Mathematics in a Cultural Context: Salmon Fishing - Investigations into Probability

For Submission to the Third International Conference on Ethnomathematics
New Zealand, February 2006

Jerry Lipka
Shehenaz Adam

1. BACKGROUND

The field of ethnomathematics has provided insights into how a local group such as the Yup'ik Eskimo may use their knowledge in mathematics education. Ethnomathematics is the study of the way people from a particular culture have common systems for dealing with quantitative, relational and spatial aspects of their lives (Barton, 1996). As such, it provides insights both into the social role of mathematics and into the nature of mathematical thinking (D'Ambrosio, 2001).

Mathematical activities are exhibited in a variety of ways in every culture, and these activities are directly related to formal, conventional school mathematics in inspiration, motivation, and mode (Adam, 2004). The mathematical activities of Yup'ik people of southwest Alaska are no exception. Their knowledge of problem solving, spatial relationships, estimation, measurement, and the interpretation of physical phenomena have enabled them to live for thousands of years in southwest Alaska.

However, it is common knowledge that cultures have their preferred ways of being, doing, and valuing. Evidence has emerged in the last 40 years suggesting some cultures display strengths in their use of certain types of abilities (Sternberg, 2004), and preference for certain ways of approaching problem solving and learning (Berry, Poortinga, Seagall, & Dasen, 2003). For example, historically Yup'ik people have successfully lived off the land and their visual acuity is accompanied by a rich lexicon of spatial locatives. Not surprisingly, Berry (1966) found spatial skills of Inuit adults as a cognitive strength when compared to other cultural groups. Similarly, Kleinfeld (1971) found Inuit youth had a relative cognitive strength on visual tasks and memory when compared to nonnative Alaskans. On the other hand, other cognitive areas and mathematical topics such as numeration and probability are not nearly as central to subsistence living and everyday activity. This paper briefly discusses the approach and the tactics used in developing *Salmon Fishing: Investigations into Probability* module; probability being a math topic not central to Yup'ik people.. This module as others in the Math in a Cultural Context (MCC) series has been tested in classrooms and we report on the initial results.

MCC is distinguished from other culturally based or ethnomathematics projects. MCC is a long-term collaborative and ethnographic approach to developing school-based math knowledge from Yup'ik elders and teachers. From the early 1990s, Lipka and colleagues have worked collaboratively in Alaska with Yup'ik Eskimo elders and teachers to create a supplementary elementary school mathematics curriculum by incorporating local knowledge into mathematics classrooms. For example, Lipka (1998) suggests that a possible way of bridging the context between school and culture is to "use some of the concrete and more experientially connected Yup'ik conceptions of math and science as a means of teaching in school" (p. 141). Their work involves (Lipka, 2002a, p.3):

- Documentation of elders' stories and related cultural practices.
- Observing mathematics in nature and society, such as the movement of stars, the building of fish racks, or making models of various cultural artefacts.
- Constructing educational or curricula practices that connect the elders' knowledge to schooling jointly with elders, Yup'ik teachers, and university researchers.

In addition, we join elders as they teach us activities such as star navigation or how to make fancy parka patterns. In doing so, we have documented their content knowledge as well as the ways in which learning is organized. In developing curriculum we pay special attention to expert-apprentice modelling, joint productive activity, and cognitive apprenticeship. Learning is typically purposeful and immediate. Young learners participate on the periphery and contribute in ways that are appropriate for them.

In addition to developing supplemental math curriculum based on Western mathematics and Yup'ik elders' knowledge, MCC has developed a systematic long-term research agenda to determine the efficacy of this curriculum and we have attempted to explain it (Lipka & Parker Webster, 2006; Lipka, Hogan, and Parker Webster, 2005). Although common sense strongly suggests that using local knowledge, ways of relating, and creating mathematics problems in a familiar context would benefit students from that group, there is very little empirical evidence to support this claim (Demmert and Towner, 2003). Part of MCC's goals is to conduct a series of quasi and experimental studies across a range of math topics and grade levels. To date, MCC has tested more than ten modules from 2nd to 6th grade and in every trial but one urban cohort students using MCC modules have outperformed their rural and urban counterparts at statistically significant levels (see Lipka & Parker Webster, 2006; Lipka and Adams, 2002). In addition to determining the efficacy of the modules we are equally interested in providing plausible explanations about its effectiveness. See Lipka, Hogan, and Parker Webster (2005) and Lipka and Parker Webster (2006) for a series of case studies that examines the effective implementation of MCC by novice and experienced teachers, teachers working in a variety of contexts (rural Yup'ik, rural Athabaskan, and urban), and by teachers who are insiders and outsiders. Thus, the long-term collaboration with Yup'ik people in developing curriculum and in researching the effects of its implementation are some of its distinguishing features.

The 'salmon fishing: investigations into probability' module is one of four published supplemental mathematics modules based on elders' knowledge and ways of transmitting knowledge[1]. To reiterate, we briefly discuss how we developed this curriculum. We look at the context for the module which includes the cultural, mathematical, pedagogical, and literacy aspects. Further, we examine the effects of piloting this module in a selected school and testing it against control groups. Then we present the findings from the piloting and testing of the module followed by a brief summary.

2. THE CONTEXT

As mentioned before, the supplemental mathematics curricula are based on the traditional wisdom and practices of the Yup'ik Eskimo people of southwest Alaska. The kindergarten to seventh-grade math modules are the result of almost two decades of collaboration between math educators, teachers, Yup'ik Eskimo elders, and educators to connect cultural knowledge to school mathematics. By working with elders we connect the recent and distant historical past to the present. The elders as they gather and meet, tell stories and share cultural practices—many of which are no longer in common use. With this, they discuss the vocabulary necessary to refine the meaning of terms that may

[1] Approximately, another five modules will be published by the end of 2006.

exist in Yup'ik but not in English or vice a versa. Through a slow and iterative process we jointly develop the math curriculum (Lipka, 2002). Within the MCC series there are basically two types of modules: 1) those that use the Yup'ik content knowledge as background material increasing student access and motivation and 2) those that use the content knowledge as part of the math of the module. *The Salmon Fishing: Investigations into Probability* is a module that uses Yup'ik contextual knowledge as part of the social and pedagogical context (background) of the math of the module.

Salmon Fishing: Investigations into Probability is designed for use in the sixth and seventh grades. The module engages students in exploring a variety of topics within probability, using activities that are based on salmon fishing in southwest Alaska. This module uses subsistence and commercial fishing as a contextual background. It includes perspectives of a Yup'ik subsistence fisherman Frederick George and his family, who know the summer cycle of salmon entering the river well and when it is a good time to catch different species of salmon. Knowledge of when to fish, how to fish, and where to fish changes the probability of catching a fish. Although concepts of probability are not typically used explicitly in the Yup'ik culture, the module taps into the everyday experiences of the Yup'ik people, including the embedded cultural values and Yup'ik games of chance where concepts of probability such as fairness are explored. These everyday experiences are used in the module as background knowledge and as a motivating factor for students to actively participate and enjoy learning the underlying mathematical concepts. The contextual familiarity and types of problems that students solve increase student access to the mathematics and increase the likelihood that students will be motivated to engage in these materials. As research evidence shows, mathematics derived from students' everyday life experiences is typically more accessible and enjoyable to them, enhancing their ability to make meaningful connections and deepening their understanding of mathematics (Zaslavsky, 1991).

The module allows students to explore probability concepts such as theoretical and experimental probabilities, the Law of Large Numbers, sample space, and equally and not equally likely events. The module is adapted specifically to events that occur in everyday life, that is, in the context of salmon fishing in Alaska. Formal mathematics is developed within this context through hands-on, inquiry-oriented activities that are intellectually stimulating and enjoyable to students. A tactic we used in developing this module was to take abstract concepts such as the Law of Large Numbers and turn them into contextualized problems. As students solve these problems they work with manipulatives and organize physical data. Similarly this strategy taps into students spatial abilities. Likewise, we build activities in which students work in groups, have ample opportunities to collaborate, and provide students structured autonomy to solve math problems. The module explores the concept of sample space—not typically taught at the sixth grade. However, through the tactic of making sample space visual through organizing all possibilities in a systematic way and embedding the concept within the storyline of the module we make the concept accessible to sixth graders. As we develop these activities we bring them back to Yup'ik teachers and consultants and we further refine the activities. Lastly, we choose topics within the MCC series that are typically underrepresented by mainstream math curriculum and/or make a contribution to the field based on cultural knowledge that is not widely disseminated.

2.1 Cultural Context

Traditionally, Yup'ik people have depended on salmon, and they continue to rely on the wealth of the fish harvest, both directly and indirectly. Salmon form a primary part of the regional diet. Not only do salmon provide food, but salmon are also a source of employment. The large seasonal influx of salmon nurtures a commercial fishing industry that brings financial resources into the community. Because of their reliance upon salmon, Yup'ik people who fish for subsistence stop fishing after they catch a certain amount of salmon – the amount they need to eat during the coming year. Such conservation reduces waste and helps maintain a large spawning population of salmon.

Through repeated experiences from year to year, Yup'ik people have learned to predict how many fish will be required. With the information they have gathered over time, they have also developed accurate predictions about fishing conditions and what time and where to catch the salmon they prefer.

2.2 Mathematical Context

In this module we focus on applying the definitions of probability, understanding sample space, and analyzing probability with equally likely events as well as not equally likely events. We also briefly investigate sampling as we tie the ideas of probability to what Alaska Department of Fish and Game does when estimating population sizes of each fishery. Part of the curriculum design of this module allows for students of different abilities and skills to access the probability concepts with varying degrees of difficulty.

At the beginning of the module students perform the experiment of flipping a coin. This allows them to think about possible outcomes and connects to their prior knowledge of chance. As students are introduced to probability versus chance they are also introduced to experimental probability as compared to theoretical probability. Continuing with the experiment by flipping the coin over and over, students see that experimental probability and theoretical probability are close (or nearly equal) for a large number of trials. This is formally summarized as the Law of Large Numbers. Next, students investigate the concept of sample space. Sample space is the set of all possible outcomes and is necessary for understanding theoretical probability. Sample space also leads into discussion of equally likely events. The subsequent activities help students to use probability in real-world situations and to investigate games of chance to understand fairness and why scoring rules are developed. They also simulate how the Alaska Department of Fish and Game estimates the number of salmon in a fishery. Finally, using the George family catch as an example, students explore how skills and experience can influence the probability that an event will (or will not) occur.

2.3 Pedagogical Context

The pedagogy of the module is adapted from expert Yup'ik elders and teachers. Thus, the module structures its activities in a way that includes expert-apprentice modeling, joint-productive activity, cognitive apprenticeship, and tasks and materials that enable students to explore mathematics but within a contained and limited universe, encouraging mathematical explorations and student autonomy.

The module is organized to provide students with five types of practice for learning probability. The main pedagogical method is experimentation, where through experience students learn concepts such as the Law of Large Numbers and learn to derive a variety of sample spaces. This inductive way of learning is supported by three other pedagogical approaches. One of these approaches has students present what they are learning for second or third grade students and this builds on the successes reported in the research associated with tutor/tutee. One major reason that peer and cross-age tutoring is effective is that tutors and their students often speak a more similar language than do teachers and students (Cazden, 1986; Hedin, 1987). Peer tutoring usually resulted in significant cognitive gains for both the tutor and the tutee (Britz, Dixon, and McLaughlin, 1989). The second approach incorporates the work of Sternberg (1997, 1998) in which he emphasized students learn more thoroughly when they use their analytic, creative, and practical intelligences. For example, in this case students use their creativity and develop games and comic-book-like presentations as a way to both demonstrate their knowledge and to teach second and third graders. Finally, the third pedagogical technique is the more typical approach of providing guided practice for students.

2.4 Literacy Context

The literacies-based activities in this module are designed from a diverse social constructivist orientation (Au, 1998). Within this perspective, learning is situated in a context where both teachers and students are actively engaged in social situations (Vygotsky, 1986), which gives particular attention to students' prior knowledge and life experiences that are influenced by culture, ethnicity, and their primary language. Given the importance of these influences on students' learning, the activities are centered within the framework of multiple literacies. Multiple literacies reflects a broader view that moves beyond the mainstream idea of literacy as reading and writing to encompass a wide range of symbol systems (e.g., music, art, math) and diverse modalities of interpretation and expression (e.g., visual, oral, aural, kinesthetic). Thus, activities may include a variety of strategies such as discussing, drawing, writing, reading, storytelling, and presenting as ways to represent student learning. One important goal of the literacy-based activities is to promote a better understanding of the math concepts presented in the module. An equally important goal is to improve comprehension and the cognitive and metacognitive processes that support and build understanding of a variety of texts. This approach to literacy matches MCC's emphasis on expert-apprentice modeling and joint activity.

3. METHODOLGY

MCC has typically conducted quasi-experimental studies to determine the efficacy of the modules in this series. However, because of the timing between when the *Salmon Fishing* module was completed and the need to test it, it was only possible to conduct a small scale study. Specifically, we contacted a local Fairbanks teacher, Tom Dolan, who had previous experience piloting MCC modules and he was selected as the treatment teacher.

He taught the module in two sixth grade classes. We had another teacher from the school district who was the control teacher and he also taught two classes. Each teacher gave their classes pre and post tests. We then compared gain scores across the treatment and control classes as well as an item analysis to see if there were any conceptual differences between the groups. Because it was the end of the school year we then tested three other classes, post-test only for purposes of comparing to the treatment group to an increased number of control group students. Our logic was that since it was the end of the school year students in the control group would have learned whatever they were going to learn about probability. In addition, we tested the test. We gave every other student in the control group the pre test or the post test to determine if the tests were balanced. In fact, the post test proved to be about 7% easier than the pre test. This allows us to make changes to the test, increasing its validity. Below (in Table 1 and Figure 1) we show the findings from our analyses.

4. FINDINGS

The treatment teacher and his students reported that they enjoyed learning mathematics when taught in this hands-on problem-oriented way. In fact, students have requested that other mathematics topics be taught in a similar way.

The findings in this study are derived from a post test comparison. Questions on the test were quite typical of test items found on standard math tests. Although not ideal in terms of the title of our project, math in a cultural context, because of the lack of credibility often associated with reform-oriented math and ethnomathematics we decided to make our testing similar and more difficult than comparable standard testing. The following items provide a sample.

- A number cube is rolled. Find the probability that:
  a. The number on top is 3.

  b. The number on top is greater than 2.

  c. The number on top is less than or equal to 5.

- If two dice were rolled over and over again, what sum would you expect to occur most often? How do you know?

- There are 4 red marbles, 6 blue marbles, and 5 green marbles in a bag. Find the probability each event, if one marble is drawn from the bag.

  a. P(green marble) =

  b. P(red marble) =

  c. P(not blue) =

  d. P(orange marble) =

We were interested in determining if there was a difference in what and how well students in the treatment group did versus the control group. In table 1 below are the summary statistics. In fact, the results of this pilot show that on average treatment students scores approximately 19 points more than control group students on the post test. This is approximately a difference of 4 questions on a test of twenty questions.

Table 1: Treatment vs. Control

	treatment	*control*
Mean	64.49383	45.58442
Variance	506.956	496.6853
Standard Deviation	22.51568	22.28644
Observations	45	77
Hypothesized Mean Difference	0	
df	91	
t Stat	4.492555	
P(T<=t) one-tail	1.03E-05	
t Critical one-tail	1.661771	

The almost twenty point difference between the treatment and control results in a statistically significant difference at the .99 level in favor of the treatment group. Also, the effect size is almost equal to 1 or 1 whole standard deviation. Again, we need to reiterate although these are very strong results this data must be looked at as preliminary data.

We were also interested in analyzing differences across the items. Figure 1 is an item analysis.

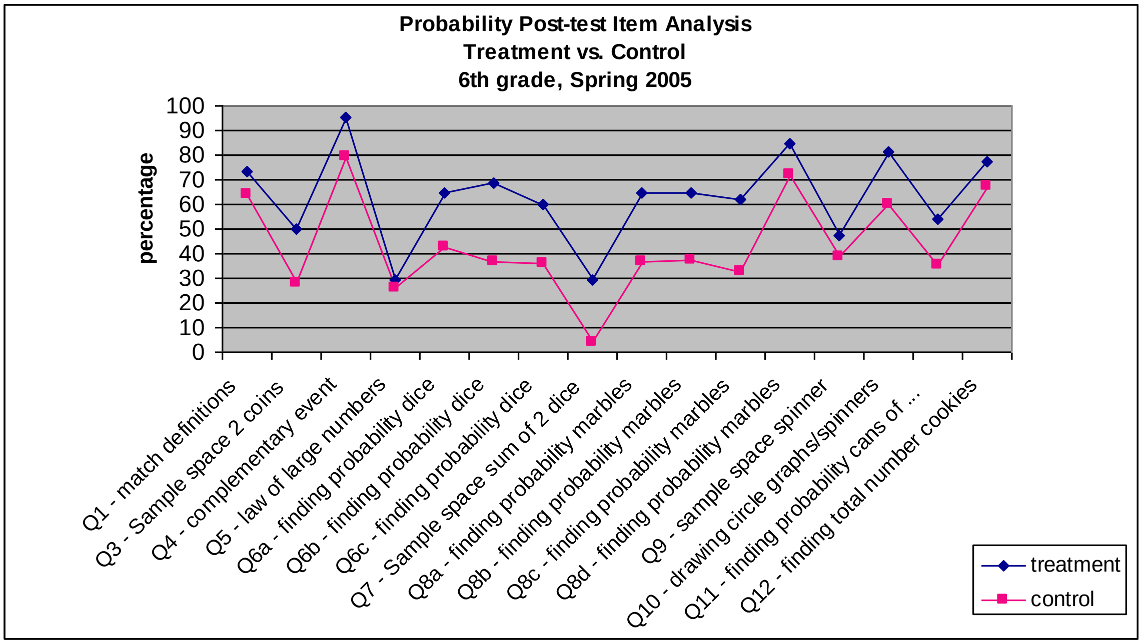

Figure 1: Item Analysis

The item analysis reveals that all except one, the Law of Large Numbers, shows that the treatment group outperformed the control across all the concepts tested—sample space, finding probability, graphing/making a spinner. Although not shown above the basic curve in Figure 1 was maintained across the individual class data. In other words, the pattern of learning probability at the end of the school year when comparing the treatment classes to each control group class was very similar to pattern shown above. This adds credibility to the results as it would be difficult to believe that the results were random.

Even though, the module was piloted for three weeks, it provided a substantial gain in a relatively short time period. Again, this lends credence to the power of this intervention. During the post-interview, all students interviewed said that they enjoyed learning the probability module and that they felt they have learned different probability concepts that were not clear initially. They also said that through studying of the probability module, they have started relating probability to real-life instances, which they did not do before. In addition, the teacher who piloted this module commented that the students were "very engaged during the implementation of the module and are not happy to be back with what we are doing now." He also remarked that the context of fishing helped the students because fishing is something that they can relate to. Further, he commented that "Activity 9 [project where students created a game of chance] was the best math lesson all year." Students confirmed this during interviews, that the lesson that they most enjoyed was the project (Activity 9).

4. SUMMARY

By working in unfamiliar settings and facing new and challenging problems, students learn to think creatively. They gain confidence in their ability to solve both everyday problems and abstract mathematical questions, and their entire realm of knowledge and experience expands. Further, by making the familiar unfamiliar and by working on novel problems, students are encouraged to connect what they learn from one setting (everyday problems) with mathematics in another setting.

The preliminary data gathered on *Salmon Fishing - Investigations into Probability* show it to be a powerful intervention. We believe that this is important as it shows that a module based in part on the everyday circumstances of Yup'ik elders can be developed into a core academic subject and can produce math learning that is equal or greater than mainstream math curricula. Further, although the context of this module is based on Yup'ik elders' knowledge and the background associated with the math of the module, urban students reported enjoying this approach to learning math more than their regular math. However, we must reiterate that this data is preliminary and more testing needs to occur especially among rural Yup'ik students and with other Alaskan indigenous students before we know more about its efficacy—what works well with which group of students and under what conditions. We will also need to do more qualitative analysis to determine what it is about the module that produces these positive results. Yet, consistent results across multiple modules across multiple topics and with diverse groups of teachers and students is beginning to make a convincing case for MCC and ethnomathematics.

REFERENCES

Adam, S; Lipka, J; Rickard, A; Adams, B; & Gilliland, K. (2005). *Salmon fishing : Investigations into probability – A curriculum module for Grades 6 and 7.* Fairbanks, Alaska.

Adam, S. (2004*). Ethnomathematics in the Maldivian Curriculum: Trialling an implementation*. Unpublished Phd, University of Auckland, Auckland.

Au, K. (1998). Social Constructivism and the School Literacy Learning of Students of Diverse Backgrounds. *Journal of Literacy Research,* 30(2), 297–319.

Barton, B. (1996a). *Ethnomathematics: Exploring Cultural Diversity in Mathematics.* Unpublished PhD, University of Auckland. Auckland.

Berry, J. W. (1996). Tenne and Eskimo perceptual skills. *International Journal of Psychology, 1,* 207-229.

Berry, J. W., Poortinga, Y. H., Seagall, M. H., Dasen, P. R. (2003). *Cross-cultural psychology*. Cambridge, UK: Cambridge University Press.

Britz, M. W., Dixon, J., and McLaughlin, T. F. (1989). The Effects of Peer Tutoring on Mathematics Performance: A Recent Review. *Journal of Special Education,* 13(1), 17–33.

Cazden, C. B. (1986). Classroom Discourse. In M. C. Wittrock (Ed.), *Handbook of Research on Teaching* (pp. 450–451). New York: MacMillan.

D'Ambrosio, U. (2001). What is Ethnomathematics, and How Can it Help Children in Schools? *Teaching Children Mathematics, 7*(6), 308-310.

Demmert, W. and J. Towner (2003). *A Review of the Research Literature on the Influences of Culturally Based Education on the Academic Performance of Native American Students*. Unpublished manuscript, Portland, OR.

Hedin, D. (1987). Students and Teachers: A Tool for Improving School. *Social Policy,* 17(3), 42–47.

Kleinfeld, J. S. (1971). Visual memory in village Eskimo and urban Caucasian children. *Arctic, 24,* 132-138.

Lipka, J. (1998). *Transforming the Culture of Schools : Yup'ik Eskimo Examples*. Mahwah, N.J.: Lawrence Erlbaum Associates.

Lipka, J. (2002). Connecting Yup'ik Elders Knowledge to School Mathematics. In M. de Monteiro (Ed.), *Proceedings of the Second International Congress on Ethnomathematics (ICEM2)*, CD Rom, Lyrium Comunacacao Ltda, Ouro Preto, Brazil.

Lipka, J. & J. Parker Webster (2006). Journal of American Indian Education (special issue).

Lipka, J; Hogan, & Parker-Webster (2005). Math in a Cultural Context: Two Case Studies of Successful Culturally Based Math Project. *Anthropology and Education Quarterly* 36(4), 367-385.

Sternberg, R. (1997). *Successful Intelligence.* New York: Plume.

Sternberg, R. (1998). Principles of Teaching for Successful Intelligence. *Educational Psychologist*, 33, 65–72.

Sternberg R.J. (2004). Culture and intelligence. *American Psychologist*, *59,* 325-338.

Vygotsky, L. S. (1986). *Thought and Language.* Cambridge, MA: MIT Press.

Zaslavsky, C. (1991). World Cultures in the Mathematics Class. *Learning of Mathematics*, 11(2), 32–35.