Math in a Cultural Context: Two Case Studies of a Successful Culturally Based Math Project

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Math in a Cultural Context (MCC) was developed from ethnographic work with Yup'ik elders and teachers. The need for culturally based curricula seems obvious to those in the field of educational anthropology, but not necessarily to policymakers. Two case studies of novice teachers, one cultural "insider" and one "outsider," illustrate how each effectively taught MCC. The insider transformed her teaching by allowing student ownership through inquiry and cultural connections. The outsider deepened her mathematics content knowledge and found a perfect pedagogical fit through MCC. [culturally based curriculum, Yup'ik, mathematics teaching and learning, teacher enactment of curricula]

> When you look at someone else's culture you get more ideas—he [Lipka] helped us to open our eyes to see that our culture had more math in it. I am looking that way with open eyes, how they [the elders] used math to survive.—Nancy Sharp, 2003 Math Summer Institute, Fairbanks, Alaska

The widely accepted notion of using local culture and language in the process of schooling in American Indian/Alaska Native (AI/AN) communities has been noted by the federal government since the 1928 Meriam Report (Meriam et al. 1928), as it has been by education researchers (see, e.g., Deyhle and Swisher 1997). Yet Demmert and Towner's (2003) exhaustive review of culturally based education found little empirical evidence to support what seem to be obvious contentions. Of the more than 8,000 studies Demmert and Towner reviewed, only a few used quasi-experimental designs, found statistically significant results, and involved core academic content. Of these studies, only the Yup'ik work is ongoing (Lipka and Adams 2004a; Lipka, Sharp, Adams, and Sharp in press). Brenner (1998) and Doherty et al. (2002) also conducted quasi-experimental studies in core academic content areas and found statistically significant results.

Persuasive arguments can be made beyond those based on positivistic research for developing and implementing culturally based curriculum and pedagogy.

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Yet a review of recent articles on the topic in this journal provides only limited evidence that culturally based programs improve the academic performance of AI/AN students; research describing how this occurs also is rare. These few examples highlight the need for research that both contributes to the improved school performance of AI/AN students and describes the processes influencing student learning. In today's high-stakes test environment, under the regime of "no child left behind," our responsibilities in this regard are heightened. As Sleeter notes, "Ethnographic work may be ignored in policy debates when ethnographers do not speak to the language of power. Currently that language is test scores" (2004:135). It is increasingly important for those who work in Indigenous and minority contexts, at the intersections of culture and education, to make persuasive arguments for those who make education policy.

Our research has shown repeated favorable results in implementing Math in a Cultural Context (MCC), a culturally based mathematics curriculum for both urban and rural (mostly Yup'ik) students. This research design uses both quantitative and qualitative/ethnographic methods. However, the quantitative methods do not provide insights about how curriculum is enacted, nor do they illuminate student–teacher interactions that may contribute to students' improved performance (Erickson and Gutiérrez 2002). It is the detailed ethnographic descriptions and analyses that show the interaction between the curriculum, the community, and the local culture, and between teachers and students, that help us understand how to improve student learning.

Situating the Cases

This article is based on our long-term collaboration with Yup'ik elders, teachers, schools, and communities as we jointly developed a supplemental culturally based math curriculum, MCC, for elementary school students. MCC is based on Yup'ik cultural knowledge and norms, and it seeks to bridge the culture of the community with that of the school. Our definition of culturally based math education includes math content knowledge (informed by both Western knowledge and that of Yup'ik elders), pedagogical knowledge (informed by school-based practices and community-based ways of teaching, communicating, and learning), and contextual knowledge (ways of connecting schooling to students' prior knowledge and the everyday knowledge of the community).

Philosophically and practically, MCC supports an adaptive implementation of the curriculum. Each teacher must make accommodations based on her or his mathematical knowledge, pedagogical knowledge, and familiarity with the local culture, language, and history. It is through case study analysis of how different teachers implement MCC and how students engage with MCC that we can begin to articulate the nature of these interactions and what factors may be contributing to students' improved mathematics performance.

Theoretically and practically, we designed MCC to create classroom and community interaction in which mathematical and pedagogical knowledge connect to both the school and community context. Similarly, MCC was designed to include both Western reform-oriented instructional practices and local ways of learning and knowing. Surrounding these aspects and included within them are cultural and contextual factors. Such a complex curriculum design by necessity includes a steep learning curve similar to what reform-oriented math programs have found (see Alrø and Skovsmose 2002; Senk and Thompson 2003).

We present and analyze two different cases to examine the ways in which two novice teachers—one a cultural "insider" and the other new to Alaska, each with different pedagogical and math content knowledge—implemented MCC. We analyze each case separately, identifying salient features that account for students' improved math performance as well as changes in the teachers' relationship to the content, culture, community, and students. Further, we analyze across the two cases to identify factors and approaches shared by these teachers. We argue that both teachers were able to successfully carve out a "third space" (Gutiérrez, Rymes, and Larson 1995) in which the goals of the curriculum could be realized. Lastly, these cases shed light on the different trajectories that teachers with different backgrounds face when implementing this culturally based math curriculum.

Conceptual Framework

From an anthropological perspective, *culturally based curriculum* is a redundant phrase. All curricula and pedagogy are culturally based. The real question is, whose cultural knowledge and practices are they based on? In Indigenous contexts, this has almost always been the culture of the dominant society. The notion of culturally based curriculum in a core academic content area reveals the academic options available to Indigenous people. hooks (1994) has called this "engaged pedagogy," in which the marginalized or "marked" culture takes center stage, becoming "unmarked."

There are few references in the literature to local, everyday knowledge that may connect well to students learning mathematics in school (Carraher and Schliemann 2002). Yet we know that students' prior knowledge helps them to make connections and inferences, draw conclusions, and assimilate new ideas, thus making the curriculum more accessible. Our work, therefore, is guided by cultural mismatch theory (Philips 1983; Vogt, Jordan, and Tharp 1987) and work in cross-cultural cognitive psychology that connects out-of-school knowledge to in-school learning (Cole and Scribner 1974).

D'Ambrosio (1994) points out that culturally diverse groups have their own ways of knowing and hence quantifying, perceiving, measuring, proving/justifying, and ordering space. Harris (1991) suggests reversing the emphasis in math from numbers and algorithms to spatial relations, geometry, and measurement and connecting the topics that are more relevant within Indigenous cultures to numbers and arithmetic. Critics of math education view participant structures that emphasize standard initiation, response, and evaluation (IRE) routines as overly controlling, fostering an epistemology of authority, making mathematics mystifying, and relegating students to nonquestioning and nonthinking roles (Alrø and Skovosmose 2002). White (2003) views these math strategies as particularly pernicious among minority students.

Through the culturally based math modules, the connections to students' experiences and prior knowledge that originate and often reside outside of the traditional school curriculum are brought into dialogue with the academic content knowledge taught in school (González, Andrade, Civíl, and Moll 2001; Heath 1983). We suggest that the culturally based curriculum creates a "third space" in which this dialogue takes place. Equally important, the notion of third space refers to the opening up of a place in which historically silenced knowledge of Indigenous peoples such as the Yup'ik is privileged alongside traditional academic discourses. Thus, culturally based education, as a third space, creates possibilities for social and epistemological change such that knowledge and discourse, which have traditionally been in tension with one another, are brought together to "challenge and reshape both academic content literacy practices and the knowledge and discourses of youths' everyday lives" (Moje et al. 2004:44). From a Freirian perspective, culturally based curriculum has the potential of being liberating on several planes: the community's notions of its knowledge and the place of that knowledge in the world, and the alteration of traditional relations between teachers and students and students and students as they explore mathematical relationships while simultaneously learning from their elders.

The Curriculum

Many years ago we began a long-term collaborative process to make the genius of Yup'ik elders' knowledge accessible to elementary school students. We have worked with a dedicated core group of elders and Yup'ik teachers from three regions within southwest Alaska, in particular Henry Alakayak of Manokotak, Frederick George of Akiachak, and Annie Blue of Togiak. Each has taken on leadership roles and contributed greatly to our present understandings.

In the examples in these case studies, students simulate building a fish rack (a structure used to dry salmon). To build a fish rack or any similar structure, the four corners must form a rectangle. Working with elders in Fairbanks, we built and video-recorded the construction of a fish rack. This activity connects everyday knowledge to school-based knowledge. Elders first "eyeballed" the space, laying out markers for the four corners. Further adjustments were made. Rope was used to measure each diagonal and to square the rectangle. Using an axe handle, they created a unit of measure for the posts, using body measures to mark the length of each side of the rectangular base.

The module *Building a Fish Rack* unfolds from this activity into further and deeper explorations of math more challenging than that in most math textbooks. For example, students are presented with perimeter-held-constant problems and challenged to optimize the space for drying salmon. This counterintuitive problem enables rich explorations into how area can change when perimeter is held constant. Students explore properties of a rectangle and show proof that their rectangular bases are in fact rectangles. They also explore how quadrilaterals are related. Prior to implementing the curriculum, elders engaged in these activities, thus creating a curriculum cycle from elders to curriculum writers, back to elders and Yup'ik teachers, to classroom implementation and further revisions.

The curricular and pedagogical approach includes expert–apprentice modeling, a good fit with Yup'ik ways (Lipka and Yanez 1998), within a context of problem solving and math as inquiry and communication. Thus, the curriculum includes a variety of cognitive processes: analytic, creative, and practical (Sternberg et al. 2001), tapping into different learning modalities. It is organized to involve students with different abilities in a variety of tasks so that all students have an opportunity to participate and on occasion to lead. The activities work well with heterogeneous groups as students with different mathematical knowledge can engage at their level of understanding. Further, the curricular design includes conjectures and proofs to encourage students to communicate mathematically, with design building connected to local activity.

Curriculum does not stand alone; it is part of a complex interaction between the teacher, students, and a host of contextual variables, including pedagogical, content, and cultural knowledge as well as the larger sociohistorical context. The curriculum does not "come alive" until it is enacted in the process of teaching and student learning. Thus, curriculum must be viewed as it is enacted.

Methodology

Most AI/AN research has been ethnographic, paying attention to the social organization of the classroom, classroom communication patterns (Philips 1983), and spatial and physical movements (Collier 1979). Although some Indigenous educators (e.g., Smith 1999) are wary of positivism because of its colonial vestiges, we use both a positivist and post-positivist design. This mixed methodology is situated within a third space in which quantitative and qualitative methodologies "converse" such that each can strengthen our understanding of the efficacy of the curriculum. Without the long-term collaboration between cultural insiders and outsiders, this work would not be possible.

The cases presented here were selected, in part, on the basis of relatively strong pre-/posttest gains. In addition, we were interested in how two different teachers, one insider and one outsider, implemented the module. Because of MCC's complex design, we expected different teachers to have different implementation trajectories.

Prior to implementing the ethnographic component of this study, we had already established a consistent record of improving the mathematics performance of Alaskan students, including Yup'ik and other Alaska Native students as well as urban Caucasian and Native students (Lipka and Adams 2004b). We wanted a research design that allowed us to examine classroom factors that contribute to students' improved mathematics performance. In the quantitative component we used a 2×2 research matrix: treatment and control and urban and rural. We typically used ANOVAs, paying attention to gain scores (posttest minus pretest), with individual students as the unit of analysis. More recently, we used ANCOVAs covarying on pretest scores. In each instance we found statistical significance in favor of the MCC.

In an effort to arrive at an explanatory model of these results and the factors affecting students' increased performance, we observed and videotaped teachers while teaching lessons from the module. We used a research methodology of co-analysis—having expert (culturally and pedagogically knowledgeable) Yup'ik insiders analyze the videotapes alongside university faculty members. We also analyzed the tapes with the teachers, Doreen and Stacy. While analyzing the tapes with the teachers, each separately, we audiotaped the discussion. We interviewed each teacher directly after the viewing and on a number of different occasions subsequent to the viewings. Relevant sections of the videotape and interviews were transcribed and placed on *Transana*, an advanced videotape analysis tool that coordinates video, audio, and levels of analysis. We analyzed the social organization of the classroom, teacher–student relationships, student–student talk, and math communication. Further, we attended to cultural connections made in the course of teaching the math modules.

The Cases

The two cases involve two novice sixth-grade teachers who used the *Building a Fish Rack: Investigations into Proof, Properties, Perimeter, and Area* module. The first teacher, Doreen, is Yup'ik and was born and raised in a rural Alaskan village. Doreen was in her first and second years of teaching in her own classroom. The second teacher, Stacy, is white and was born and raised in the "Lower 48." A recent graduate of a postbaccalaureate licensure program, Stacy also was in her first and second years of teaching. At first, both teachers were randomly assigned to "control" conditions and then volunteered to be "treatment" teachers (i.e., to implement MCC). Our data document the changes we observed as these two young professionals moved from control to treatment classrooms.

At the time of this research, both teachers lived and worked in small, rural, predominantly Yup'ik villages in southwest Alaska. Neither village is accessible by road; transportation is by air, boat, or snow machine. Although geographically isolated, people who live in these villages do have access to telecommunications such as phones, satellite television, and the Internet. Both villages have a modest cash economy, and residents rely heavily on fishing, hunting, and trapping for subsistence. Further, both villages are experiencing language loss—a shift from Yup'ik to English—that many rightly argue also is a loss of culture. Native villagers speak "Village English," a dialect of English common to Alaska Native populations.

Doreen and Stacy were not only participants but also coresearchers in the qualitative portion of the project. They watched videotapes of themselves teaching and provided input into the data analysis and interpretation. Each case presented below embeds classroom discourse, interview data, and analysis.

Case 1: Doreen—An Insider

Doreen,[1] a woman in her mid-twenties, grew up in a relatively large (population 1,066), rural, predominantly Yup'ik village called Beluga Bay located on the Bering Sea in the Alaskan Yukon-Kuskokwim Delta. Although Doreen's primary language is English and she has adopted some Western ways of talk and dress, she identifies as Yup'ik. After coming to the University of Alaska Fairbanks to receive her bachelor's degree and certification in elementary education, Doreen wanted to return to a rural setting to teach. Her first job was as a sixth-grade teacher in Kovak, a Yup'ik village (population 755) on the northern end of the Yukon River. As a new teacher in this village, Doreen participated in the MCC project and was randomly assigned as a control teacher during the 2001–2002 school year. Doreen reported early on that she felt strong in math and that she was comfortable teaching math content.

A researcher from the team traveled to Kovak on February 13, 2002, to observe and tape Doreen's math class, an hour-long lesson about perimeter. On the tape are a group of 15 sixth graders sitting in three even rows facing the board and the teacher. After modeling one example of finding the perimeter of a square, Doreen handed out a homemade worksheet saying, "OK, today we are going to have some fun with perimeter." The worksheet had several problems in which the students were to find the perimeter of various geometric shapes (e.g., a girl, a butterfly, a house) on graph paper. After students completed the worksheet, mostly in silence, Doreen instructed the students to get a fresh piece of graph paper, draw their own geometric figure, and have a peer solve for perimeter. Although the children were excited to do this second activity, time quickly ran out and they never got to it.

What strikes us about this tape is how controlled and teacher-centered the lesson is, and how little discourse is evident. In fact, most of the tape is complete silence, with inaudible murmurs and whispers from the students as Doreen helps individual students at their desks.[2] In an hour-long tape, the teacher talked for 15 minutes, asking simple questions that required a definitive answer and receiving either nominal individual answers or choral responses. For example, when modeling at the board Doreen pointed to an L-shaped figure she had drawn:

Doreen:	What's the first measurement?
Students:	Three centimeters! (choral response)
D:	Then we have a line like this. (pointing) What's the measurement?
S:	Five centimeters. (choral response)
D:	What's the length here?
S:	Two! (choral response)
D:	And here?
S:	Five! (choral response)
D:	What's the length here?
S:	Two! (choral response)
D:	And here?
S:	Eight! (choral response)
D:	Let's see. Who can give me the perimeter? Melinda?
Melinda:	Twenty-six.
D:	OK. Let's move on to number two . . .

This teacher-centered discourse was typical in Doreen's classroom in Kovak. The discourse pattern differs somewhat from the traditional Western classroom routines of IRE in that Doreen did not directly evaluate student responses, although that was implied by moving on to the next example. She typically spoke to the group and students had the "right" to respond, often doing so chorally. This brief excerpt gives us pause regarding the depth of student thinking required in this lesson segment. Most of the time, the children were either silent or whispering and discouraged from talking to one another. For instance, one girl on the tape kept looking over at her neighbor's worksheet. When she looked at the video camera she quickly turned her head away and focused on her own worksheet, presumably because she was afraid of getting caught not looking at her own paper. She tried to sneak a peek a total of five times, and each time she corrected herself within seconds. Other students did this as well. When students became restless, they got up, sharpened their pencils, went to the bathroom, and made brief visits to one another's desks. They seemed to be killing time or looking for excuses to see what their peers were finding as answers. Finally, Doreen said, "OK! There are too many people out of their seats!" The children quickly sat down and went back to their individual work.

We do not want to suggest that this was an overly hostile or strict classroom—it actually felt warm and caring. What we do suggest is that it was teacher-centered and tightly controlled; procedure was emphasized over content, and working collaboratively and discussing mathematical concepts with age mates was discouraged. Even though Doreen made the handout herself, she made no connection to rural Yup'ik culture, so the worksheet was no more culturally relevant than textbook math. In subsequent visits to Doreen's classroom in Kovak, the researchers documented a similar classroom dynamic.

In the fall of 2002, Doreen had moved and was teaching sixth grade in her home village of Beluga Bay. This time, she was a treatment teacher using the sixth-grade *Building Fish Racks* module. Here, the researchers found a completely different classroom dynamic in almost all respects. The lesson was on the properties of a rectangle, and the children were in the gymnasium for the first part of it. Unlike the controlled Kovak lesson, the students had free rein, running around, chatting, laughing, and even doing gymnastics. But they soon settled into pairs, working with a length of string given to them. The goal of this part of the lesson was to make a rectangle using a length of string on the gymnasium floor. This seems easy enough. However, the children also had to show how they knew it was a rectangle; they had to provide a proof. Doreen moved around to the different groups, asking questions such as: "Is it really exactly a rectangle?" "How do you know this is a rectangle?" "How can we find the middle of this rectangle?" "Is there another way we can find the middle?" These are the kind of questions that require conceptual understanding of the properties of a rectangle. Furthermore, the questions allowed for a variety of answers rather than one "correct" answer.

The second part of the lesson took place in Doreen's regular classroom. Here she provided a follow-up to what had taken place in the gym. Students sat at their rowed desks. On the wall were pictures of children climbing real, life-size fish racks in Beluga Bay. Doreen asked students to take out their math journals and asked for the properties of a rectangle. One student said, "Four lines." Another said, "Four sides." Another said, "A closed shape." Another said, "Longer than a square." Doreen asked, "And what do you mean by longer?" The student said, "One side is longer. One longer leg." Doreen asked, "Did anyone have anything else?" This continued until the children were satisfied that they had listed most of the properties of the rectangle. There was no protracted time of absolute silence or children working alone as in Kovak.

Next, Doreen asked each pair of students to come up to the chalkboard to show how they made a rectangle. The children went to the board, drawing and explaining what they did. Seven different groups explained seven different strategies, from measuring the sides to determining if the diagonals of the rectangle were equal.

Then, spontaneously, a group of three decided to show the class how they could use a notebook as a nonstandard measurement. Following up on the students' enthusiasm, Doreen asked, "Could you have used your feet to measure [in the gym]? Could you have used a pencil? Could you have done it that way too?" The children said yes. Doreen then asked, "Could we have used an arm—one person's arm to measure the sides?" The children said yes. "Now, what if we used a different person's arm to measure one side? Could we do that?" Doreen inquired. One student replied, "No, then that would be wrong." Doreen said, "Right, then that would be inaccurate." Here Doreen was suggesting that whatever the unit of nonstandard measurement, it had to be consistent for measuring all four sides.

In this lesson, the children used a wide range of strategies to both create the rectangle and prove it was, indeed, a rectangle. This was in stark contrast to the Kovak lesson, in which only one answer was correct. What the activities and dialogue above show is that with the *Building a Fish Rack* curriculum, the students were able to access a variety of cognitive processes—analytical, creative, and practical—that are so important to learning (Sternberg et al. 2001). What allowed this to occur was Doreen's changed questioning technique. For instance, 10 times in the lesson she said, "Who had something different?" "Who did it another way?" These kinds of questions allow for multiple strategies and answers, opening up new discourse possibilities and new levels of conceptual understanding and cognition.

In contrast to the Kovak lessons, Doreen also invoked cultural connections to make the lesson relevant. The children were able to see that only certain sizes of rectangles would be appropriate for a fish rack. They knew this because they saw fish racks in their village on a regular basis. Also, the artifacts on the wall helped to contextualize the entire project, reminding students of why one would need to know the properties of a rectangle in the first place.

To summarize, Doreen's perimeter lesson in Kovak was very different from the rectangle lesson in Beluga Bay in a number of ways. The physical space, configuration of groups, participation structures, use of manipulatives, amount of discourse, and number and types of questions asked were all poles apart. In the Beluga Bay environment, the students employed multiple strategies, took a leadership role in sharing them, and used math to solve practical problems grounded in local cultural realities.

Although students in both of Doreen's classes had moderate and comparable gains on their posttests, it is worth noting that her Beluga Bay students' pretest scores were low compared to other classes. This is important because the lower-scoring students typically do not make the greatest gains, as noted within project research. Furthermore, Doreen's transformation as a teacher was noteworthy. This was evident to the researchers who observed her in both villages. Doreen, however, insisted that her teaching had not changed that much: "My teaching style didn't change, it was just the material that I was using."

In the summer of 2003, Doreen, as coresearcher, sat down with the rest of the research team to watch herself on tape in both villages. We then interviewed her.

D: The other day I was asked if I thought my teaching style had changed from the control and the treatment group, and I said no, but now that I watch the videotape and took notes and mental notes I do see a lot of differences. Like one difference was in the fish rack module I notice I had the students take more control of what they were doing, and I was more the moderator, just making sure that they were pretty much on task, but they were in control of communication between each other . . . they were communicating mathematically more with the fish rack unit. . . .

And then of course, again, following the textbook there's more worksheets, and you make copies, and you follow whatever the textbook asks you to do step-by-step. With the fish rack unit it's kind of they're more into the conceptual process and not just trying to get so many problems. . . . I was more open and observant with the fish racks than trying to take control with the textbook, like I have to control everything and everything has to be in a certain procedure.

[When] I followed the textbook . . . it had to be this certain way, and I shut out a lot of this other stuff that was around. And with the fish racks it seemed like I was more aware . . . I noticed we were all comfortable, we were all in the classroom; my students and I were comfortable. . . . We had this ownership, so I didn't have to introduce them to a whole lot of material. They knew all the stuff already and it was a good way to teach, or have them discover math concepts and strategies to find the solutions or whatever.

Jerry Lipka: Could you provide an example of how they have more ownership?

D: For example, when they had to construct their fish rack, there were just a few guidelines they had to follow, but they were relevant to what we were getting at. And they took the material that they had and they—I noticed they worked individually at first to get whatever they needed to go over in their minds, and they started looking around in their groups saying, I like the way you did that, and then they incorporate what they thought was strong components of something, and then they'd start, you know, collaborating . . . they took ownership of their learning, and the ways that they were going to get there [. . .]

JL: What did the parents say about the fish racks module?

D: They're really interested. Even when they drop off their kids or something they've asked about it. . . . I noticed with the fish rack they're really asking a lot questions about what we were doing.

Finally, a question was asked about culture and student involvement.

D: One of my students, he knew how to make the fish rack. He saw an actual fish rack being built before, and he was talking about it—and he never talks in class. If he does, it's usually bullying other kids, but he was participating.

Doreen noticed that while using the fish racks module her teaching changed. She became more relaxed and comfortable even as she relinquished control to her students. The students, Doreen observed, had more power over and thus ownership over their work and communicated with their peers about their learning. They also said they would remember the unit as special. Furthermore, a student—perhaps a bit of a bully—who rarely verbally participated, eventually engaged as he remembered and shared his observation of a fish rack being built. And finally, parents became more curious about and connected to what was going on in the classroom.

What can explain these differences? We are cautious in claiming that the changes were due to the culturally relevant math module alone. After all, we were comparing students from two different villages learning two different geometric concepts on two different days. Nonetheless, we believe the changes documented are significant. The classroom in Beluga Bay seemed much more promising for long-term mathematical conceptual understanding. Because Doreen's students knew about fish racks, she did not have to explain the cultural context of the math. She focused more on helping students discover math concepts and strategies to find the solutions. Because of the contextual familiarity, the teacher and her students devoted more time and concentration to cognitively demanding work than was the case in the more procedurally oriented control-group setting. For example, they had to not only recognize the properties of a rectangle but also make conjectures and prove it was a rectangle. Students' mathematical thinking centered on properties and proofs. They also were able to see that there were many different acceptable strategies for their proofs. This is a completely different, more sophisticated cognitive process than those observed in Kovak, where we found no evidence of such strategies. Not only did the math become more conceptual and accessible to the children, but also Doreen was able to employ a more student-centered, open-ended, inquiry-based pedagogical style, which supported the very kind of mathematical learning that the MCC aims to provide.

What this suggests is that the MCC curriculum changed the classroom dynamics class for the better, at least in this context. The level of engagement in and talk about math was higher in the treatment classroom (Beluga Bay) than in the control classroom (Kovak). A complex of dynamics could explain this. For example, perhaps Doreen was more comfortable in her home village and thus was more willing to relax and open herself up to new ways of teaching. Perhaps she was more willing to take risks because she knew the children in Beluga Bay, and their families, for many years. However, the changes between the control and treatment classrooms were so radical that we believe the MCC curriculum played a significant role. Doreen, although Yup'ik, had originally taught the way *she* was taught. In Kovak, her approach looked very Western: It was top-down, teacher-centered, procedural, and heavily reliant on textbooks and worksheets. In Beluga Bay, the MCC module opened up new possibilities for teaching, learning, and communicating. Doreen, the students, and the community all changed; the relationships among them also transformed in coming together for a common goal. Perhaps the most important outcome of this case study is that because the math content was grounded in the local cultural context, all involved found a new sense of ownership and a new, more cognitively challenging connection to math concepts. All of this created a powerful math learning experience for the children. In our interview with Doreen, she said, "[The curriculum] is something I know they're going to remember for the rest of their lives."

Case 2: Stacy Clark—An Outsider

A teacher in her mid-twenties, Stacy took her first teaching job in the village of Ilutaq directly after receiving a postbaccalaureate elementary education degree from the University of Alaska Fairbanks. Stacy surfaced in our quantitative data as a control teacher whose students had high posttest scores from a low-performing rural school district but showed no gain from the pretest scores. Later, as a treatment teacher, Stacy's students made significant gains on the project's pre-/posttests, outscoring all the students in the project, including rural and urban classrooms. Such compelling outcomes led us to want to tease apart the qualitative data that might help us understand what factors contributed to Stacy's and her students' success. The following describes several of these factors.

Stacy Clark as a "Control" Teacher. The following transcription is from Stacy's sixth-grade classroom, a lesson on congruent shapes:

Stacy: What is that word? What do we call shapes like that?
Student 1: Rotated.
Student 2: Concord.
Student 3: Concording.
St: Concord? (laughter)
Student 4: Congo.
Student 5: Popcorn.
Student 6: Oncorn.
St: All right, I'm putting you out of your misery. (Stacy begins writing the word *congruent* on the board.)
S1: Congregate.
S2: Congruent!
S3: Congruent!
St: Congruent. Who can tell me which two of these are congruent?

St:	Raise your hands and tell me if you agree. (Students raise their hands.)
St:	Did the shape change?
All:	No.
St:	Okay, let's add that to our list here. Who can give me a definition of *congruent*?
S1:	Same way, but turned around.
S2:	Same shape, but turned, rotated.
St:	Oh, rotated, that's a good one.

In the above exchange, Stacy created a discursive environment that allowed for "shout outs" and multiple responses in which students' collaborative communication built on each other's contributions. They helped each other remember the word *congruent* and discovered its definition. The jokes and laughter indicate that the children felt safe and comfortable.

Stacy Clark as a Treatment Teacher. As the lesson began, Stacy was in the front of the room. The students were at their desks, arranged facing each other. This allowed for students to work in close proximity in groups of three or four. Stacy began with a story about a crime—the theft of the class Tootsie Roll stash. "Now, if I am a cop, and I am looking for evidence in a crime, looking for things that will *prove* the crime, what are some things I might look for?" The students called out responses such as "footprints," "fingerprints," and "find out who has a lot of Tootsie Rolls all of a sudden."

Stacy recorded their answers on the board. She often wrote down key words or phrases either on the board or on an overhead, always using the words that students provided to describe the concept, vocabulary word, or process about which they were talking. This was important to Stacy, because in order for students to construct meaning, "they have to begin with what they already know. . . . I am careful to write down their exact words because it is what they understand. . . . I tell them if they don't understand something, they shouldn't write it down."

Stacy stated that "accessing students' prior knowledge and experience is the way to make connections that can provide pathways to understanding of more abstract terms and open up ways of describing unfamiliar concepts."

From this beginning analogy, which draws on the familiar, Stacy then moved to the idea and task of using a piece of string "to prove, to find evidence that the shape you have created is in fact a rectangle." Her pedagogical philosophy and style of teaching, which she said were a "perfect fit with the modules," seem to be an overarching theme within which key factors define her success and her students' achievement.

Case Analysis: Stacy as a Treatment and Control Teacher. In analyzing Stacy's case, first and foremost seems to be the long-term positive relationship between the teacher and her students, which contributed to a classroom environment in which trust and mutuality were constructed over time. A novice teacher and new to the Alaska bush at the beginning of the project, Stacy had been teaching her multiage class for three years. This allowed for long-term relationships to develop with her students and their parents, both in and out of school. A key element in Stacy's pedagogical philosophy was that her classroom was a "safe zone" where students could "enter to learn and have fun learning, and feel safe about taking risks. I tell my students that they need to leave anger outside, that we are a family and we need to respect and trust each other." In fact, building a community of respect and trust was so integral to Stacy's approach that the class spent the first week of school outside the classroom doing team-building activities in their environment, usually by the river where they spent most of their out-of-school time. By extending the learning environment to include the physical and cultural environment of the local community, Stacy opened up the potential for students to act as more knowledgeable peers within learning events, thus setting the stage for building a community of learners who could exchange roles within the various zones of proximal development that occurred during the school day (Vygotsky 1978). This blending of environments, which allowed her to meet and interact with her students in a space that was their own, seemed to come naturally to Stacy, whose undergraduate degree was in outdoor education and who also was a product of alternative schools outside the norm of conventional schooling.

One way in which this safe community built on trust and respect manifested itself in Stacy's classroom was in the variety of discourse patterns exhibited between the teacher and her students. This was particularly evident in the ways in which she relinquished control of communication in order to foster student inquiry and math talk among the students. In Stacy's class, there were often multiple speakers co-constructing meanings, both verbally and nonverbally, of concepts and terms embedded in the module lessons. One student might begin to explain a process or describe a concept and another student would chime in to complete the thought or add additional information.

Students also used gestures and communicated nonverbally with each other and in collaborative class discussions. For example, in one lesson, Stacy was trying to emphasize the idea that opposite sides of a rectangle are parallel, but the students used the word *across* instead.

Stacy noted, "The module stated that opposite sides are parallel but the students gave me 'across,' but the module said it wanted them to have 'opposite.' But, I realized that it is more important to define these properties in their words." One student in the videotape had hands in a cross showing the teacher the word *across*.

In another instance, four students were experimenting with different ideas about properties of a rectangle. They performed this "math talk" without actually speaking; rather, they employed gestures while moving the string to determine diagonals, vertices, and so on. The students took turns leading the "discussion" and moved in and out of their close group proximity in synchrony (Collier 1979). One student, Lucy, often took the role of leader, gesturing to the different corner angles to direct the other students' ways of positioning and manipulating the string. This role was not a usual one for Lucy; according to Stacy, "Lucy feels confident here . . . she has the confidence and willingness to participate." Thus, for Lucy, the safe learning environment, in which nonverbal communication was honored as a cultural way of "talking" and communicating mathematically in the classroom, allowed her to take a leadership role and contribute her knowledge in a culturally congruent way. Stacy reflected, "It is the setup such as the idea of cops and proof of a crime that they can understand instead of the more abstract words used in the module such as *proof* and *conjecture*." For Stacy, allowing students to actively construct meaning in their own words in a safe learning environment encouraged them to take risks and try out different ways of representing content knowledge.

Another discourse pattern emerged when Stacy called on students during a lesson. As a lesson unfolded, she sometimes "nominated" students but did not always expect an answer, as she knew it would not be forthcoming from some students. For example, when Stacy called on Larry, a special education student who was making eye contact but who rarely contributed openly in class, she said, "[H]ow are we going to word that, Larry?" He then looked up at the board. This was significant for Stacy, because she knew he was engaged and he was right there with the rest of the class. "It is just a 'how are you doing?' " Stacy said. "I have to give acknowledgment [to the student] for being a part of it [the class discussion]. I secretly think they like when I acknowledge them." This acknowledgment occurred when Stacy called a particular student's name but allowed other students to answer. At other times, Stacy called on specific students when she knew they were ready to contribute an idea that would further the discussion and meaning-making for the entire class. This notion of nominating students was an evolving process, much like the building of relationships and a safe community. Stacy said,

> In teacher school, we were taught not to call on a kid—it would put them on the spot; for me as a kid I didn't like to be put on the spot. But, as I got more comfortable with the kids, and they got comfortable with me, I began to call on kids.

Of course, there were still certain students whom Stacy continued not to openly nominate in class. One example was Zach.

> Zach and I had an agreement that he would initiate the move for me to give him help. These were nonverbal cues like flipping through the pages of his book—this translated that he didn't know what was going on. Another was a "look at me" and he would shake his pen or pencil. This was a signal that he needed help. Sometimes he would just put his pencil down; these became signals that we both communicated without saying anything . . . we both understood.

Another factor supporting the openness within this learning community involved two different styles of communication the class often moved in and out of while discussing the content of a lesson. It was a kind of code-switching in which the conversation moved back and forth between academic talk and more familial talk that included joking and laughter. The fact that Stacy allowed and even fostered this conversational style further promoted a community of learning built on trust and respect. The following interaction is not only an example of this code-switching but also a concrete illustration of how one student made a connection between a math concept and the notion of family relationships that were foundational to the classroom environment. The interaction began with Charles, who was initiating a discussion about the properties of a rectangle:

> **Charles:** A rectangle has four sides.
> **James:** The square is a relative to the rectangle.

The class broke into laughter. As Stacy watched the video, she suggested that "the class has code-switched, and it is a time for joking, the signal that they were out of the academic talk." The interaction then continued with Stacy asking, "Are they not related?" to which students began to suggest other properties. According to Stacy, at that moment, the students began to rethink their laughter and attribution of James's contribution as being a joke instead of an academic response. In other words, they began to question their assumptions about code-switching and considered James's remark as being more in line with the academic style and content. What seems important in this interaction is the fluidity of conversational styles supported by Stacy and the ease with which she brought the discussion back to the academic style by picking up the family connection suggested by James.

In summary, Stacy's pedagogical philosophy and style of teaching, which emphasized relationship-building in a safe environment that fostered communication through a variety of discourse styles and incorporated inquiry-based learning, was a "perfect fit" with the pedagogy underlying the MCC curriculum. However, in addition to these highly important factors, Stacy also stated that the modules provided her with a framework for math content that she did not have as a control teacher. As a control teacher, Stacy had to put together a math curriculum that attempted to draw on conceptual knowledge development but that was, in actuality, more of a vocabulary development and definition approach that was loosely based on exploration through an inquiry process. As a treatment teacher, Stacy stated that modules provided a systematic approach to conceptually based math curriculum and at the same time filled the gap in her own content knowledge. Thus, for Stacy, using the modules not only became a way to practice the pedagogy that was a natural fit with her own philosophy of teaching but also provided her with the framework for content she needed to help her students gain important mathematical conceptual knowledge. Through implementation of the MCC curriculum, Stacy found a "perfect fit" that not only helped her become a more successful teacher but also helped her students acquire conceptual mathematics knowledge and demonstrate high gains on assessment measures.

Findings across Cases

The analyses above illustrate the influence the curriculum had on Doreen and Stacy as they found alignment with its goals, though in different ways. Doreen's style changed from control to treatment, allowing her to relinquish authority and be more comfortable in the classroom. Stacy found that the MCC curriculum nourished her already open-ended, inquiry-based style but also supported the math content better than when she was a control teacher. Additionally, Stacy's pedagogical style remained constant; in terms of the underlying pedagogy supporting the content of the math modules, Stacy exhibited behaviors that were more in line with being a treatment teacher, even when she was designated as a control teacher. Both teachers created classrooms that allowed for extended math discourse and multiple responses.

Perhaps the most significant similarity between the two teachers was that each created a strong sense of community among the various stakeholders—parents, students, teacher—built on trust and respect. Doreen built her community from the shared context of the local community and culture through everyday activities in which she and her students participated. Doreen used the curriculum to capitalize on community knowledge, establishing more culturally aligned ways of communicating and valuing. Stacy's multiyear relationship with her students helped her create strong bonds that anchored changes in her discourse style. Each teacher kept the math complex. In some classes in which the students did not fare well, the math was simplified. In addition to keeping the math complex, the teachers persisted until students understood the concepts. Each allowed students to assist other students and to use nonverbal communication to explain "proofs." The students gained access to complex mathematics based on a practical problem that elders and others in Yup'ik villages solve every time they build a fish rack.

Different pedagogical, school, and community contexts with different teachers result in different enactment trajectories (Lipka et al. in press). As Abreu (2002) reports, context is all-important. Different teachers fit different culturally based math curriculum and resonate more or less with different modules along the dimensions of culture, pedagogy, and mathematical knowledge. For example, Doreen's knowledge of math, culture, and pedagogy appeared to coalesce through the implementation of the module—each aspect reinforcing the other. Stacy's implementation trajectory relied more heavily on her pedagogical knowledge and relationships with her students than on her mathematical and cultural knowledge. The module helped support and organize her presentation of the mathematics and its connections to the culture. As we study additional cases, we expect that our investigation of the enactment process will yield more explicit knowledge of the complex array of processes involved.

Conclusion

In response to colonial and neocolonial education policy and practices, we have created a culturally based curriculum, a "third space" in which Yup'ik elders' knowledge and ways of knowing come together with Western mathematics concepts, valuing elders' knowledge, increasing curricular choice, and supporting Indigenous educational self-determination. There is strong evidence that this curriculum has been statistically and practically significant in improving Alaska Native students' academic performance, promising to help close the academic achievement gap. Further, our ethnographic data suggest that the cultural themes of each module create real and positive connections for students. By using complementary research methods, we can unpack particular classroom data and analyze how the curriculum is enacted in situated contexts.

MCC appears to alter the social organization and communication in the classroom. We note that control teachers used IRE-type structures that ensured efficiency in student response patterns when the math curriculum was procedural and supported one correct answer (Alrø and Skovsmose 2002). However, when teachers follow the intent of MCC, the classroom organization supported guided inquiry, the use of cooperative work groups, and classroom communicative norms more conducive for problem solving that included multiple speakers who had multiple responses and solutions to math problems.

We identified several possible factors common to successful teachers and students. First and foremost was the long-term positive relationship between teacher and students that contributed to a classroom environment in which trust and mutuality were constructed over time. One way this manifested itself was in the variety of discourse patterns exhibited between the teacher and her students, particularly the ways in which the teacher relinquished control of communication in order to foster student inquiry and promote math talk among a community of learners. The micro themes that emerged in the case studies of Doreen and Stacy showed pedagogical practices aligned with curriculum goals, including changes in the physical and social organization of the classroom, extended discourse, and multiple or overlapping responses. As both teachers made gains in pre-/post-test math scores, we are encouraged by these results.

The macro themes that evolved concern positive changes in relationships, both in the classroom and between the classroom and community, pride in identity and culture, and ownership of knowledge. This curriculum is unique in that it is locally and culturally based while meeting both the state of Alaska's cultural standards and the national standards of the National Council of Teachers of Mathematics (2000). We believe this curriculum holds great promise to improve Alaska Native students' mathematical understanding while bridging the culture of the schools to that of the community. Although this culturally based curriculum can be used and adopted by other Indigenous groups, it also can be viewed as a way to tap rich Indigenous cultural heritages, thus liberating communities from the legacy of colonial education and the restrictive pedagogical forms it prescribes.

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Notes

1. All names other than the teachers' are pseudonyms.
2. In some cases, but certainly not all, silence is a Yup'ik cultural value and so the silence we observed could be a manifestation of "Yup'ikness." For example, when Yup'ik children are observing parents and elders modeling a task, it is generally understood that they will observe and remain silent. So silence does not mean that children are not learning, nor is it an invalid way of knowing. In this case, however, the silence we witnessed seemed to have more to do with classroom control rather than a respectful silence while observing the teacher. Further, the children in this classroom clearly *wanted* to talk about their worksheets and compare answers, but they knew that they should not be out of their seats. Ironically, the silence we observed could come from the notion, taught to the Yup'ik people through their history of missionary schooling, that teachers are strict, authoritarian figures not to be challenged.

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