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Visuospatial reasoning: a comparison between the construction of a native american hand drum and surgical geometry

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Abstract: This paper focuses on the construction of a hand drum by a Native American drum maker, and the construction of an anastomosis by a thoracic cardiovascular surgeon. Neither activity occurred with written instructions or illustrations. Each construction occurred through the ability to move mental images and procedures to their fingertips using their visuospatial reasoning (Owens, 2015). For the drum maker, learning was through mentorship, observation, and practice. Each of them, the drum maker and surgeon, developed rich spatial reasoning skills that are built on relationships. For the drum maker the relationships have to do with the geometry of the drum and it's components just as the surgical geometry relationships exist in the operating room. For the drum maker tensions are felt with the fingertips, the same experience of the surgeon. Parallels are highlighted between these seemingly unrelated activities with a discussion of possible implications for Mathematics Education.

Keywords: Ethnomathematics. Drum Making. Emic. Etic. Visuospatial Reasoning.

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Raciocínio visuoespacial: uma comparação entre a construção de um tambor de mão nativo americano e a geometria cirúrgica

Resumo: Este artigo centra-se na construção de um tambor de mão por um fabricante de tambor nativo americano e na construção de uma anastomose por um cirurgião cardiovascular torácico. Nenhuma das atividades ocorreram com instruções ou ilustrações escritas. Cada construção ocorreu através da sua capacidade de mover imagens e procedimentos mentais na ponta dos dedos com a utilização do raciocínio visuoespacial (Owens, 2015). Para o fabricante do tambor, o aprendizado ocorreu por meio da orientação, da observação e da prática. Cada um deles, o fabricante do tambor e o cirurgião, desenvolveu ricas habilidades de raciocínio espacial baseadas em relacionamentos. Para o fabricante de tambor, os relacionamentos têm a ver com a geometria do tambor e os seus componentes, assim como as relações de geometria cirúrgica existem na sala de operação. Para a resistência do tambor, as tensões são sentidas com a ponta dos dedos, a mesma experiência do cirurgião. Paralelos são destacados entre essas atividades aparentemente não relacionadas com a discussão de possíveis implicações para a Educação Matemática.

Palavras-chave: Etnomatemática, Construindo Tambores, Êmica, Ética, Raciocínio Visuoespacial.

Razonamiento visuoespacial: una comparación entre la construcción de un tambor de mano nativo americano y la geometría quirúrgica

Resumen: Este artículo se centra en la construcción de un tambor de mano por un fabricante de tambor nativo americano y en la construcción de una anastomosis por un cirujano cardiovascular torácico. Ninguna de las actividades ocurrió con instrucciones o ilustraciones escritas. Cada construcción ocurrió a través de su capacidad para mover imágenes y procedimientos mentales en la punta de los dedos con la utilización del raciocinio visuoespacial (Owens, 2015). Para el fabricante del tambor, el aprendizaje ocurrió por medio de la orientación, la observación y la práctica. Cada uno de ellos, el fabricante del tambor y el cirujano, desarrolló ricas habilidades de raciocinio espacial basadas en relaciones. Para el fabricante de tambor, las relaciones tienen que ver con la geometría del tambor y sus componentes, así como las relaciones de geometría quirúrgica existen en la sala de operación. Para la resistencia del tambor, las tensiones se sienten con la punta de los dedos, la misma experiencia del cirujano. Los paralelos se destacan entre estas actividades aparentemente no relacionadas con la discusión de posibles implicaciones para la Educación Matemática.

Palabras clave: Etnomatemática. Construyendo Tambores. Ética, Ética. Raciocinio Visuoespacial.

1 Introduction

In 2006, Shockey wrote about the Ethnomathematics of left ventricle reduction. Since that time he has worked with a Penobscot drum maker, Mitchell, and recognized that there are parallels between *surgical geometry* and the making of a drum. Our research question is: What are the similarities between the creation of a Native American hand drum and the creation of an anastomosis[1]? This paper uses the tenets of visuospatial reasoning (Owens, 2015) to explore these similarities. We argue that each described activity had its own Ethnomathematics (D'Ambrosio, 1985) and that the drum maker and surgeon belong to a respective culture, as defined by Gilsdorf (2012), who defined culture: "When a collection of people follow a similar trend in assigning meanings and beliefs, they have what anthropologists call a culture" (p. 4). For our purposes, the drum maker and the surgeon are members of two cultures, the drum maker is a member of a Native American culture and the surgeon is a member of a professional culture.

2 Literature review

Owens (2015) suggests that visuospatial reasoning, while having important pedagogical implications, is also a framework for understanding phenomena. Two phenomena are considered here, the making of a Penobscot hand drum, and the creation of an anastomosis. Each of these activities is performed through visuospatial reasoning (Owens, 2015). The maker of the hand drum went through an apprenticeship model of learning (Lave & Wenger, 1991) as did the surgeon. The hand drum maker was educated through Native pedagogy and the surgeon through Western pedagogy. In defining Ethnomathematics D'Ambrosio (1985) includes the codes and jargons of particular groups, the codes and jargons differ for the drum maker and the surgeon. While each may speak differently about their actions, each uses his eyes to measure, not necessarily using

[1] Anastomosis is the surgical joining of two vessels, see Figure 1.

standard units of measure. Each has a mental representation of their respective outcome and is able to transfer their mental images to their fingertips.

Many times parallels are recognized in the practices of individuals working in very different domains. This story is framed under the auspices of Ethnomathematics. When D'Ambrosio coined the phrase in 1985 he included in his definition the codes and jargons used by groups. Shockey (1999) stated:

> Mathematical ideas embedded within cultural activities are often not recognized as mathematics by the Indigenous cultural population. There are three reasons for this: (1) these are cultural activities developed to pass information from generation to generation, (2) most of the Indigenous cultures explored through ethnomathematics do not have a formal writing system, and thus lack a formal mathematics, and (3) the mathematics embedded in cultural activities do not resemble formal mathematics. The mathematical researcher in search of such cultural activities that can be mathematized is akin to the archeologist uncovering artifacts (p. 14).

Davison's (2002), a pioneering ethnomathematics researcher, work with Native American students found that while he recognized Mathematics within cultural activities, this was not the case for the Native students with which he worked. In his interviews Davison found that the students "did not regard the cultural activities as intrinsically mathematical" (p. 19).

3 Visuospatial Reasoning

"Visuospatial reasoning is the mental process of forming images and concepts and mentally modifying and analyzing these visual images" (Owens 2015, p. 8). Both the surgeon and drum maker rely on their personally developed visuospatial reasoning. With respect to the education of each Owen's (2015) ecocultural education theory is relevant because

> the notion of ecocultural education implies a place-based experiential education in which the learners construct knowledge, skills, and values from making meaning from direct experiences in their ecocultural places through the learning cycle of reflection, critical analysis, and synthesis. Conceptualization of that place in terms of beliefs, values, taken-as-shared understandings, and language representations are embedded in meanings about space and geometry and of necessity are associated with that place (OWENS, 2015, p. 12).

For these seemingly unrelated activities of drum making and construction of an anastomosis, each activity functions in the capacity as described by author (1999) previously. First, each activity passes information to the next generation of drum maker or surgeon respectively when this next generation is observing. Second, while formal written systems for making a hand drum are not employed, and while a medical student would read about the construction of an anastomosis, neither activity has a formal western Mathematics associated with it and neither activity occurs with a written set of "instructions" being read while the activity occurs. Finally, mathematical practices embedded in these two activities do not resemble formal, western Mathematics. Each of these activities uses measurement, approximation, spatial reasoning, and some tenets of three-dimensional geometry. We use the language of western Mathematics, or the etic view (Pike, 1967) is employed as a technique for engaging the reader. According to Gilsdorf (2012):

> Writing about the topic of cultural mathematics for readers with backgrounds primarily in Western mathematics western mathematics brings one to a dilemma: on one hand, using Western terminology and notation to describe mathematics of non-western cultures is inherently inaccurate because people in such cultures would not think of the mathematical content in the same was as it is perceived in Western culture. On the other hand, if the goal is for people of Western backgrounds to understand how cultural activities can be understood as mathematics, then one must speak to readers in familiar mathematical terms. (p. xii)

Neither the drum maker nor the surgeon thought of their actions as related to Mathematics.

4 Methodology

All four sessions of the creation of the hand drum by Mitchell were video recorded. During these sessions interviews was conducted by Shockey. These interviews may be considered semi-structured as Shockey did not have an anticipatory set of understanding of what it meant to make a drum. Mitchell talked through his work as he created the drum which allowed for discussion to occur. All sessions were transcribed verbatim. In Shockey's dissertation work, he spend months in operating rooms observing surgical procedures. During these times in the operating rooms written field notes were created. These field notes were the foundation for recorded interviews that occurred outside of the operating room. All of the interviews were transcribed verbatim.

Contributions

This research attempts to establish relationships of Ethnomathematics between the construction of a Native American hand drum and the thoracic cardiovascular creation of an anastomosis. Both of these activities rely on visuospatial reasoning that rely on understandings of geometry and spatial reasoning.

Surgical Mathematics

Author (1999) found that the group of thoracic cardiovascular surgeons he studied relied on various calculated values and measurements to provide information about aspects of quantity, space, and chance related to heart functions, but these surgeons did not perform procedural Mathematics. Surgical geometry is the most critical aspect of these cardiovascular surgeons' Ethnomathematics.

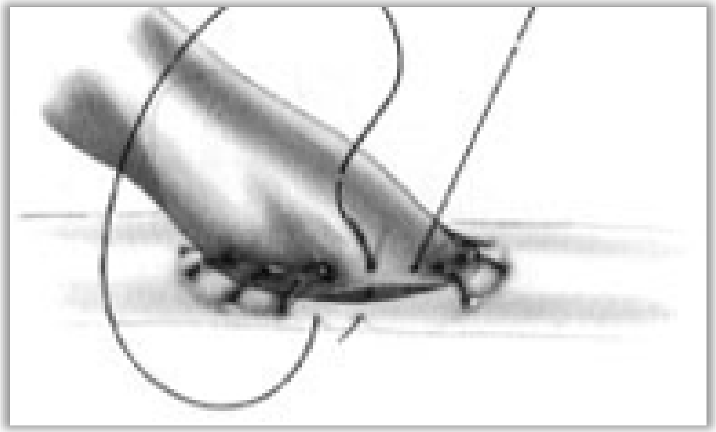

Figure 1: End to Side Anastomosis (KHONSARI & SINTEK, 1988)

According to Shockey (2006, p. 4) "surgical geometry is the most critical aspect of these TCV surgeons' ethnomathematics."

> The term "surgical geometry" was introduced to me when I was requesting permission for entry to the hospital. "Surgical geometry" (Rosa, personal communication, suggest this may be "ethnogeometry") is a surgeon's language to sum up the surgical procedure of a creating an anastomosis: "We want to create [the anastomosis, see Figure 1] so it does three things: one, doesn't leak, two, stays open, and three, it's formation will create a hood." The end of the vein being sewn into an artery has to be "about one and a half to two times bigger than the artery." The surgeon continued, "length width, and diameter are measured with our eyes, then we put the stitches in to create that appearance. (Surgeon, phone interview, day 8). This is the key element of TCV, "that's the whole thing here." The initial definition was restricted to coronary artery bypass anastomosis, and end-to-side anastomosis but also came to include end-to-end anastomosis and re-shaping of the left ventricle during left-ventricle reduction surgery. (AUTHOR, 2006, p. 4)

The thoracic cardiovascular surgeon, at the time of the study, was the chief surgeon in an academic hospital setting. He was responsible, as part of the medical school faculty, to pass information on to the next generation of surgeons that were residents in his program.

For Mitchell, the knowledge he held was passed on to him from previous generations of drum makers and he teaches tribal members his learned skills in drum making, an ecocultural education. There is no formal writing system for Mitchell, his knowledge is passed on through his oral traditions. It was challenging for Shockey throughout the data collection to not impose his etic views as a western trained mathematics educator. As stated by Rosa and Orey (2016) "when researchers investigate mathematical knowledge developed by the members of distinct cultural groups, they may be able to find distinctive characteristics of mathematical ideas and procedures these members developed throughout history" (p. 198). Finding the "distinct characteristics" was only achievable by Shockey through his etic view. While there is a tremendous amount of writing about thoracic cardiovascular surgery, when a resident is standing next to the chief in the operating room, the learning occurs through the spoken word at the operating table, observation, and mental recall by the resident that is recall of learned material away from the operating table. As a mathematical education researcher, what the author recognizes as Mathematics is often not recognized as such, in this case by either Mitchell or the surgeon.

According to Shockey (1999) the surgeons did not "see" mathematics in their procedures.

> It is probably an easy out to remark that everything is mathematics. The reality is that mathematics pervades much of what is done in the world and the task for the interested is to seek out this mathematics. While I was being introduced to thoracic cardiovascular surgery within the first week I realized that my perception of mathematics and the surgeons' perceptions of mathematics were different with respect to scope. Specifically, mathematics for me is much more than what is taught in the classroom and it was my impression that the mathematics perception of this group is limited to their past classroom experiences.
>
> I received numerous comments such as " We 'don't use mathematics," "there is some mathematics for you, how many questions do I have to ask a resident to get the truth," "how many times does the resident have to count these sutures to get fricking fifteen," and "the Blair index, the ratio of sandwiches eaten per patient seen".
>
> Comments like these occurred during the entire study. The belief structure of these surgeons seemed to focus on mathematics being confined to the classroom. Gradually the participants began to sense their uses of mathematics, but never quite let go of initial thoughts. (FIELDNOTES & AUTHOR, 1999)

When Mitchell is making a drum, he does not perceive his practice as mathematical, just as the surgeons felt Mathematics was the event that occurred in the confines of a classroom, so did Mitchell.

In both of the cases cited, neither activity relies on the Mathematics that is taught in classrooms. The drum maker and the surgeon rely on their respective codes and jargons (D'Ambrosio, 1985). Their respective codes and jargons are elements of their respective emic knowledges (Rosa & Orey, 2016). According to Rosa and Orey (2016) the emic knowledge is the local knowledge that allows "for an intuitive and empathic understanding of mathematical ideas, procedures, and practices developed by the members of distinct cultural groups" (p. 196). The surgeon and Mitchell each rely on their emic (Pike, 1967) perspective. The linguist Pike (1967) defined emic and etic. Emic refers to the insiders view and etic refers to the outsiders view. Shockey is the outsider in drum making and surgery.

Pike (1967) states that "emic systems and emic units of these systems are in some sense to be discovered by the analyst, not created by him" (p. 64). For the purpose of our research, etic systems are the language of Western Mathematics. The codes and jargons of Western Mathematics are not necessarily congruent [etic] to that of surgery or drum making. As Gilsdorf (2012) reminded us earlier, contributing to Mathematics Education scholarship requires a language for the audience.

Pike (1967) reminds us of his intent; "The etic approach treats all cultures or languages – or a selected group of them – at one time. The emic approach is, on the contrary, culturally specific, applied to one language or culture at a time" (p. 37). The emic perspective is brought forward for comparison purposes. As will be shown below, while Pike tells us that the emic units must be discovered, that can be a challenge when the observer only has the codes and jargons of Western Mathematics to talk about his observations. According to Pike, "Etic units, within this point of view, would vary: insofar as they approached the emic units of a system, they would be discovered within that data" (p. 55-56).

Knowledge

Each individual, drum maker or surgeon, relies on his conceptual understanding of his respective activity. Hiebert and Lefevre (1986) state that conceptual knowledge

> is characterized most clearly as knowledge that is rich in relationships. It can be thought of as a connected web of knowledge, a network in which the linking relationships are as prominent as the discrete pieces of information. Relations pervade the individual facts and propositions so that all pieces of information are linked to some network. In fact, a unit of conceptual knowledge cannot be an isolated piece of information; by definition it is a part of conceptual knowledge only if the holder recognizes its relationship to other pieces of information (p. 3-4).

As the reader will note, each of the stories below involve tacit knowledge, but in the case of the surgeon, his tacit knowledge is verified with sophisticated medical technology. The surgeons' tacit knowledge is verifiable through his academic preparation, which includes understanding medical equipment as well as the role of others in the operating suite during a surgical procedure. Mitchell tacit knowledge is not verifiable with such an apparatus, but through his traditional preparation as a drum maker, an ecocultural education.

Data Collection

During four video taped sessions Mitchell engaged author in a conversation about making a sixteen-inch (diameter) hand drum from the torn drum head of a larger drum. Author, a western trained mathematics educator, and Mitchell, a member of the Penobscot nation, were frequently using the language of their particular backgrounds. Shockey's etic view and Mitcell's emic view sometimes overlapped. All of the videos were transcribed verbatim. It was during these episodes that Author began to recognize parallels to his previous research as an observer of thoracic cardiovascular surgery. In that research Author spent three months in surgical suites observing procedures. During that research field notes were taken by hand in the operating rooms and interviews were conducted using an audio recorder. All of those recordings were transcribed verbatim.

The Drum Maker

At the time of the observation of a drum being made, Author was focused upon the etic perspective, as a western trained mathematics educator, he had no other perspective. Years later, revisiting the episodes, and having gained an understanding of emic perspectives, there is yet another perspective that emerges, Native pedagogy. As Mitchell was constructing the drum, he was "teaching" as is highlighted below in the analysis. Even the moment described in detail below when the surgeon was holding a patients' aorta and engaged his support personnel that the numbers flashing through the technology were wrong, was a teaching moment.

Preparing to make a drum begins with soaking the hide so it is flexible enough to be stretched across a drum ring. "This is an old drum head that I'm recycling, it's going to be for a 16 inch." When asked if this value represented the diameter of the circular drum ring, the maker holds up the drum ring with a finger on opposite edges where a diameter could cross and responds "yeah." With the wet hide resting on a tabletop, "what I'm going to do is, I'm going to pretty much try and center this," a reference to centering the drum ring on the hide.

Inadvertently introducing diameter, turned the focus for Mitchell to attempting to describe what he was doing through this etic lens, not his emic perspective, "we need to cut it, needs to have twelve flaps, what does that mean, well basically we need to have space to … I guess I can't explain it right now." The conflict of academic language of diameter does not allow the emic to come forth from Mitchell. The codes and jargons of western Mathematics, is not the language used when he learned to make drums. To impose this on him now and not allow his emic perspective with his language of a drum maker potentially divorces the activity from its intent.

With the drum ring centered on the wet hide, it was immediately apparent that he was engaging his visuospatial reasoning with respect to position. The reason a drum was being recycled was due to it tearing. The older drum was a larger and was being recycled down to a sixteen-inch drum. The position of the tear was an important consideration in placing the new ring, Mitchell did not want the new drum to have a tear, so positioning the ring such that one of the flaps would occur by the old tear was critical, (see Figure 2).

Figure 2: 12 Flaps on the Back of the Drum (SHOCKEY, 2006)

The tear in the old drumhead became an edge for one of the flaps. With a knife, Mitchell scratched the hide around the edge of the drum ring. He then positioned twelve paper clips such that they were evenly spaced around the drum ring circumference (etic). The tendency for the mathematics educator is to impose Mathematics and first determine how close the knots are to the center of the drum ring, (see Figure 3).

Euclidean geometry tells us that a perpendicular bisector of a chord contains that circle's diameter. In Figure 2 the perpendicular bisector of AB and DE are very close to the center, considering this was measured with Mitchell's eyes, it is spot on. Mitchell's visuospatial reasoning aligns with Euclidean geometry students would experience in school.

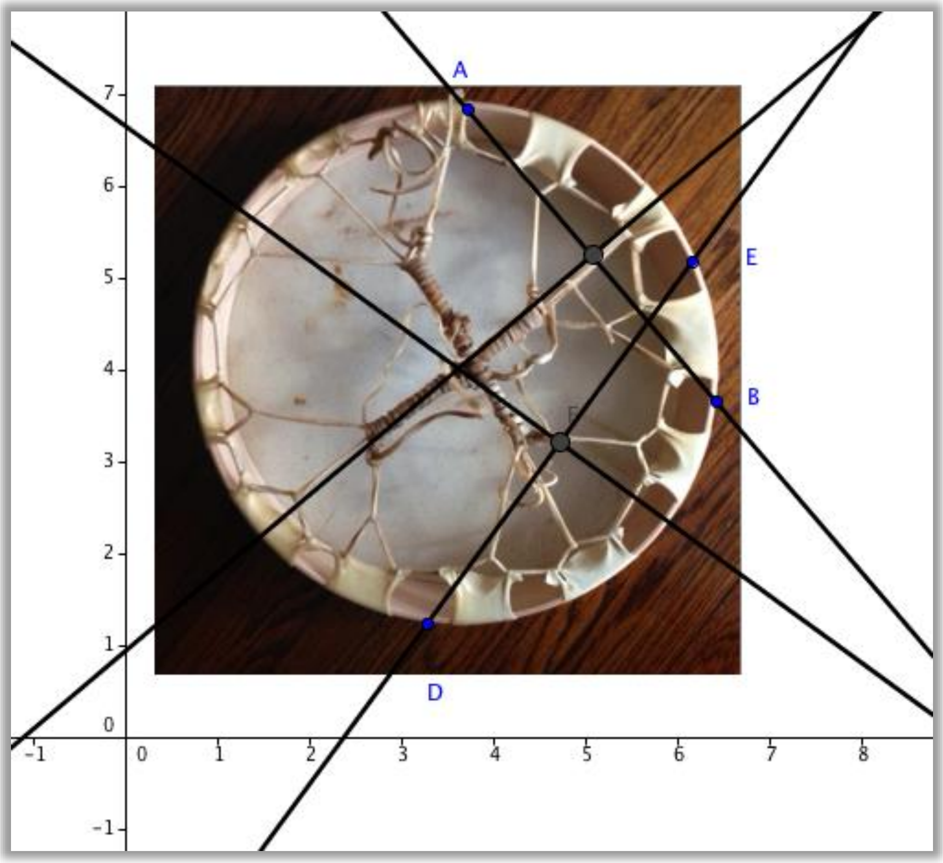

Figure 3 Center of Drum Ring (SHOCKEY, 2006)

Considering the measure of the central angles, (see Figure 4), for the respective measures was authors perspective. The visuospatial reasoning of recycling a larger drumhead down to a sixteen-inch drumhead with no "formal" measurement (i.e. ruler) is rich in relationships. While this paper focuses upon Ethnomathematics and the etic, emic perspectives, there is a loss in oversimplifying the drum to language of Western Mathematics. As Doolittle (2006) stated, a tipi is not a cone.

> Ethnomathematics is far more reflective and respectful to Indigenous traditions of thought than the simpler reflex to help Indians at improving their outcomes on standardized tests. However, the danger of oversimplification remains, perhaps more insidious because the motives are put forward as purer. And example of such oversimplification which I have encountered repeatedly in discussions with well-meaning people I call Cone on the Range. "The tipi is a cone," I have heard countless times. But that is surely wrong; the tipi is not a cone. Just look at the tipi with open eyes. It bulges here, sinks in there, has holes for people and smoke and bugs to pass, a floor made of dirt and grass, various smells and sounds and textures. There is a body of tradition and ceremony attached to the tipi which is completely different from and rivals the cone. (DOOLITTLE, 2006, p. 20)

The drum has texture, it has a story, and for the larger drum now becoming a smaller drum, a new story begins. This story of the relations that existed for the larger drum exists.

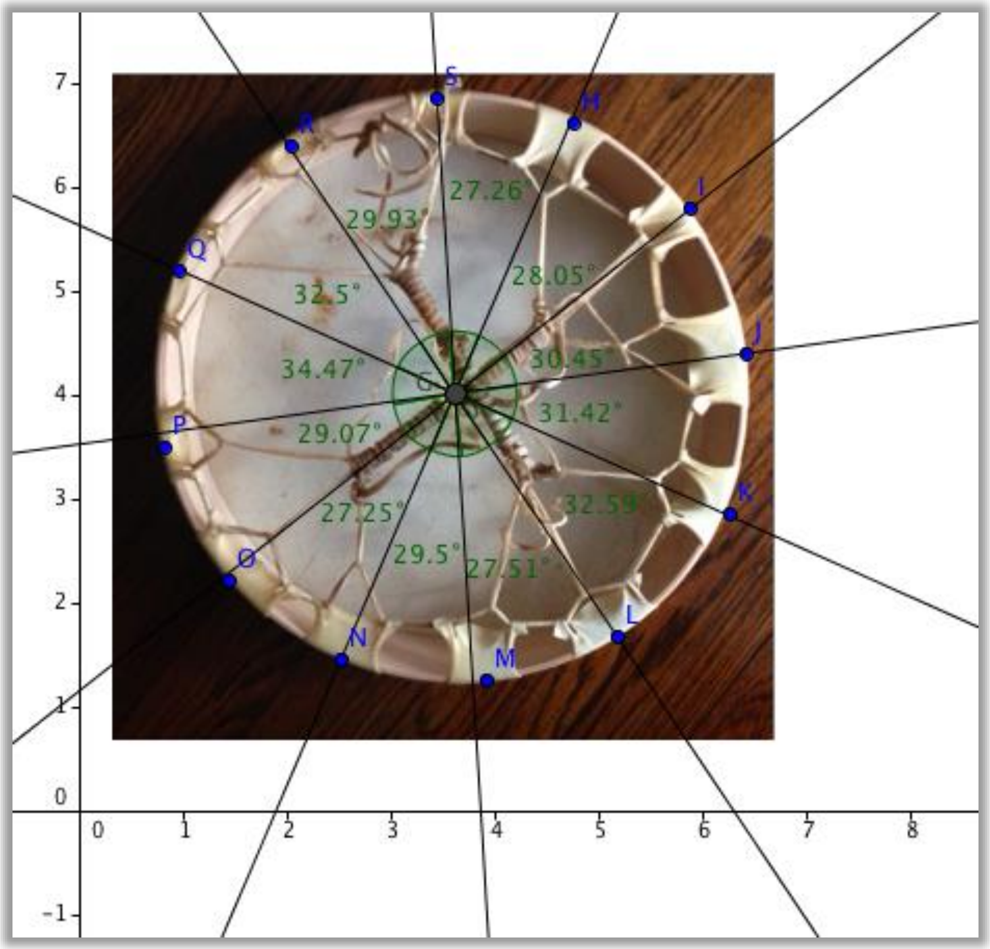

Figure 4: Central Angle Measures (SHOCKEY, 2006)

There was never a discussion or verbal consideration for margin of error. In this example of making a drum it is not appropriate. The visual measurement of Mitchell is remarkable. A keen observer recognizes that if a school unit on central angles in a Native school using a hand drum in the Mathematics curriculum has the potential to "deepen students' knowledge" (Bassanezi ,1994, p. 31).

As the observer/interviewer, the choice of twelve was a curiosity. From the field notes (I is the interviewer and DM is Mitchell):

I: Why twelve?

DM: cause we need twelve flaps.

I: Why twelve?

DM: you'll have to wait and see because I don't know how to explain it [this was frequently an element of our conversations. When Mitchell was sharing how he did things, he framed my questions as that of a mathematics teacher wanting to know how he got a solution, not too concerned with the solution. "It just is" was a recurring theme throughout, in hindsight, this goes back to the diameter remark made earlier in that Mitchell felt he needed to use the language of western mathematics in his response.]

The twelve flaps had to do with "it's the tension, it gives you equal amounts of tension." Mitchell remark about equal tension situates his making of a drum to what Mount Pleasant Jette (personal communication) coined as "Ancestral engineering." As shown in Figure 5, the Mathematics Education perspective that the twelve flaps were determined by the central angles was wrong. The twelve flaps were equi-spaced about the circumference based on visual arc length measurement done by Mitchell. Using Pike's (1967) concepts of emic and etic, the incorrect interpretation by Shockey, using the etic view of Western Mathematics is not always the correct lens to view activities. While Mitchell emic view of "equi-spaced" translates to Shockey using arc lengths, this too imposes the etic perspective of the language of Western Mathematics.

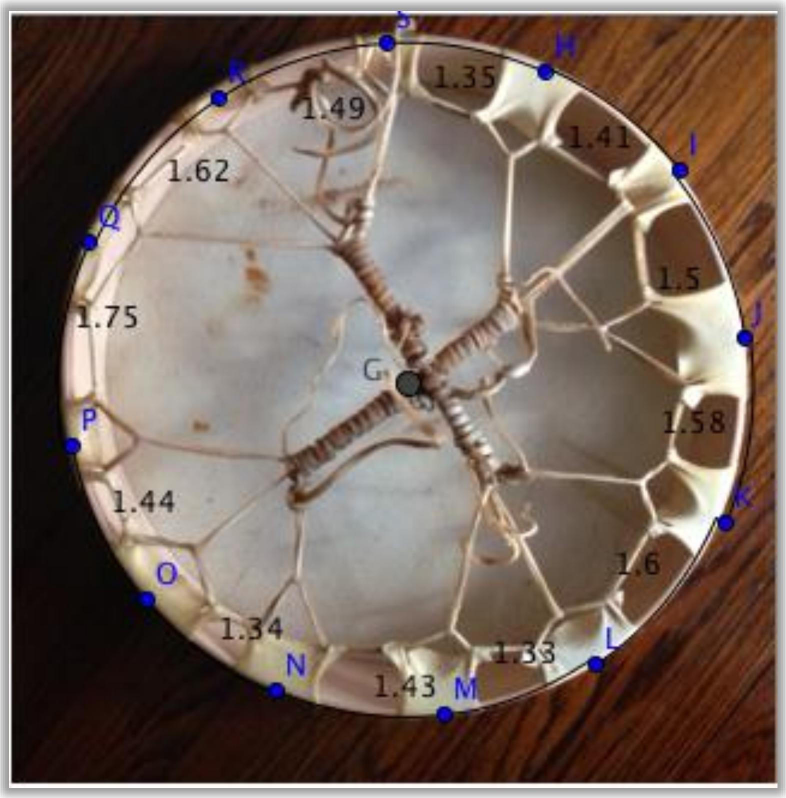

Figure 5: Arc Lengths Measured with the Eye of by Mitchell (SHOCKEY, 2006)

With respect to the arc lengths, Mitchell stated:

> Just kind of eye balling, want every paperclip to be about the same distance apart and it doesn't have to be exact. Then what I'm going to do, each one of these paperclips is going to represent one of my flaps that are going over the drum. Then from the center of my hoop, I don't know about an inch, I want to make V's.

For the surgeons in the operating room, a frequent remark was "don't let perfection be the enemy of good" (Field notes). The surgeon understands what the outcome needs to be and that he does not have the advantage of time. He needs to perform the surgery in a timely fashion, as there are consequences for the patient under anesthesia too long. The making of a drum takes a tremendous amount of time. There are days involved through the process of soaking the hides, creating the drum, and then allowing the drum to dry. The material the drum is made from has imperfections, so perfection while desirable, should not get in the way of good.

The V is a reference to the shape of the hide that will be cutout between flaps. The one-inch reference was not from the center, but from the edge of the hoop. The notion of "it doesn't have to be exact" was obvious in the cutting of the V's from the hide. Mitchell had used a knife to scratch the V's around the circumference, but the reality was these were visual aides, not necessarily the actual V shapes that were to be cut out.

> So I'm just cutting these out and I'm totally, obviously not going exactly by my scratch because I'm trying to make up for … the first flap I cut out is pretty much the guiding one. As far as that goes so I can work my way out from this even though it's going to contradict my other marks.

As he was cutting the V's, he realized that the hide was not as wet as it needed to be: "This flap came out a little short but once it's soaked that'll put a half an inch stretch on it." The visualization of the "half and inch stretch" was not able to be articulated. It is fair to say that after years of making drums this artist recognized how hides stretch and what he can expect. Shockey (2006) writing about left ventricle reduction, "How much of the ventricle we out was certainly not very quantitative. I mean, we had heard that the advice is that you take out as much as you can bear, and then take out some more" (p. 2). These two examples amplify how precision is not always achievable with respect to a predetermined value.

The flaps, how they are cut out, and then lay over the edge of the drum ring impact the drum's sound quality. "Pretty even so far as angles go, when they flip over onto the drum, if it is too close then they take away from some of the sound," see Figure 6 for image sketched in field notes.

Figure 6: Flap Illustration for Fieldnotes (SHOCKEY, 2006)

The right hand image in Figure 6, Mitchell remarks "too close together, they come together like one piece…don't want them to do that and when we string this you'll see why" deserves a comment. First, Shockey was observing the creation of a drum for the first time in his life and second the idea that he would "see" after the drumhead was strung is not a reality. It is a reality for

Mitchell, as he sees this drum mentally through all the stages of its creation and has a vision for the final drum that he striving toward. These spatial renderings do not exist for Shockey.

The reader, looking at Figure 5 may recognize that the flaps are not uniform in size, Mitchell stated; “notice our flaps, obviously they’re all different sizes, it does not make a difference.” The difference, a reference that includes that final sound of the drum, is impacted by the flap placement, not dimension. While we consider visuospatial reasoning as the mental manipulation of something real, in this case a drum, Mitchell visuospatial reasoning is also related to the abstract sound quality of the drum. The visuospatial reasoning of the surgeon is similar as he has in his mind’s eye the sound of the human heart beating naturally. With this phase of the drumhead completed, Mitchell turns his attention to the needed rawhide string that will hold the drumhead to the drum ring.

Mitchell reached into the water bucket that was holding the raw hides that were soaking. The effect of soaking allowed the leather to be more pliable, allowing it to stretch, such that when the leather dried it would shrink and tighten up. This tightening process was important for the drumhead as well as the rawhide string holding it in place. All of these interacting parts contributed to the final sound of the drum. The visuospatial reasoning can be thought of as cyclic. The dry, torn drumhead from the larger drum is soaked to complete absorption. This drumhead then is now positioned on a new drum ring, being recycled down to a sixteen-inch drum. This soaked hide is stretched, restrung, and allowed to dry, all the while Mitchell is able to “hear” the sound of the new drum, just as he had heard the sound of the large drum.

“To make that one piece of string…it’s going to probably be thirty feet when I’m done” a reference made to a piece of rawhide that in his mind he had determined it’s approximate final length based on his cutting technique. Figure 7 is a sketch from the field notes of the rawhide shape that would be used for the strings.

Figure 7: Rawhide sketch for strings from field notes (SHOCKEY, 2006)

Mitchell mental strategy to arrive at the approximation of “thirty feet” of string (enough for two drums he later stated) was based on trimming the shape shown in Figure 7 to the shape show in Figure 8. This mental calculation took into account these edges that would have made cutting the string too difficult, notice the points in Figure 7 are removed.

Figure 8: Trimmed rawhide for strings (SHOCKEY, 2006)

The continuous cutting of the string from the rawhide shape shown in Figure 8 began around the shape's perimeter. The width of the string was approximately a quarter of an inch, another piece of the mental calculation to get the thirty-foot length of string. The emic perspective of Mitchell was restated for the benefit of Shockey's etic perspective. This was the first occurrence by Mitchell to discuss the creation of this drum in the language of standard units. Recall that he is making a "sixteen" which Shockey attached the language of inches and diameter to when the story began.

As a side note, there was a tremendous amount of humor occurring during the observations of the drum making. After another twenty-four hour period to allow the drum head and the string to soak, the drum making resumed. [I: Interviewer, DM: Drum Maker].

> DM: So this is the sinew that makes canoe seats or snowshoes.
>
> I: With the blue scissors.
>
> DM: No, actually for snowshoes you need green ones.
>
> I: Oh [Mitchell tone was serious, Shockey not understanding just went along with the idea that the color of the handles on a pair of scissors, green versus blue, may be important].
>
> DM: I know that sound contradictory cause it's snow.
>
> I: Okay [Again, Shockey has no idea of why green scissors are contradictory with respect to snow].
>
> DM: Because this drum I'm making right now is going to be playing a lot of the blues and therefore the scissors really make a difference.

While Mitchell was cutting the string needed for the drum, he and Shockey discussed his learning of drum making. This dialogue is included for the potential pedagogical implications, discussed later in the paper.

> I: Was there a lot of talking, do you remember, when he was showing you how to make a drum?
>
> DM: No, because there's not much to say…once you know how to make the twelve flaps and I don't really know why twelve flaps on a drum, then you make two holes and you get twenty-four points when you string these drums together. When you're putting tension on twenty-four points of a drum that's sixteen inches in diameter … it's going to make different sounds but the tensions all are going to be the same, so that's pretty much what I had to learn.

As Mitchell is sharing his learning experience he is focused on cutting the string, “any thicker than this is going to be way too thick any thinner might be too thin, cause this is going to stretch.” If the rawhide is too thin, during the stretching process of securing the drumhead, the string could break. During the stringing of the drum, the stretching of the raw hide results in; “when you start putting the string on you get another six to eight inches per every maybe three feet.” An etic perspective on this stretching, six inches per every three feet is about 16 2/3 % and an eight-inch stretch is about a 22% increase in length. It is worth noting that during the second episode, after the materials soaked in water another twenty-four hours, Mitchell jargon switched to the language of Western Mathematics for the benefit of Shockey who had no previous experience with the creation of a drum.

With all the needed materials, Mitchell began stringing the drum together. In comparing the construction of a hand drum to a large drum that a group of singers would sit around, “the stringing process is different, you can still feel it when you know you have enough tension on it.” This act of “feel” is the intersection with surgical geometry. Surgeons “feel” the tension of the sutures and have to be careful not to place too much tension. “Feel” is quantitative jargon of the drum maker, not measured with a metric or unit of measure as could be expected from a Western perspective.

> Because you’ve got to know when to stop putting too much tension on it when you’re tightening up a drum. Too much tension on it, then it dries, it might be so much it rips.

If the tension of sutures around an anastomosis are not correct, when blood flow moves through, the sutures could fail, a disastrous outcome as in the drum, but the ripping of a drum head has a potentially different outcome than that of a torn coronary artery bypass graft.

> The drumhead opens as it’s drying, you don’t want it to do that. You want it to have time to cure slow, slowly, and also you want it to try and cure at the right tension and I don’t know how to explain it. But when we do string a drum I can just feel if I’ve got enough on it or not or too much. And there’s a way that we string these that we can add or take away tension while working on it and that’s the only time we can do it. So if you don’t know how to guesstimate the tension then you’re probably going to be too tight or too loose, or lucky.

5 Visuospatial reasoning

During the making of the drum, Mitchell was constantly making mental estimates, creating mental models, reducing a previously large drum head down to a sixteen, all while considering how the new drum will sound. The experience of an observer interested in the process through an Ethnomathematics lens, while novel, was new. Questions that were posed during the process were frequently responded to ‘it just is.’ In his mind Mitchell model was moving from a large drum to a sixteen and he had a mind's eye view of each step, leading to the sound of the new drum. This is very similar to a thoracic cardiovascular surgeon who's outcome is for the sound of the human beating heart.

In Shockey's (1999) unpublished dissertation there were many instances of a surgeon getting a mental image to translate through his fingertips into a "surgical geometry." The observed procedures included heart transplantation, carotid endarterectomy, left-ventricle reduction and coronary artery bypass grafts. Each of these procedures required consideration of equi-spaced sutures, attention to pressures felt with the fingertip of the surgeon (which he oftentimes would look to the technology to affirm that what he felt matched the shown numerical value), pressures after blood was re-introduced into a vessel, and how the final product would perform when a patient was off bypass.

The Surgeon

Shockey (1999) writes:

> In the operating room when something goes bad the attending no longer relies the assistants performing their tasks without his intervention. This became apparent only once during my observations while the attending was holding the patient's aorta and his intuition told him the monitor was reporting the wrong blood pressure.
>
> As the attending was holding the aorta and checking the heart he was quick to state that the pressure on the monitor was wrong, "way wrong." The tone of his voice rang of immediate danger for the patient, I completely removed myself from the proximity of the procedure as the attending was demanding more pressure. Physically I felt my heart race and chest swell, it didn't sound good for this patient. 'I know you guys are reading his pressure is one forty [the attending was looking at the surgical monitor] I'm telling you it is no where near that, give me some pressure.' Immediately the anesthesiologist was instructed to look at the patients' face, 'he looks fine.' The circulating nurse now got involved as the attending stepped away from the operating table, removed his outer layer of gloves, requested a flashlight and stuck his head under the surgical drapes to personally inspect the patients face. I was really getting anxious and worried that this was going south. The perfusionist was reacting to the situation, the attending had now removed his sterile gown, appeared perplexed, and then the monitor pressure reading changed drastically to "58" over something. This immediately explained an occurrence during the surgery that the attending and fellow simultaneously recognized. Within three minutes there were three anesthesiologists at the head of the table. The attending requested administration of a pharmaceutical and asked if the calcium had been given. The anesthesiologists quickly administered the calcium. The patient was on a pacemaker at this point. The attending requested the pacemaker be shut off then waited to see what the patient's heart rate was. The rate dropped from 100 to the upper fifties, the attending was satisfied and the fellow initiated closure.

The visuospatial reasoning of this surgeon included the ability to understand the "feel" of pressure and to physically judge pressure on his fingertips to that of the illuminated technology values shown on the monitors above the sterile zone.

6 Discussion

Zaslavsky (1994), talking about her correspondence with O. F. Raum (author of Arithmetic in Africa, 1938), who taught at Fort Hare University, in modern day Tanzania, "He stated that good teaching "lays down the importance of understanding the cultural background of the pupil and relating the teaching in school to it" (Raum, 1938, p. 5 *apud* Zaslavsky, 1994, p. 4).

Shockey (2006) stated: "For these surgeons "the eye" did their measuring" (p. 3). This aligns with the construction of the drum described above. Shockey (2006) introduced the role of technology and its importance in thoracic cardiovascular surgery.

> The context of these thoracic cardiovascular surgeons demands accurate measurements often to the nearest hundredth, calculated by technology. These thoracic cardiovascular surgeons use precise surgical instruments to estimate inside diameter of blood vessels and rely on medical technologists to provide accurate, precise technologically computed values associated with quantity and space as it relates to the human heart. (p. 3)

Technology of the nature for the surgeons is not employed in the construction of a drum. The drum maker measures with his eye, having the cognitive ability to "move" his mental image to his fingertips to create the necessary components of the drum.

> Many of the surgical observations presented in follow-up interviews within a mathematical context, for example quantifying an anastomotic site (an anastomotic site is the location where two blood vessels are sutured together) for the placement of sutures, had not been thought of by these surgeons to be mathematics. Mathematics for this group of surgeons was confined to their past classroom experiences as students enduring a lecture in calculus or statistics. (SHOCKEY, 2006, p. 2)

The anastomotic site for the surgeons is an example of their "surgical geometry" (SHOCKEY, 2006, p. 4). An interesting comparison between the creation of an anastomosis and a drum, whether surgeon or drum maker, each is thinking beyond the immediacy of their effort, to the final outcome. In the case of an anastomosis, a surgeon must place sutures accurately and firmly such that when blood is released into the vessel the sutures will hold the pressure. The surgeon also constructs an anastomotic hood. The purpose of this hood is to allow space for scar tissue, which will develop, such that the scar tissue does not impede later blood flow. The drum maker is thinking beyond the wet hide stretched over the drum ring. He is thinking about how the wet rawhide will dry and the tensions that will be created. The tensions cannot be so great as to tear the drumhead or the flaps overlapping the ring. The tensions cannot be so great that the knots will break during the drying process. An interesting contrary item for the two groups is time.

The surgeon needs to be efficient and complete the procedure “quickly.” As Shockey (2006) observed: “These thoracic cardiovascular surgeons were fast problem solvers, for obvious reasons. They did not have the luxury of analyzing and re-analyzing patient results, as the consequence could be dire, death” (p. 3). The drum maker has the luxury of time on his side. Working with the wet hide, adjusting and re-adjusting tensions on the drum, analyzing the placement of the drum hear were all observed elements. As remarked above, the drum has to ‘cure slowly.’

7 Closing

The writing of this manuscript is not meant to trivialize the importance of thoracic cardiovascular surgery or drum making in Native communities. The intent is to bring to the forefront activities that many of us experience that through an ethnomathematical lens, can be described with the language of Western Mathematics. The visuospatial reasoning can serve as an important pedagogical tool for educators working with Native learners, if the educator is willing to “learn with them.”

> To appreciate the human resources, explore and develop teachers’ and students’ skills, making them feel able to give the community their contribution and form socially active individuals. In other words try to follow Morley’s proposal: “Join your people and love them. Learn with them, plan with them and serve them. Start with what they already know. Build and teach them with what they have.” Teaching should deepen students’ knowledge, and for that they must be motivated to face mathematics not only as a science for its own sake but as an instrument for the understanding and possible modification of reality (BASSANEZI, 1994, p. 31).

Utilizing Owens (2015) ecocultural education theory may be an important lens to consider experiential learning. Both the drum maker and the surgeon participate in the cycle that Owens describes as “reflection, critical analysis, and synthesis” (p. 12). Both groups use language representations that are “embedded in meanings about space and geometry” (p. 12) that are element of their codes and jargons (D’Ambrosio, 1985). These understandings may have implications for Native American Mathematics Education and possibly for the surgical education.

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