An ethnomathematics approach toward understanding a Penobscot hemispherical lodge

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Abstract
This paper introduces an ethnomathematical model for Penobscot ways of knowing based on the construction of a traditional Wabanaki hemispherical wigwam. The Penobscot people are part of the Wabanaki Confederacy of Eastern Tribes: Micmac, Malisseet, Passamaquoddy, and Penobscot. Appropriate curriculum and pedagogy for Native American students is central to their success in mathematics. Zaslavsky (1988) points out three benefits for students when mathematics education is culturally responsive. She sees the opportunity to improve individual students' self esteem, increase their interest in mathematics and develop an appreciation of different ways of thinking. Incorporating relevant mathematics, that is, mathematics that is perceived as useful by students enhances interest in mathematics. Appreciation of different ways of thinking is a product of recognizing our diverse global population. We agree with Presmeg (1988), that the incorporation of cultural traditions and history will create "real" and "relevant" (p. 214) mathematics.
Keywords: Mathematics education; Ethomathematics; Indigenous knowledge.

Uma abordagem etnomatemática para o entendimento da cabana hemisférica dos Penobscot

Resumo
Este artigo introduz um modelo etnomatemático para os modos de saber dos penobscot, que está baseado na construção do tradicional *wigwam,* de forma hemisférica, dos wabanaki. Os penobscot fazem parte da Confederação Wabanaki das Tribos Orientais Micmac, Malisseet, Passamaquoddy e Penobscot. A adequação do currículo e da pedagogia são essenciais para que os alunos nativos americanos tenham sucesso em matemática. Zaslavsky (1988) ressalta três benefícios para os alunos quando a educação matemática é culturalmente responsiva. Ela contempla a oportunidade da melhoria da auto-estima individual dos alunos, o aumento do interesse deles pela matemática e o desenvolvimento da apreciação dos mesmos sobre os diferentes modos de pensamento. Assim, a incorporação de uma matemática relevante, que seja percebida como útil pelos alunos, realçará o interesse dos mesmos pela matemática. A apreciação dos diferentes modos de pensamento é um produto do reconhecimento de nossa população diversa e global. Concordamos com Premeg (1988) que a incorporação das tradições culturais e da história criará uma matemática "real" e "relevante" (p. 214).
Palavras-chave: Educação matemática; Etnomatemática; Conhecimento indígena.

Introduction

The State of Maine, the eastern most state in the United States, has enacted Legislation requiring that all Maine schools teach Wabanaki studies in all subjects and in all grades from EC-12. This law more commonly known as LD 291 has taken effect during the academic year 2004-2005. Many people see this as a social studies exercise and do not believe that mathematics could be part of Wabanaki studies. We believe that mathematics is a viable content area for Wabanaki studies for two reasons: 1) the ethnomathematics of Wabanaki people taught to non-Wabanaki students provides a unique connection to a different culture and 2) recognizing and respecting Wabanaki ethnomathematics validates knowledge Wabanaki students bring to the academic classroom and provides rich opportunities for creating pedagogical bridges between their culture and academic mathematics. These pedagogical bridges have to be two-way bridges that connect mathematics educators to indigenous ways of knowing as well as developing connections between indigenous ways of knowing and academic mathematics. As Jones (2002) states:

> *Multicultural mathematics activities that use culture to make connections with typical mathematics topics can motivate culturally and ethnically diverse students to investigate and gain respect for their own cultural heritage while learning significant mathematics content. Multicultural mathematics enriches the study of mathematics for all students by illustrating the global*

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nature of the development of mathematics, as well as mathematics concepts and ideas that are shared across cultures. (p. 180)

Understanding the mathematics education of underrepresented groups in the United States is gaining attention with respect to learning, pedagogy, and making mathematics connections between Indigenous ways of knowing and academic ways of knowing. In 2002 the National Council of Teachers of Mathematics published *Changing the faces of mathematics: Perspectives on indigenous people of North America*. This seminal piece has created mathematics education awareness of what and how the mathematics needs for Indigenous students can and should be improved. The contributors to this publication are recognized as leaders in this area of research in the United States.

The project

The authors entered this project without a theoretical framework as this was to our knowledge, the first experience for students in the state of Maine to experience a hands-on learning experience of Penobscot ways of knowing. Most of the participants were not aware of Native American communities in Maine and had not been "students" of a Native American educator. Data was collected through video, field notes and interviews. What follows is our interpretation of one event and how we construct a pedagogical bridge between Penobscot ways of knowing and academic mathematics.

For two weeks in October of 2004, nearly 180 students converged on the Damariscotta River Association (DRA) to construct a traditional Wabanaki Village. The DRA is non-profit group in Maine that holds land in trust. Their initiation of this project had the purpose of a hands on learning experience for students that allowed youngsters exposure to Native American culture and activities on a piece of land that is ancestral for Wabanaki people. John Bear Mitchell directed the educational experience. Mr. Mitchell is a member of the Penobscot Nation and a recognized leader in Native education in the United States. During this two weeks event students, under the direction of John Bear Mitchell, constructed three traditional wigwams, a smoker, two fire pits, and a mortar and pestle. We focus this paper on the construction of one of the wigwams, the hemispherical lodge, see Figure 1. This lodge was used as a summer sleeping lodge with the interior having three designated functional "areas." Upon entering the lodge the space opposite the door was where the adults slept, the area to the left was the children's sleeping space, and the space to the right of the door was for food preparation and/or a sleeping space for guests. These lodges did not have interior fire pits due the combustibility of the material used to construct the wigwam.

Figure 1

There were many lessons learned by all in attendance. Students questioned John Bear about his life today as a Penobscot. The Penobscot Nation is on an island in the Penobscot river in the state of Maine, United States. This indigenous population is one of the four Native American tribes that constitute the easternmost United States Confederacy of Native American tribes. This confederacy, the Wabanaki, translates to the People of the Dawn. The four tribes are the Penobscot, Passamaquoddy, Maliseet, and Micmaq. These indigenous groups live in the state of Maine as well as the Maritimes of Canada (New Brunswick, Nova Scotia, New Foundland).

Students asked questions about where John Bear lives, his educational background, and his professional life. Of course there were a few personal questions but the final outcome was the development of understanding by all participants and we conjecture enhancement of tolerance. Inherent in John Bear's teaching was the history associated with the ancestral grounds where the village was being constructed as well as the history of Penobscot people. These were very rich social studies lessons but when the actual construction began, we recognized that there was a wealth of mathematics and mathematical ways of knowing inherent in the designing and building.

According to D'Ambrosio (2006) "The word Ethnomathematics may be misleading. It is often confused with ethnic-mathematics. I see ethno is a much broader concept, focusing on cultural and environmental identities. The name also suggests different mathematics" [2, p. 1]. In this work we subscribe to this broader context focusing on the cultural and environmental identity of the Penobscot people. "If indigenous peoples are to gain ownership of western technology and survive as cultures they must be able to master the mathematical basis behind the technology without forfeiting their traditional ways of learning and their ethnomathematics" [3, p. 48]. Bishop (1988) states that mathematics occurs across all cultures in six activities: explaining; measuring; locating; counting; designing and building; and playing. We ask the reader to keep these categories in mind while we describe this two week event in Maine with 180 middle school students to build a traditional Wabanaki village on ancestral grounds held in trust by the Damariscotta River Association at the Great Salt Bay region of Maine.

Pedagogy and learning

We consider this project through the use of Ernest's (1996) metaphor to describe constructivism,

> *What the various forms of constructivism all share is the metaphor of carpentry, architecture, or construction work. This is about building up of structures from preexisting pieces, possibly especially shaped for the task. The metaphor describes understanding as the building of mental structures, and the term restructuring, often used as a synonym for accommodation or conceptual change, contains this metaphor. What the metaphor of construction does not mean in constructivism is that understanding is built up from received pieces of knowledge.* (Ernest, 1996, p. 335-336)

The students as well as teachers were not passive receivers of Penobscot knowledge. The Penobscot model demonstrated here was to first model the activity, pose and answer questions, then have the participants take over the task to create their own meanings and engage their problem solving methodologies toward the desired outcome. "What I'm going to do, I'm going to do one of these myself and let the volunteers do the rest." [This reference is to setting the first lodge pole.] We might go as far as to consider this an "apprenticeship" but in this limited period of time the participants certainly do not take on the habits, language, or disposition of the Penobscot teacher. Even in an apprentice mode we would argue that the non-Wabanaki participants would never take on a Penobscot world view, but possibly begin to appreciate this world view.

Building the wigwam

The building of the hemispherical wigwam begins with the circular layout of the base. A post pounded into a level piece of ground establishes the center of the lodge. The non-standard unit of measure for the diameter of the lodge was 1.5 times John Bear's height. This dimension, approximately nine feet, ensured that there would be enough floor space for the traditional use of this summer lodge, sleeping and staying dry when it rained. A hemispherical lodge, based on this circular dimension, would allow two adults space to sleep on the west side (directly opposite the entryway), space for children to sleep on the south side, and space for working or guests to sleep on the north side. The circular base can be considered from a geometric perspective of dividing the living circular space into three congruent pieces each with a central angle of 120º, see Figure 2. The reality is that the sleeping space for adults would be larger than that of the children.

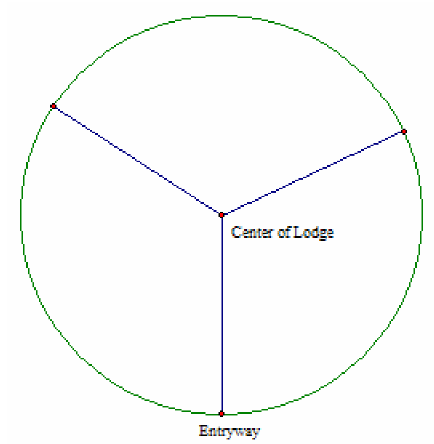

Figure 2

This configuration amounts to a sleeping space of approximately:

$$\frac{\pi(4.5)^2}{3} \approx 21.2 \text{ ft}^2$$

All of the construction materials had previously been harvested and students participated in moving these materials to the village site. By moving the materials the students were gaining a sense of the size of the materials, lodge pole length and diameter. The lodge poles were approximately three inches in diameter and fifteen to twenty feet in length. The poles were immature birch trees. The students were also appreciating that the materials were naturally occurring and locally found; an important consideration as Penobscots traditionally only had access to immediate resources, "we didn't go out hunting for trees, we landed and used what we had." The physical effort aided students' in developing an understanding of how local materials were utilized.

This hemispherical lodge was an eight pole living lodge, not a twelve pole ceremonial lodge. Locating the four cardinal directions, which established the location of the first four poles and the door: "We [Penobscot] always go to the east, we always face our door to the east and that way the sun rose over our head. Now two different things, first of all that's a ceremonial direction, that's the direction we came from, Wabanaki, the dawn people. It's also a good idea to have your door to the east because we didn't have any windows, what happens when the sun comes up on a cold morning?" A few students mention that right before the sun comes up it is the coldest but one student realizes that the rising of the sun means "heat." With a hand gesture to show how to open a flap on the lodge door John Bear states "the heat will come into your house and it will warm up in there." This location of east and understanding that the sun rises in the east allowed students to appreciate the thermal benefit of this knowing.

Knowing the location of east was instrumental in negotiating the location of that lodge pole. If the pole had been placed directly east, then the lodge entry would have a pole centered in the door way. The east lodge pole was placed slightly south and another vertical pole was pounded into the ground opposite this pole to establish the entry way, see Figure 3.

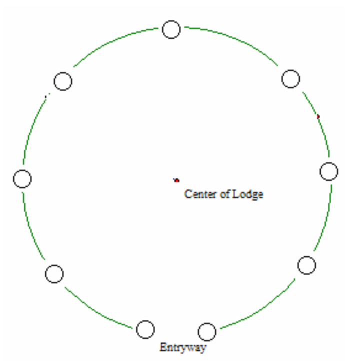

Figure 3

Mathematically the placement of the lodge poles was a rich exercise for the students. Students needed to demonstrate concepts of opposites, perpendicularity, and congruent arc lengths. The east, west lodge poles were in a perpendicular alignment with the north, sout lodge poles. With these four poles placed the students had to mentally approximate the placement of the remaining four poles such that these were equidistance on the arc from opposite poles and from a central angle perspective, the measure of which is approximately 45º. The positioning of the lodge poles introduced reasoning associated with lodge pole length and diameter, appropriate opposite lodge poles had to be similar with regard to these dimension. Proportional reasoning of the depth needed for each lodge pole hole relative to lodge pole length had to be also considered. John Bear demonstrated another aspect of understanding "that one doesn't look good, doesn't look that bendable." This observation was based on the base of the lodge pole which was crooked and his learned experience allowed him to dismiss this pole's use.

To the outside observer the placement of the lodge poles seemed a straight forward task of creating a vertical hole in the ground, placing the pole, and then stamping the ground around the pole. However, this was not the case. "Are we going to put the base in straight like this?" John Bear makes a hand gesture to show a perpendicular placement of the lodge poles followed by a hand gesture to show the bending of the lodge pole toward the interior center of the lodge. "What would happen if we put a pole here [perpendicular] and try to bend it?" One student thought the pole would "break" which John Bear agreed with but he wanted the students to also realize that the perpendicular placement of the pole would likely lead to the pole popping out of the ground when it was bent toward the center. This could lead to injury as well as compromise the rigidity of the lodge. "We're [meaning the participants are going to be engaged in setting poles after his demonstration] going to come in at an angle to make holes for the poles." The angle, approximately forty-five degrees, allowed the interaction of the pole and earth to work against each other thus securing the pole in the ground, Penobscot Ancestral Engineering in action. The depth of the needed lodge pole hole, while not explicitly calculated, was determined by John Bear to be approximately eighteen inches. His proportional reasoning is based on the approximate length of the lodge poles, the lodge pole diameter, and his Penobscot ethnomathematics, see Figure 4.

Figure 4

"What I'm going to do, I'm going to do one [set the first lodge pole] of these by myself and let the volunteers do the rest." While John Bear was creating the hole in the ground he was talking to the participants, "I just want the hole to get kind of wide but not too wide," another visual estimation of the needed hole diameter relative to the lodge pole diameter. With the setting of the first lodge pole, which had already been matched to its opposite by John Bear, participants were asked to get the remaining poles and start placing them. Opposites were very important as the first two poles placed were the north and south poles then the east and west poles, recalling that the east pole was slightly south to allow the doorway. Without explicit instructions students were observed comparing pairs of lodge poles for length, by standing them up or by holding pairs horizontally, and judging base diameters. While this was occurring the first volunteer hole was being dug while John Bear stood by to answer questions and help with an appropriate angle.

The gathering of the last six lodge poles coincided with the completion of the placement of the second lodge pole. Now John Bear demonstrated how to bend the lodge pole, see Figure 5, toward the lodge center while a student stood at the opposite lodge pole and mimicked John Bear's actions. This task was done by placing his feet against the base of the pole and "walk[ing] myself up." This motion was hand over hand while his feet stayed stationary against the base of the lodge pole and pulling the pole toward the center of the lodge. In the center of lodge stood the tallest student whose "job is going to be to grab my tree, not pull but hold it when I bend it to you." While John Bear demonstrated this action and the student grabbed the pole when it was bent far enough, the student on the opposite pole proceeded to bend her pole. When a teacher intervened to assist, the two of them managed to move the angled lodge pole to a perpendicular position as the student was not strong enough with her feet placement to resist the pushing by the teacher. This was an interesting observation as first it was not the action that John Bear had demonstrated and second the student had not been allowed an opportunity to try to bend the lodge pole, the teacher immediately intervened.

Figure 5

Finally, the teacher moved the student and took over the task of bending the lodge pole. The student in the center held each of the lodge poles together while John Bear asked observers "Now are these pretty even?" This was question of symmetry relative to the circumference of the base, the center of the lodge as well as the height that these two arcs created. Even the passive observers found themselves involved as their responsibility was to answer the question, see Figure 6.

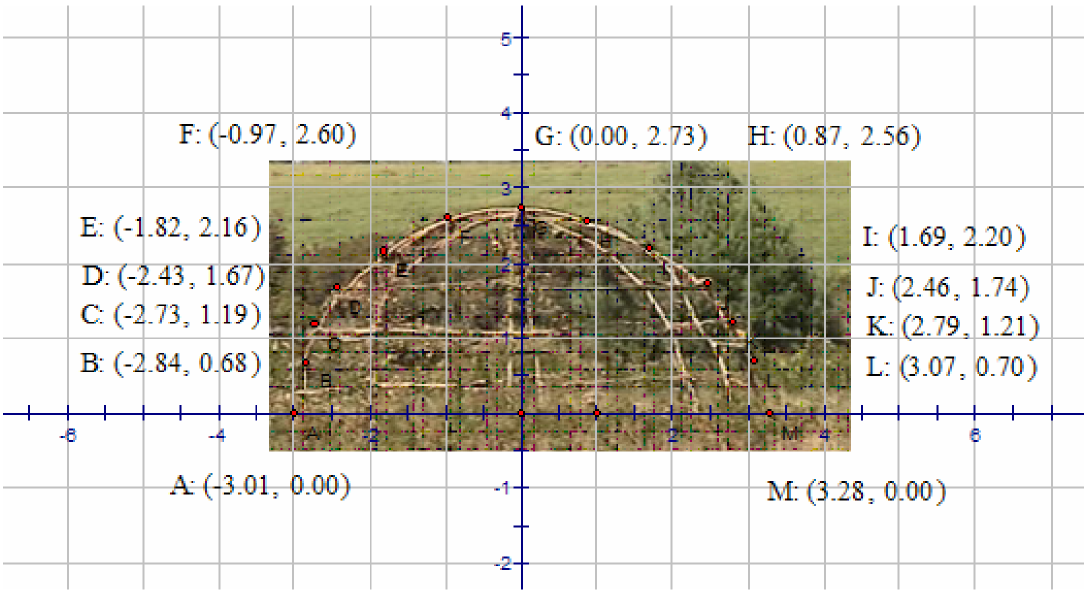

Figure 6

We have imported the image, Figure 13, of the lodge into Geometers' Sketchpad and plotted points associated with a view to determine symmetry. The symmetry is an important element of Penobscot ethnomathematics, but with the use of this technology and a graphing calculator we were able to connect this ethnomathematical knowledge with academic mathematics. The ordered pairs in Figure 6 are nearly symmetrical, considering that these poles were secured bases on best visual estimates this lodge is "symmetric." Entering these points into a graphing calculator and plotting them yields Figure 7.

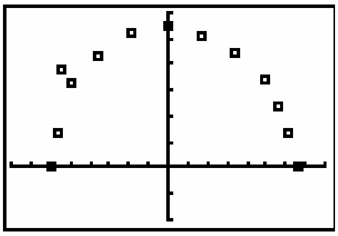

Figure 7

We curve fitted a quadratic, see Figures 8 and 9, as well as a quartic, see Figures 10 and 11.

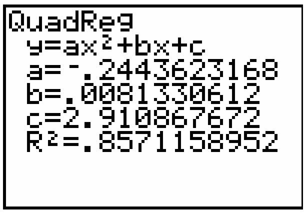

Figure 8

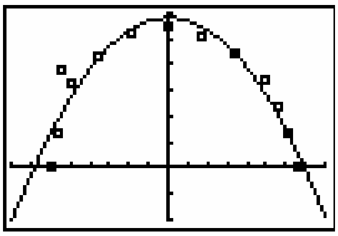

Figure 9

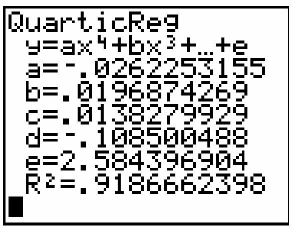

Figure 10

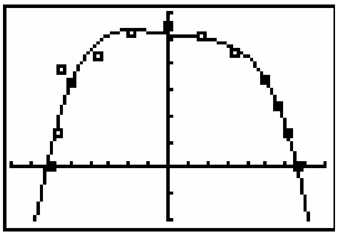

Figure 11

The quartic yields a "better" fitting curve. The use of this wigwam as a tool to algebraically explore symmetry is unique and rich in mathematics. If technology is available then appropriate curve fitting explorations can be done through students testing and examining their conjectures.

There was a tremendous amount of negotiation between students, between teachers, and between students and teachers. They had all assumed the role of "student" and were now in charge of completing the frame of the lodge, see Figures 12, 13, and 14. Their poles, without being explicitly told how to select them, were a good height and diameter match. Individuals took turns creating the holes and attempting to bend the poles toward the center. Still, the observers were charged with giving instructions as to the "evenness" of the lodge. Unless asked directly John Bear now took on the role of observer. John Bear's teaching was done; he had modeled what the students needed to do and was satisfied to watch the students assume the tasks.

Figure 12

Figure 13

Figure 14

Conclusions

We have provided a snapshot into the first construction in this two weeks Wabanaki studies exercise. From this we believe that the non-Wabanaki participants: 1) appreciated that there is an incredible wealth of knowledge to be understood; 2) Wabanaki people have lives in some ways that are very similar to the participants'; and 3) this glimpse of Wabanaki ways of knowing is very important to understand for pedagogical purposes. This is the beginning of unfolding the rich ethnomathematics of Penobscot People. We hope that these culturally relevant experiences helped to foster positive attitudes towards mathematics (Taylor; Stevens, 2002). Through this cultural lens mathematics comes to the forefront and lends itself to the construction of pedagogical bridges between Penobscot ways of knowing and academic mathematics.

Understanding the pedagogy demonstrated by John Bear is vitally important for inservice teachers, preservice teachers, and educators in higher education. Wabanaki children enter our classrooms with a way of learning which may be contrary to our teaching methods. While we did not elaborate each detail of visual measurement, designing, estimation, or proportional reasoning which are inherent in Bishop's six activities, we, educators, must understand these abilities and skills are those of Wabanaki youth. How can we create pedagogical bridges between Wabanaki culture and academic mathematics? We believe that "all learning is necessarily cultural in character (Pallascio et al., 2002, p. 59)" and activities such as these are a start for all students to appreciate how Indigenous ways of knowing can connect to academic experiences. This one wigwam example has a wealth of activities inherent within it. The circular base of the lodge was designed with the use in mind (sleeping and food preparation); the connection to academic mathematics realizes the differences in circular base area by increasing or decreasing radius. The hemispherical lodge while having eight main lodge poles has numerous external side rails that are attached in a horizontal format to aid in structure rigidity as well as serve as attachment sites for coverings. The spacing of these rails on the hemisphere and visual estimation on the part of students was quite remarkable. The covering of this lodge was done with branches, cattail mats, and grass mats. Multiple layers served to create a wigwam that was rain "proof." Academically we explore the surface of area of spheres and hemispheres through algebraic manipulations. Students were frequently overheard using the language of mathematics to convey their meaning to peers while engaged in the construction. This ability to communicate is desirable for all of our students. If we understand experiences Wabanaki children bring to our academic environment, respect and honor this knowledge, create pedagogical bridges, then we conjecture mathematics education is improved for all students.

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