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Rectangles and Fish Racks: An Example of Connecting Indigenous Culture and Mathematics

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Abstract

Using the Yup'ik subsistence activity of building a fish rack for drying salmon as a cultural context, and a sixth-grade mathematics module as a curriculum resource, mathematical connections between rectangles and fish racks are unpacked. An example of how a Yup'ik elder uses mathematical properties of rectangles to determine the corners (vertices) of the foundation for a fish rack (rectangle) is detailed. Furthermore, how a sixth-grade student uses geometric relationships between rectangles and circles to verify that the corners (vertices) of a fish rack (rectangle) are positioned properly is also explored. Taken together, these examples demonstrate how mathematics may be embedded in indigenous culture and how students can connect informal mathematics in familiar cultural contexts and activities to understand and explain formal mathematics.

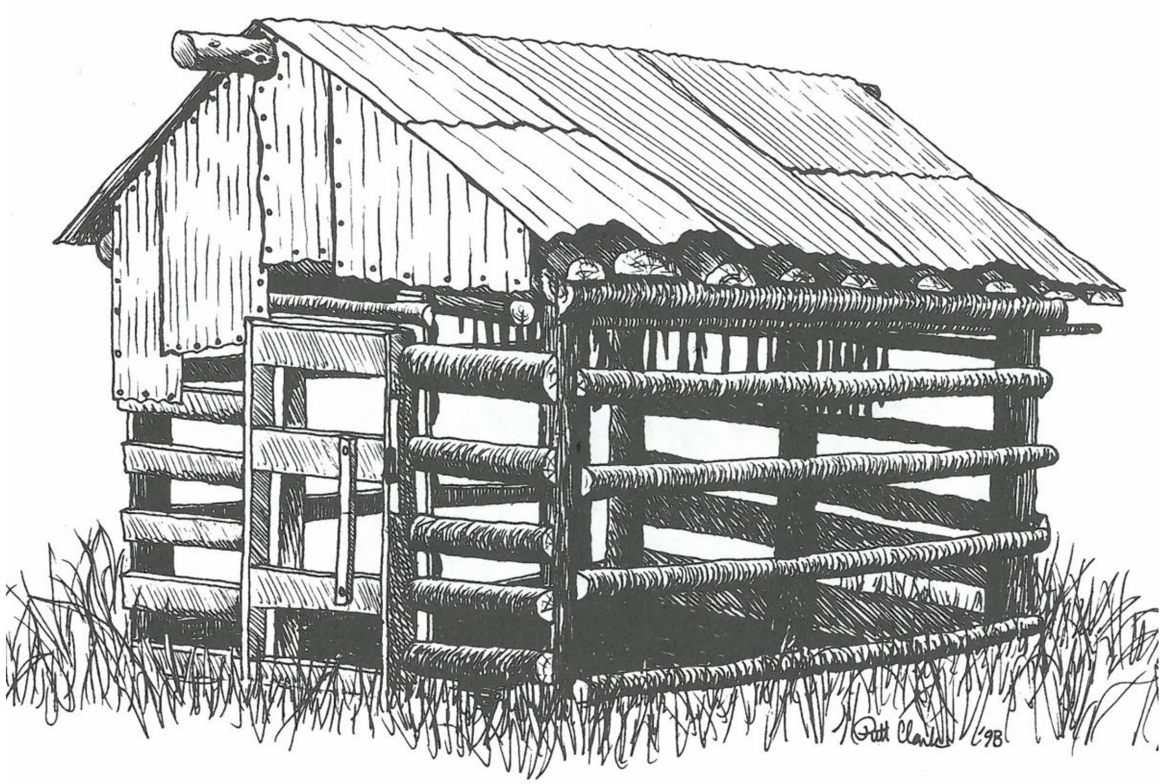

Figure 1. Drawing of a fish rack near the village of Manokotak, Alaska (Adams & Lipka, 2003, p. 75).

> [T]he method of building a rack used by the elders is one possible method out of many. Remember that building a fish rack is not engineering or formal mathematics; it is practical building and everyday mathematics. This means that visual estimating and getting your structure sufficiently accurate is good enough in real world application. "Good enough" and "sufficient" means that it will stand, it will hold the weight of the salmon, it will be stable, and it will last a long enough time. It is possible that built in this way, the fish rack may not exactly be made with ninety-degree angles or perfectly equal opposite sides. However, this is the difference between everyday knowledge, including Yup'ik cultural knowledge, and pure mathematics. (Adams & Lipka, 2003, p. 71)

The above illustration and excerpt are from *Building a Fish Rack: Investigations into Proof, Properties, Perimeter, and Area* (Adams & Lipka, 2003), a sixth-grade mathematics module that is part of the *Math in a Cultural Context* (MCC) project. Like all MCC modules, *Fish Rack* connects rich mathematics content that is aligned with the National Council of Teacher of Mathematics (NCTM, 2000) *Principles and Standards for School Mathematics* and with traditional cultural practices of the Yup'ik people of southwest Alaska and other Alaska Native groups.[1] Among the cultural and mathematical connections made in *Fish Rack* are how the base outline of a typical fish rack, which is used for drying harvested salmon, is rectangular. The rectangular base of the fish rack allows students to explore the geometry of rectangles in the

[1] See www.uaf.edu/mcc for more information about *Fish Rack* and other MCC modules.

authentic Yup'ik cultural context of designing and constructing a fish rack. The primary motivation behind the development of *Fish Rack* and other MCC modules is to improve the mathematics achievement of all K-8 students in Alaska, particularly Alaska Native students. Multiple case studies and large-scale studies have shown that MCC modules, including *Fish Rack*, do indeed contribute to significantly improving students' mathematics achievement and, as intended, this is especially the case for Alaska Native students (e.g., Kisker et al., 2012; Rickard, 2005).

This article provides an example from the MCC *Fish Rack* module of how a Yup'ik elder uses a technique for determining the base of a fish rack that informally utilizes geometric properties of rectangles. The author continues this example by sharing how a Yup'ik student, after completing one of the *Fish Rack* module activities, is able to connect the elder's technique to the formal geometric relationship between a rectangle and a circumscribed circle. Moreover, the student is able to explain how this formal mathematical relationship could be used to verify whether the fish rack base was really in the shape of a rectangle or would need to be adjusted. Putting the cultural and mathematical components of this example together demonstrates the potential of a central multicultural education strategy for teaching and learning that is embedded in *Fish Rack* and other MCC modules – i.e., that using familiar and authentic activities and contexts from students' own cultures and backgrounds can be employed in powerful ways to connect students with unfamiliar formal mathematics (Sleeter, 1997). This finding is consistent with decades of research showing that, whether in rural, suburban, or urban contexts, students' learning of mathematics is supported and potentially enhanced when students see how mathematics is used in their own community or culture (cf., Gollnick & Chinn, 1998; Gutstein, 2016; Legaspi & Rickard, 2004).

MCC and the Fish Rack Module: Cultural and Mathematical Connections

MCC is the result of a sustained collaborative effort between university based researchers and mathematics educators, K-8 teachers, and Yup'ik elders and other Alaska Native experts and consultants (Kisker et al., 2012; Rickard, 2005). These efforts culminated in producing ten K-8 mathematics modules, each of which uses traditional Yup'ik cultural and/or subsistence activities as a context for teaching and learning mathematics. *Fish Rack* is one of the MCC modules and centers on the subsistence activity, common among the Yup'ik people of southwest Alaska, of building fish racks to dry salmon that have been harvested from local rivers or coastal waters (Adams & Lipka, 2003).The *Fish Rack* module unpacks the purpose of fish racks in drying salmon (e.g., how they are traditionally constructed using available materials), how fish racks fit into Yup'ik cultural values of respecting the environment and subsistence animals, and the mathematics of fish racks, including geometric properties of rectangles, that are embedded in the techniques elders use to make fish racks. Yup'ik elders and other cultural experts, as well as K-8 Alaska Native teachers, heavily participated in the development of all MCC modules so that both the cultural contexts and the mathematics are rich and aligned with NCTM recommendations and Yup'ik cultural values (Rickard, 2010, 2015).

In the *Fish Rack* module, Henry Alakayak, an elder from Manokotak, Alaska, explains a technique he uses to construct a fish rack (Adams & Lipka, 2003). Mr. Alakayak first determines an outline for the foundation for the fish rack by starting with four logs that are all of equal length. He then arranges these logs so that they meet at a common point and opposite logs form a straight line. The point where the logs meet is the center of the fish rack base and the ends of each of the four logs are the corners of the rectangular base of the fish rack where the posts for each corner of the fish rack will be placed. Mr. Alakayak adjusts the logs as needed to make sure that the opposite logs form are straight while also maintaining the common point where they all touch at the proposed "center" of the rectangular base of the fish rack (see Adams & Lipka, 2003). Figure 2 shows what Mr. Alakayak's four logs would look like when arranged with the sides of the rectangular base of the fish rack sketched in.

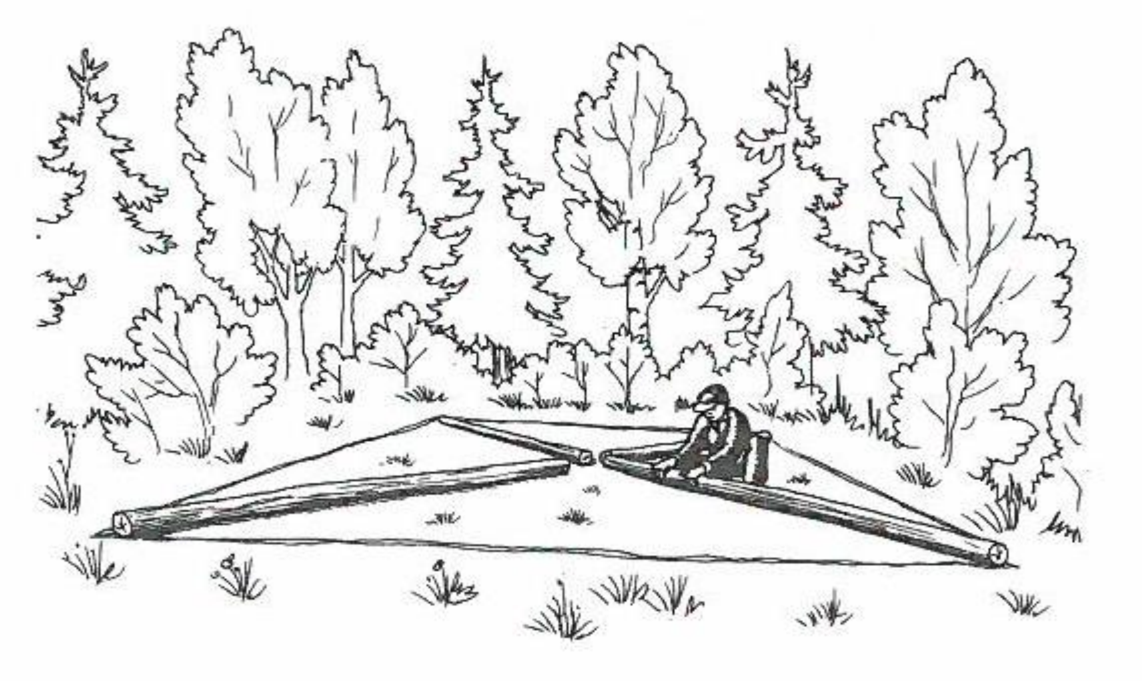

Figure 2. Mr. Alakayak's technique (Adams & Lipka, 2003, p. 93).

Mathematically, Mr. Alakayak's approach utilizes several properties of rectangles. For example, the logs are arranged to form the *diagonals* of the rectangle and the ends of the logs are the *vertices* of the rectangle. Where the four logs meet is the *center* of the rectangle. Moreover, because the four logs are of equal length, they form the two diagonals of the rectangular outline of the base of the fish rack that are, mathematically, of *equal length* and also *bisect* each other.[2] This is a sample of the connections that are made between fish racks and mathematics in the *Fish Rack* module. A key point to this example is that the geometry of rectangles is not abstract, but is made real in an authentic cultural context – i.e., Mr. Alakayak's technique for determining the foundation outline for a fish rack is based on rich cultural knowledge. While the mathematics embedded in Mr. Alakayak' approach is informal, it is, nonetheless, an appropriate use of mathematical properties and demonstrates that mathematics is a human endeavor that is utilized, in this case, in an indigenous culture as well as in traditional school, mathematical research, and natural and social sciences (Legaspi & Rickard, 2004; Rickard, 2005; Sleeter, 1997).

[2] See Adams & Lipka (2003) and Rickard (2005, 2010) for detailed discussions of the mathematical connections made with fish racks in the MCC *Fish Rack* module.

Connecting Rectangles and Fish Racks: An Example from the Classroom

As a mathematics educator and coauthor of several of the MCC modules (i.e., Adam, et al., 2005; Kagle, Barber, Lipka, Sharp, & Rickard, 2007; Lipka, Jones, Gilsdorf, Remick, & Rickard, 2010), I have been involved in working with K-8 teachers and students as part of MCC research studies to inform the development of the modules. I have also been involved in professional development for teachers who use the MCC modules in their classrooms. On one of my visits with MCC colleagues to a K-12 school in a village in rural Alaska, I worked with a teacher and her students who were using the *Fish Rack* module. During this visit, the teacher and her class of 19 grade 5-6 students[3] were in the midst of *Activity 6: Students Establish a Rectangular Base* in the *Fish Rack* module. Since this teacher and her class were participating in a large-scale MCC study and in related MCC professional development[4], I was able to interact with both the teacher and her students as they worked.

For part of the activity, the teacher had her students work in small groups of 3-4 and use four meter sticks to determine the rectangular base of a pretend fish rack using Mr. Alakayak's technique (see Figure 2). Students used the four equal-length meter sticks as their "logs" and placed them as Mr. Alakayak did to locate the four corners of the rectangular base of the pretend fish rack. The teacher explained to the students that once they were satisfied with their rectangle, they should use pieces of masking tape to mark the center of the rectangle (i.e., the point where the four meter sticks meet) and the vertices of the rectangle (i.e., the four corners of the base of the pretend fish rack). Finally, the teacher instructed, students would need to use a piece of string and the "circle proof" technique to verify that the four corners of the pretend fish rack that they had marked on the floor with masking tape were the vertices of a "real rectangle"[5]. Each student would then need to sketch the group's rectangle and circumscribed circle in her or his math journal. Figure 3, from the *Fish Rack* module, shows the relationship between a rectangle and circumscribed circle using string to trace out the circle. As the five groups of 3-4 students went to work, I circulated around the room, observing and periodically asking students if they could explain their work. Students in all of the groups were able to make the connections that the vertices of the finished rectangle would be the corners of the pretend fish rack, that the meter sticks were each "half a diagonal" or the radius of the circle, that two opposite meter sticks (i.e.,

[3] This rural Alaska K-12 village school enrolls about 100 students. It is common in such small Alaskan village schools to have multi-grade classrooms. The school community is located in western Alaska, has a population of about 500, and is accessible only by boat or plane. Students and residents are predominantly Alaska Native. The *Fish Rack* module recommends that this activity actually be done outside (see Adams & Lipka, 2003) where students have room to make a fish rack base outline that is actual sized, but since it was windy and rainy, the teacher opted to us meter sticks and do the activity inside.

[4] See Kisker et al. (2012) and Rickard (2010) for more information about MCC research studies and professional development for K-8 teachers.

[5] "Circle proof" is how the teacher referred to geometric relationships between a rectangle and a circumscribed circle. In particular, the center of a rectangle and circumscribed circle are the same, the diagonals of the rectangle are also diameters of the circle, and all four vertices/corners of the rectangle lay exactly on the circle. If all of these conditions are met, then it's a "real rectangle" because then the opposite sides have to be parallel and equal in length; if not, the rectangle must be adjusted.

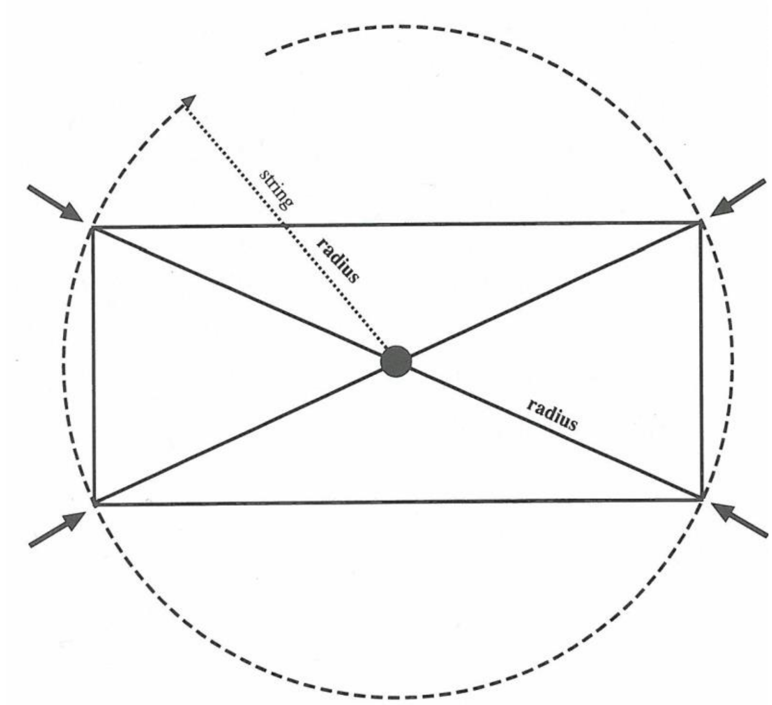

Figure 3. Rectangle and circumscribed circle (Adams & Lipka, 2003, p. 89).

two radii) together were the diameter or "whole diagonal" and that the center of the rectangle was where the meter sticks all came together and was also the middle of the fish rack. As students in each group used a string of the same length as a meter stick (i.e., the radius of the circumscribed circle) to check the corners of the pretend fish rack, some adjustments were made. For example, if the end of a meter stick did not quite coincide with the end of the string as a student rotated it around (with another student holding the other end down at the center point where the meter sticks converged); the stick would be adjusted so that it did fall on the circle. Groups used a nonpermanent marker and the string to trace out the circle on the classroom tile floor and then adjusted the meter sticks so that both diagonals were straight lines and all vertices were exactly on the circle. In all cases, students were able to correctly use mathematical terms (e.g., vertices, sides, diagonals, diameter, radius, rectangle, circle) to describe the relationship between the rectangle and the circumscribed circle and how this connected to the rectangle as a foundation outline for a pretend fish rack.

Near the end of the activity, as students were recording their work in their math journals, I asked several students if they already had known about fish racks and if that helped them understand the mathematics. Every student was not only familiar with fish racks, but many had helped adults or older siblings in their family to build one. One student excitedly explained to me that, "My dad marks out the fish rack [i.e., rectangular foundation] just like we just did it – and he uses a piece of rope to check the corners like we did and (pause) then he uses the four equal logs as the posts for the fish rack corners." I asked this student if she knew where her father learned about making fish racks and she said, "He learned about it from his dad – my grandpa – and other elders." Finally, I asked her why she thought it was important for the base of the fish rack to be a rectangle or, at least, very close to a rectangle. She quickly replied, "If it doesn't line up right like a rectangle does, my dad says it will fall over when the wind blows and ruin the fish." In other words, if the base of the fish rack is not very close to a rectangle and made properly, it may not be stable enough to hold up under the weight of the drying salmon and strong winds common in western Alaska. For homework, the teacher asked her students, who were all Alaska Native, to take their math journals home with them, show their sketch of their rectangle and circumscribed circle to adults in their family, label the parts with math terms (e.g., diagonal, radius, vertex, center) and ask about and record any Yup'ik words/terms their family knew for the same parts. The teacher explained to me that, in this way, she intended her students to see that mathematics can also be part of Yup'ik culture[6].

Conclusion

Students using the *Fish Rack* module in this classroom were able to connect rectangles and fish racks to better understand both. Studying mathematics takes on deeper meaning and relevance for students when it is connected to their culture and/or community (Gutstein, 2016; Kisker et al., 2012). As demonstrated in the above lesson, connecting rectangles to fish racks, and using the relationship between a rectangle and circumscribed circle to adjust the rectangle, is something real to students as it is an authentic aspect of their own culture. Making mathematics real to diverse students, in this example, Alaska Native students, is a key strategy behind multicultural education in mathematics (Sleeter, 1997) and mounting research evidence supports its effectiveness as part of mathematics curriculum generally and MCC in particular (cf., Legaspi & Rickard, 2004; Rickard, 2005, 2010). The above lesson from the MCC *Fish Rack* module demonstrates how mathematics curricula can be used to help teachers and students use culture as a context for learning rigorous mathematics that is both valuable and real.

[6] "The [Yup'ik] word for rectangle is *taksurenqellria* and means 'one that is long'" (Adams & Lipka, 2003, p. 83). The next day in class while discussing the homework assignment, several students shared this Yup'ik word for rectangle as they had just learned it from their family. The teacher had all students record *taksurenqellria* in their math journals to add it to their "math vocabulary" list.

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