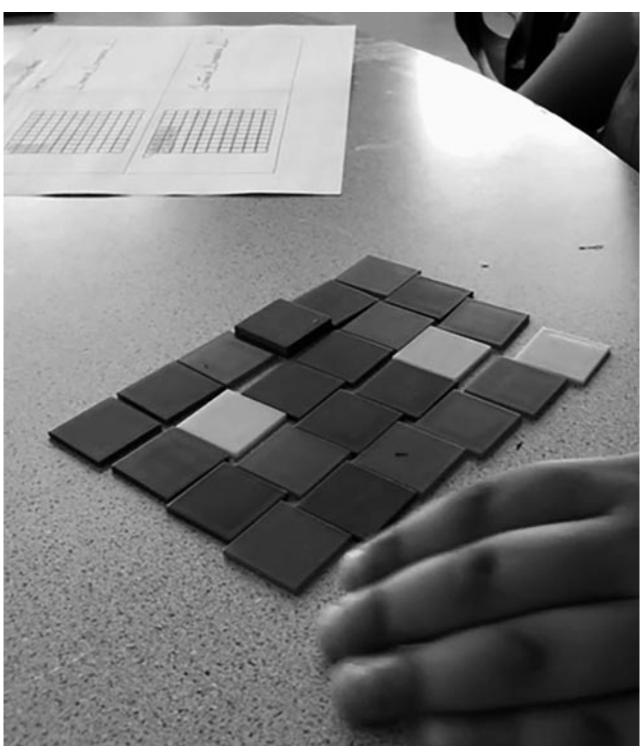

Figure 3. Building a model of 4 rows of 6.

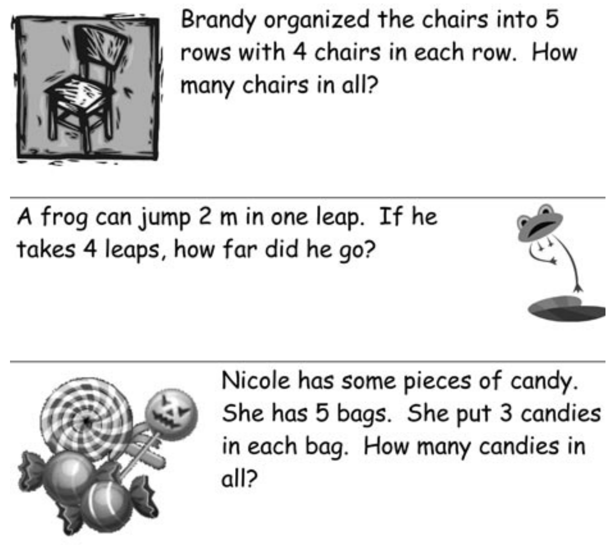

Figure 4. Story problems for multiplication.

As we were engaging in discussion, one student explained that she was building things a certain number of times: "I built 3 four times and I built 2 five times". Then she paused and said, "Wait a minute, this is just times!" She then told everyone in the room that this was, "just times!" She declared, "I know what times is now, it's just groups!" Thus, bringing her own meaning to this word 'times' she had heard so often in relation to mathematics, claiming it as a way to describe something being built a certain number of times.

Emergent structures of mathematical understandings

Our goal with these lessons was to move from process to concept. We wanted students to structure multiplication both architecturally and organically before we introduced the name and the symbols for the concept. This intentional decision to remain with the actions and processes is what we see as verbing. Because students made sense of multiplicative situations through structuring architecturally and organically, they brought this knowing to contextual and symbolic questions. This is where we saw the students engaged in the sort of generalising from varied specific experiences described by Mason, Stephens and Watson (2009). For example, as we had a debriefing conversation, Suzanna showed us examples of her students' set constructions using the concrete materials and then offered:

> But when I gave them questions like that [5 × 3], it was hard. It was not like they couldn't do it, it was like, "Well what does this mean?" and I was like, "Well you tell me what it means," and they were like "Is it the same thing we were doing with the sets of?" and I was like "Yes!" and they were like "Oh so you just draw 5

> groups and you put 3 in each group?" and I was like "Yeah!" So they were okay after that.

She remarked that she found this to be a very effective approach and liked the way it introduced the concept of multiplication by building representations of quantities and using language familiar to students. As she stated:

> It was overwhelming when you just gave them questions, if you gave them like 5 × 3, they didn't understand but when you said 'show me 5 sets of 3,' then they could go and make it themselves. They could draw it out if they wanted to but they understood a sense of groups of and stuff like that. It was better than writing it out as symbols.

The verbing is not simply the drawing or writing but the way in which students were able to now conceptualise multiplication as the forming of equal sets or groups. We observed students confidently assembling groups of counters and extending their counting strategies to include skip counting (groups of fives) and doubling (6 + 6, 12 + 12). The forming of groups is consistent with how Mi'kmaw number words act as verbs and literally describe objects forming into a group of that quantity. Also, students showed us their joy in building these quantities, excitedly using fingers and hand gestures to articulate how these groups were forming and subsequently how their understanding was also forming. The variety of materials available on the tables meant students could hold the mathematics in their hands. The students' actions reflected the actions inherent in the mathematics as they proceeded to make sets, show jumps on a number line, or group counters together—this is verbing mathematics.

Verbing tasks

The activities allowed us to see how students were thinking about quantities and working with repeated quantities—forming equal groups, sets, rows, lengths. We were intentional in focusing on the processes that students enacted with the spatial models to develop an understanding of multiplication in a way that aligns with a Mi'kmaw worldview. While one might create a similar task without thinking about verbing, we distinguish this design of verbing mathematics from good task design by this intentionality of rooting in the epistemological view of flux and movement as being crucial for learning for Mi'kmaw students.

With the focus on students' structuring of ideas through exploratory processes and actions rather than completion of products, students playfully abstract concepts by manipulating non-abstract materials that allow specific ideas to form. We resist naming until the students themselves begin to generalise and make connections. Students moved easily from one model to another depending on the context, often favouring set models and area models over the number line model. We intend in future to bring a 'lengths of' model with Cuisenaire rods into the centres to see if it might serve as a bridge to number lines. The students generalised their learning and applied it to problem solving contexts before formalising multiplication. This verbing approach allowed students to name the process when they figured it out, just like mathematicians do.

It is worth noting that the teacher shared that she used a similar approach when introducing division as fair sharing and had the students starting with the whole and forming groups of equal amounts. One student said, "Oh, it's like multiplication but the other way around." Suzanna described this as a lightbulb moment for this student. These pedagogical practices align with the *L'nuita'simk* approach to learning and thus were culturally rooted for the children in this class, however, we believe these approaches are good for all learners.

Collective knowing in the learning space

The MATH Project aims to create a playful space for learning mathematics. Inspired by community, we enacted Lisa's framework and the notion of *mawikinutimatimk*, by inviting students to come together to learn together. Often, as we observe students' playfulness and sheer enjoyment with hands-on activity, we are filled with joy as well. We wonder too how to sustain the level of engagement we see in the children and how to share this approach more widely. We believe the two areas of focus that frame this work—verbing (the actions) and spatial reasoning (the models)—are key components of the project. Verbing afforded all students an entry point into exploration and inquiry in a way that aligned with their worldview thus allowing for cultural synthesis. As students took up the prompts to model multiplication, they embraced the actions needed to show their thinking while the structuring of materials enabled them to conceptualise multiplication, an understanding that arose collectively in the learning space.

In our work, a learning space is a playful space. It is through playful interaction with others that students begin making sense together. We see this in the generation of original methods to organise materials that a group of students introduced for all to use. With emphasis on verbing, we see students making the sets, grouping the objects, aligning the rows of counters, and taking jumps along the number line. Students, collectively, became the mathematicians in the action, in the doing, and in the thinking. Their being unfolded from the doing and thinking, as evidenced in the delight of a student who held up her hands to show fingers grouped simultaneously in two ways.

A collective wisdom emerged as students made sense of their models together. In the jubilant pronouncement of one student who says "it's just times" we hear an urgency to share the realisation with others. Her voice expresses a collective knowing, as grouping and making sets take on a new conceptual structure. It is as though the clarity of the concept is so compelling that she demands others to see it, too. We emphasise the structuring of this event that allowed her to see the concept emerge with her peers. Concept development was contingent on collective engagement with all students building models to represent new multiplicative structures. Better together than individually, students embraced the communal aspect of learning to embody *L'nuita'simk,* Mi'kmaw ways of knowing rooted in making sense of the world through community practices, rituals, and relationships.

Questions continue to arise as we move forward in the MATH Project. For example:

> How can verbing sustain the students' playfulness across the mathematics strands and across grade levels?

How can verbing tasks across the mathematics strands invite students to engage as a community, rather than a collection, of learners?

How do we design verbing tasks for other concepts that allow students an opportunity to architecturally structure mathematical ideas in a way that leads to organically structuring these concepts? Are there some concepts for which verbing will work better than others?

We invite responses to our noticings and wonderings as we continue this project. In Fall of 2018, we again visited this group of students, then in Grade 4, and engaged in a very interesting discussion about odd and even numbers that led us to believe these ideas have stuck with them. That lesson will be analysed and shared in a future article.

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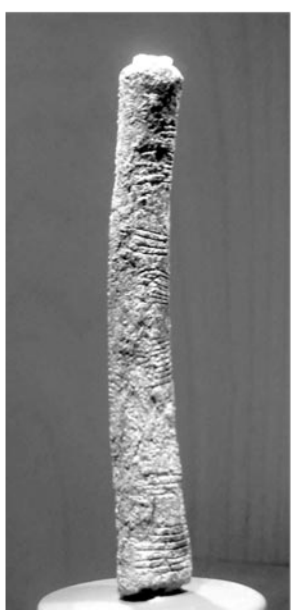

The Ishango bone is more than 20 000 years old. The scratches on it may be tally marks, but what was being counted is unknown. Some have claimed the bone to be a lunar calendar. Others have noted the doubling pattern in the right column. Adapted from a photo by Daniel Baise, CC BY-SA 3.0, and a drawing by Crickxson, CC BY-SA 4.0.