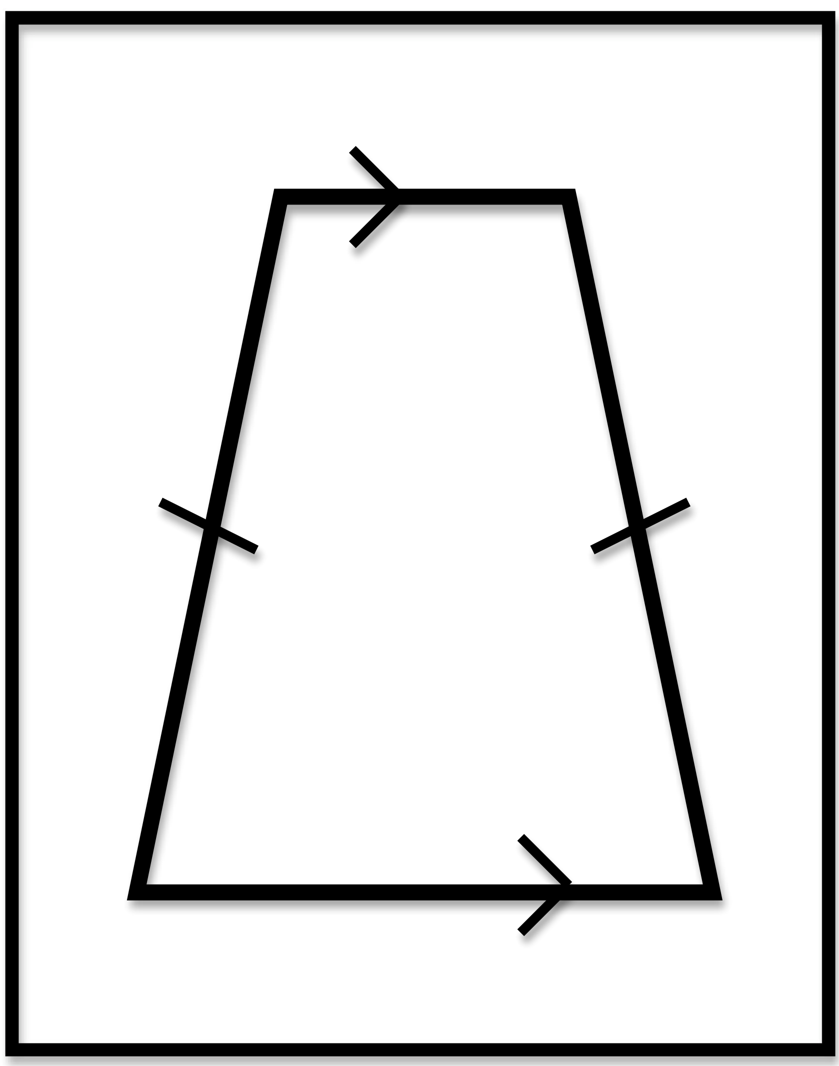
vinculum

Journal of the Saskatchewan Mathematics Teachers' Society
Volume 2, Number 2 (October 2010)

FIRST NATIONS AND MÉTIS CONTENT, PERSPECTIVES, AND WAYS OF KNOWING



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SMTS objectives – as outlined in the January 1979 SMTS Newsletter – include:

1. To improve practice in mathematics by increasing members' knowledge and understanding.
2. To act as a clearinghouse for ideas and as a source of information of trends and new ideas.
3. To furnish recommendations and advice to the STF executive and to its committees on matters affecting mathematics.

vinculum's main objective is to provide a venue for SMTS objectives, as mentioned above, to be met. Given the wide range of parties interested in the teaching and learning of mathematics, we invite submissions for consideration from *any persons interested in the teaching and learning of mathematics*. However, and as always, we encourage Saskatchewan's teachers of mathematics as our main contributors. *vinculum*, which is published twice a year (in April and October) by the Saskatchewan Teachers' Federation, accepts both full-length **Articles** and (a wide range of) shorter **Conversations**. Contributions must be submitted to egan.chernoff@usask.ca by March 1 and September 1 for inclusion in the April and October issues, respectively.

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EDITORIAL: TWO YEARS AND FOUR ISSUES LATER

Egan Chernoff

Recently, I looked back over my first two years as editor of *vinculum*. I would like to take this opportunity and elaborate on some of the trials, tribulations, and triumphs I have encountered and, in doing so, hopefully, help to generate some discussion within the mathematics education community.

In October 2008, as the newly appointed liaison between the University of Saskatchewan and the Saskatchewan Mathematics Teachers' Society (SMTS), I found myself at the society's annual general meeting. During the meeting it was announced that the SMTS was looking for a new editor for their journal. Once the meeting was adjourned, I mentioned, casually, to a few of the individuals I was sitting with (at the back of the room), that I had, at a point prior, thought about the position of editor. (To be honest, what happened next is still sort of a blur.) Unintentionally, and unexpectedly I had volunteered for the position, had been quickly vetted, and, subsequently, right then and there, was appointed the new editor of the journal! I left the meeting an accidental-editor.

In dealing with the task of producing our first issue, I set three goals. First, I wanted to set up an editorial board. After a few emails to particular members of the SMTS, I quickly had an editorial board filled with local individuals heavily invested in the teaching and learning of mathematics. When given the reins of the journal, I was also given the opportunity (if I wanted) to start from scratch. After deliberating for quite some time, I did decide to start over. Starting with (if you will) a blank slate, I spent a great deal of time reading other journals, however, in a much different fashion than I had before. Instead of "reading the articles," my focus turned to which types of sections to include and, for the majority of time, layouts. After finally putting together a structure and layout that I considered aesthetically pleasing and adaptable for subsequent issues, I had but one last task left: getting people to write for our journal.

Although I had been told that, in the past, previous editors had difficulties procuring submissions from members of the SMTS, I was not concerned. After all, I had a back-up plan. Over the past five years, while attending a number of local, provincial, national and international conferences, I consistently received the following message: The mathematics education community (i.e., mathematics educators, mathematicians, mathematics teachers, and other individuals with a vested interest in mathematics education) was a unique collaboration of individuals interested in the teaching and learning of mathematics and, further, mathematics teachers. Having received the message loud and clear, I thought, if I had any difficulties in getting submissions from local members, I would simply rely on the mathematics education community (and their interest in the teaching and learning of mathematics and mathematics teachers) to contribute articles to our journal; if the local mathematics teachers were not going to submit, I would still be able to get submissions from mathematicians, mathematics educators, graduate students, and others.

After putting together the fist call for papers, I excitedly faxed and emailed the call for papers everywhere. I contacted school districts, provincial associations of mathematics teachers, list-serves, mathematical organizations, and mathematics and education departments, colleges, and faculties in a variety of universities and colleges. In short, if you were, at that time, a member of the mathematics education community, I tried to get our call for papers to *you*. All I had to do now was sit back and wait for the submissions to start pouring in.

I waited and waited, to no avail. With the original deadline a thing of the past and only a few submissions from members of the SMTS, I extended the deadline. Further, I sent out special invitations to certain individuals of the mathematics education community who I knew, for sure, were interested in the teaching and learning of mathematics and mathematics teachers. Once again, I sat back and waited for the submissions to start pouring in. Once again, I waited and waited, to no avail. With the extended deadline a thing of the past, we started to scramble. Down, but definitely not out, we rallied. As seen in the author list of our first issue, members of our editorial board stepped up to the plate and wrote some interesting pieces for our first issue. Anecdotally judging from emails we received, our fist issue was a success and definitely of interest to the members of the SMTS. However, and even with the SMTS satisfied, I began feeling a sense remorse.

Even long after our first issue was published, I was unable to shake the fact that there were no submissions from certain members (e.g., post-secondary) of the mathematics education community. As such, I hedged my bet for the second issue (which I'll explain shortly) and decided to focus my time and efforts on explaining, at least to myself, the lack of submissions.

To determine whether or not the low submission rate for our first issue was, perhaps, an isolated incident, I took a similar, yet much more subdued, approach to advertising our second call for papers. For example, placed on the inside of the back cover of our first issue was the call for papers for our second issue, which meant that members of the SMTS had been notified well in advance of the deadline for our second issue. While I did send out our second call for papers through similar channels, I did very little to further promote (e.g., extra faxes, posters) our upcoming issue. This time, while waiting to see if the response from the mathematics education community would be different, all the while expecting the worst (i.e., no submissions), I had a special issue – written by a diverse group of mathematics teachers taking a summer graduate course – already canned, which, if necessary, would become our second issue. Having hedged my bet, I was able to, without worry, sit back and wait for submissions, which also meant I could now investigate a few explanatory hypotheses I had created over the past few months.

Explanatory hypothesis one: The mathematics education community was writing articles for the journals of their respective (i.e., local or regional) mathematics teachers' association / society. Examining the publication records of mathematicians, mathematics educators, and a variety of other individuals interested in mathematics education debunked my hypothesis. Curriculum vitas, those available, were not peppered and were definitely not littered with professional journal articles, as I had expected. Although distraught, I was able, through my investigation, to find a few individuals who had invested the time and the effort – often as a graduate student or very early on in their academic careers – and had written an article (or two) for a professional journal. Examining these particular publications led me to my second explanatory hypothesis.

Explanatory hypothesis two: The mathematics education community was only writing articles for refereed or peer reviewed professional journals. To investigate my new hypothesis, I first categorized the existing (North American) professional journals into three categories: *refereed* (i.e., perhaps blinded and reviewed by experts in a particular topic area), *non-refereed* (i.e., reviewed by an editor or an editorial board before publication), and *other* (i.e., not belonging to the previous two categories). Having sorted a large number of journals, it became quite clear that the majority of them fell into the non-refereed or other category and only a small number of the journals were refereed. I became convinced that the lack of submissions from the mathematics education community was a direct result of the non-refereed status of our journal. After all, given that the journal was not receiving any submissions and the non-refereed status of our journal, one would expect a lack of submissions from individuals involved in a publish or perish environment (where articles categorized as non-refereed or other are not recognized). For me, this meant that the non-refereed status of *vinculum* was at the root cause of our lack of submissions.

Unfortunately, but now expectedly, we received one submission for the second issue of our journal. Fortunately, through hedging my bets, as detailed above, I was well prepared for the lack of submissions and our special issue went to press as our second issue. Unfortunately, I was not well prepared for the now overwhelming feeling of remorse, which manifested from the following realization: I was, at the very beginning of my academic career, devoting the majority of my time, efforts, and resources to a non-refereed publication, which had value for the members of the SMTS, but held little to no value in the academic setting I was now a part of. Thinking about my path to tenure and promotion, the remorse became debilitating. I was convinced, by becoming an accidental-editor I had made a tactical error in my young academic career.

Once the initial debilitating wave of remorse had subsided, I spent my time attempting to reduce the dissonance (i.e., accidental-editor's remorse) I was experiencing. But, no matter how hard I tried, I was unable to adjust my beliefs to align with my editorial actions. In a desperate attempt to cope, I thought: why not remove my dissonance entirely and change the status of our journal from non-refereed to refereed.

While revisiting my earlier investigation of professional journals, I noticed a certain vagueness associated with declarations of refereed status. To be clear, there are a few journals, but definitely not the majority, which are traditional refereed journals. However, there are also a large number of journals that simply self-declare refereed status. Attempting to remove my accidental-editor's remorse would have led to an entirely new sense of remorse derived from anointing refereed status to our non-refereed journal. While *vinculum* does possess certain elements of a refereed journal (e.g., acceptance rate less than 1, peer reviews of submissions), I was and still am struggling with the notion of refereed status for professional journals. After all, refereed status, as I had determined, was the root cause for our lack of submissions from the mathematics education community.

Attending a conference in May of 2010 provided me with an (ad-hoc) opportunity to sit and discuss issues (e.g., refereed status, submission and acceptance rates) with other journal editors. From this conversation, a number of themes emerged (see Chorney, Chernoff, & Liljedahl, in press, for full details), including: drawing in post-secondary members of the mathematics education community (e.g., mathematics educators and mathematicians) to be further involved with all aspects of professional journals; recognizing the need for continued dialogue between all members of the mathematics education community; and journal structure and organization (e.g., the development of two-tiered journals). The message that emerged from our group's session was clear: professional journals should be a collective effort of the mathematics education community specifically for mathematics teachers. I left the session somewhat more comfortable in my role as accidental-editor of a non-refereed journal.

Revisiting our third issue, which came out just after the May 2010 conference, I noticed that vinculum was beginning to take shape. For example, we had, despite maintaining our non-refereed status, a much stronger post-secondary influence in our submissions. Nevertheless, even with the evolution witnessed in the third issue of our journal and even with the recent community support I had received, I could not entirely remove the remorse I continued to feel. While I had somewhat reduced the dissonance, in order to cope, I was still an individual, early in my career, focusing my time and efforts on a non-refereed publication.

After reading some recent retrospections by prominent members of the mathematics education community, I was able to send, this, the fourth issue of our journal to press without an ounce of accidental-editor's remorse; it was completely gone. Sure, it still took a tremendous amount of effort the get submissions for our latest issue; sure, the mathematics education community still does not see professional journals as a priority venue for publication; sure, I have, with the latest issue, added more lines to the non-refereed sections of my curriculum vitae; and, sure, I could go on. However, as Mason (2010) asserted (and as I now understand), "it is incumbent upon us to remain steadfast that the purpose of our work is to understand and contribute to student learning of mathematics" (p. 3). After reading this resonant quotation, I now feel quite embarrassed for once having accidental-editor's remorse. After all, being the editor of *vinculum* is not about me, it is about the members of the SMTS. Part of being a journal editor is contribute to different areas of the mathematics education community and to contribute to the student learning of mathematics, which can be achieved by contributing to a professional journal, like *vinculum*. As such, I ask *you*, as a member of the mathematics education community, to contribute an article; however, do not think of it as a line on your CV (do not make the same mistake I did), but purely for the learning of mathematics.

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PRESIDENT'S MESSAGE

Evan Cole

It always seems like there is not enough time to get things done, especially around the start-up of the school year. Just when we think that everything is in place, something new pops up. There are lessons to plan, fees to collect, and professional development sessions to schedule. We are pulled in all kinds of directions including curricular outcomes, school division priorities, personal and professional growth, and accommodating our students' needs (all of which try to command our attention), and the easiest way for us to cope with it all is to fall back into familiar patterns and routines.

Teachers hear about how we need to change our practices and include new teaching strategies (such as *assessment for learning* and *differentiated instruction*), as well as the inclusion of aboriginal perspectives. If we focus on incorporating each of these issues or the above things on our to-do list one at a time we create more work for ourselves than if we take a step back and see how we can fit all of these pieces together. I was pleasantly surprised when I realized that through a few small changes in how I design assignments and tests, which I was in the process of doing anyway with new courses and new curricula, and how I approach the evaluation of these pieces of evidence of student learning, that I can positively impact how my students learn and have more impact on a larger segment of my classes.

To help math teachers put these pieces together, the Saskatchewan Mathematics Teachers' Society is involved with hosting two conferences this year. The first is Sciematics, which we partner with the Saskatchewan Science Teachers' Society to hold every other year. This year, Sciematics is in Regina on November 4–6 at Winston Knoll Collegiate and you can register at http://sciematics.com. The other conference is the annual Saskatchewan Understands Math (SUM) Conference, which looks like it will happen May 6–7, 2011 at the University of Saskatchewan Education Building. Watch for details about SUM on http://smts.ca starting in February.

GUEST EDITORIAL: FIRST NATIONS AND MÉTIS CONTENT, PERSPECTIVES, AND WAYS OF KNOWING

Gale Russell

One might ask, why Fist Nations and Métis content, perspectives, and ways of knowing as the theme for a special issue – especially in a journal for teachers of mathematics? Well, you'll have to read the journal to decide on that for yourself; however, I will give you a few mathematical reasons for why such a topic would even come up, no, must come up, in Saskatchewan. Pull out your copy of the *2009 Saskatchewan Education Indicators Report: Kindergarten to Grade 12* (available on-line at: http://www.education.gov.sk.ca/Default.aspx?DN=dfaff52e-a0f2-485e-9213-daaa59424ffe&l=English). On page 12, you will find statistics relating to the growing population of self-declared Aboriginal students compared to non-Aboriginal students in Saskatchewan. If those numbers do not make you see the point of why this issue is so important to the teaching and learning of mathematics in Saskatchewan, check out Figure 6a on page 21 which shows that 43.1% of self-declared Aboriginal people between the ages of 25 and 54 have not graduated from grade 12 compared to 15.4% of their non-Aboriginal counter-parts. Still not convinced? Go to page 51 and compare the passing rates of self-declared Aboriginal students in Mathematics 10 and Mathematics 20 to those of the non-Aboriginal students, and to the provincial standard. How can this be happening? We know there is no *math gene* – what else could it be?

This is the point of this special issue of vinculum: to start to explore what research tells us about First Nations and Métis students and the teaching and learning of mathematics. You will find that not all the articles in this journal agree with each other, but being aware of the different perspectives, interpretations, and ways of thinking is better than not knowing that they exist.

The opening article of this journal, *Indigenous, personal and Western mathematics: Learning from place* written by Gladys Sterenberg and Theresa McDonnell from the University of Alberta, explores the question of how to make mathematics learning relevant for Aboriginal students. Concerned by the low achievement rates of Aboriginal students in the K-12 education systems in Canada, as well as the low enrolments and completion rates for those same students in post-secondary institutions, the researchers sought ways to foster Aboriginal students' interests and abilities in learning mathematics. In their study, the researchers worked with grade 12 students within a Blackfoot community, focusing on the Western mathematics concepts of similar triangles, the Pythagorean theorem, and trigonometry, while embedding the learning tasks used within the culturally significant contexts of place and land. The article details one student's learning and engagement related to four tasks that were designed to value Blackfoot cultural knowledge and traditions, as were shared by an Elder, within contexts intertwined with Western mathematics and technology.

The second article, *Ethnomathematics in the classroom* by Aileen Nienaber, asks the reader to consider the validity of the statement 'mathematics is a universal language'. The author, an undergraduate student from the College of Education at the University of Saskatchewan, provides an informative introduction to the field of ethnomathematics, or the study of different ways of thinking and working mathematically as found in different cultures around the world. Nienaber introduces the reader to the elitist and oppressive history of the mathematics taught in Western schools, as well as the richness and variety of mathematical thinking and doing that has not been accepted or considered within this Western mathematics. The author encourages the reader to consider ways to infuse their classroom mathematics with these ethnomathematical knowledges in order to open up the learning space to the valuing of alternate cultures, with the benefit of inviting the students to bring their own ways of thinking and doing mathematics to the classroom.

Like Sternberg and McDonnel, Tracy Shields and Ann Kajander of the University of Manitoba, authors of *A change in pedagogy: Success for Aboriginal students in the mathematics classroom*, are also concerned by the low achievement rates of Aboriginal students in mathematics. In particular, the researchers are concerned about Aboriginal teacher candidates who, through a mandatory mathematics content test, have been determined to be at-risk in their mathematics understandings and abilities. The researchers have focused their work on improving the teacher candidates understanding of mathematics through the use of mainstream pedagogical methods rather than concentrating on "Aboriginal learning styles". The article details the tutoring of two of the at-risk Aboriginal teacher candidates and how the researchers approached the learning of the teacher candidates. As a result of their study, the researchers make a number of recommendations regarding the teaching of mathematics to at-risk students, and for engagement of all students.

The fourth article, *Racism by numbers* written by myself, raises the question of whether mathematics is culturally biased. At first, this question seems to be one of mere fantasy. Mathematics is pure, non-emotional, and abstract – it has nothing to do with culture, does it? The article considers whose math has been chosen to be taught, and what the implications of those choices are with respect to differing worldviews, perspectives, and hence cultures. Specifically, the article explores just a few of the different ways in which cultures and areas of the world have, and continue to represent quantities. Moreover, the article considers what those representations reveal about what the people using those representations value and how they communicate those values. Are there mathematical understandings and ways of thinking that allow people to math that Western math cannot do? Can numbers be less abstract, but just as useful and meaningful? Can numbers preserve history? These are all questions that become relevant when one starts to consider the cultural bias of our Western number system, and how to deal with that bias so that student learning can be improved.

The final article in this special issue is Kanwal Neel and Mark Fettes' (Simon Fraser University) *Teaching numeracy in a community context: The roles of culture and imagination*, approaches the development of students' numeracy through the situating of mathematics learning within cultural context in order to make the learning more accessible to all students. This article, based upon a study done by Neel (2007) with Aboriginal students of Haida Gwaii in British Columbia, provides a detailed example of how a teacher can start with a cultural practice that is familiar to the student, and by getting to know the significance and values embedded within that practice can find connections to the mathematics curriculum. The cultural practice and the mathematics connections become the starting point of a learning unit in which the teacher incorporates additional contexts, all of which are intended to continue the engagement of the students' imagination and interests within the mathematical learning. Following the article, the authors include a number of resources that highlight curriculum connections, a unit plan designed using *Understanding by Design* (Wiggins and McTighe, 1998), an assessment rubric, as well as a variety of tasks to be used by students.

So now, enter into the intersecting worlds of Aboriginal students and mathematics teaching and learning. If you find an article speaks to you, your students, and your teaching and learning of mathematics, dig in further to see where the ideas and research can take you. If you find that you do not agree with an article, arm yourself through research and inquiry so that you can take a stand against what that article proposes. Either way, enjoy engaging with this fascinating and significant area of research and thought – perhaps you may even consider making a submission to an upcoming issue of *vinculum* as the result of your emerging ideas and reflections!

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INDIGINEOUS, PERSONAL AND WESTERN MATHEMATICS: LEARNING FROM PLACE

Gladys Sterenberg and Theresa McDonnell

In Canada, Aboriginal[1] postsecondary enrolment and completion rates are significantly lower than those of non-Aboriginals (Canadian Millennium Scholarship Foundation, 2004; Mendelson, 2006). This is most evident in disciplines involving science and mathematics (Indian and Northern Affairs Canada, 2005). Moreover, Aboriginal student achievement in K – Grade 12 mathematics courses is significantly lower than those of non-Aboriginal students (Neel, 2007). In the contemporary Canadian context of low Aboriginal participation and completion rates in postsecondary studies of mathematics, it is important to provide Aboriginal students with experiences of mathematics that foster their interest and ability in the early stages of their schooling (Bourke, Burden, & Moore, 1996; Council of Ministers of Education, 2002).

Mathematics can become relevant for Aboriginal students when it is linked to the environment around them through place-based education (Boyer, 2006; Hill, Kawagley, & Barnhardt, 2006). Learning from place recognizes the intimate relationship that Indigenous peoples have with the land. In this project, we focused on the relationship of Blackfoot peoples, whose knowledge has accumulated over millennia through interactions with the land, to the place now labeled Southern and Central Alberta, Eastern Saskatchewan, and Northern Montana. For us, learning mathematics from place means enacting mathematics lessons that revere the land and people from whom the students came. We claim this can be accomplished by continuing to find meaning in places and inviting students to intertwine various dimensions of Indigenous, Western, and personal mathematics (Ogawa, 1995).

Drawing on historical connections of the Blackfoot community to the Big Rock near Okotoks, we created four learning from place lessons for Grade 9 Aboriginal students that focused on similar triangles, trigonometry, coordinate geometry, and topography. While there exist other initiatives involving place-based mathematics curriculum for Aboriginal students, our lessons focused on learning from place within a particular Blackfoot community. Learning in this specific context is necessarily unique and results are not meant to be generalized for all Aboriginal students. Multiple perspectives are essential and this project contributes to one such perspective. This paper is a preliminary exploration into one student’s experiences of learning mathematics from place.

Indigenous, Western, and Personal Mathematics

Mathematics can be defined and understood in many different ways. Drawing on Ogawa’s (1995) distinctions between Indigenous science, Western modern science, and personal science,

[1] In Canada, the term *Aboriginal* is used to describe Indigenous peoples who are First Nations, Inuit, or Métis. Throughout this report, I follow this convention but also use the term *Indigenous* to include peoples of Aboriginal descent who may not have official Aboriginal status in Canada and peoples of Indigenous descent in an international context. The term *Native American* is used to reflect conventions in the United States.

we similarly recognize a relativistic perspective of mathematics. Ogawa defines science as "a rational perceiving of reality where perceiving means both the action constructing reality and the construct of reality" (p. 588). Rationality is not the same as Western rationality but is viewed in a relativistic perspective where rationality is linked to worldview. He supports his argument by quoting Takeuchi:

> Worldview is just like the axiom in a mathematical system. Thus, worldview upon which rationalism is based must have logical consistency in itself and give high priority to the reason of humans, but it is not necessarily the only one form of worldview. (cited in Ogawa, 1995, p. 587)

Ogawa believes that all cultures have empirical-based rational descriptions and explanations of the physical world and his work suggests that this notion of science is superordinate.

Ogawa proposes that there are three subcategories of science of interest to educators: Indigenous science, Western modern science, and personal science. Indigenous science refers to the science in a particular culture that reflects a collective worldview. Examples of Indigenous science could include Chinese science, Japanese science, or Aboriginal science. Ogawa describes Western modern science as "a collective rational perceiving of reality, which is shared and authorized by the scientific community" (p. 589). Rather than focusing on natural phenomena, "Western modern science pertains to a Cartesian materialistic world in which humans are seen in reductionistic and mechanistic terms" (p. 589). Personal science is unique to each person and involves personal observations or explanations of the world. Ogawa claims there is a vast gap between Western modern science and Indigenous science.

Cajete (2000) distinguishes Western science from Indigenous science by suggesting that Native science is "the collective heritage of human experience with the natural world; in its most essential form, it is a map of natural reality drawn from the experience of thousands of human generations" (p. 3). He writes, "*As we experience the world, so we are also experienced by the world.* Maintaining relationships through continual participation with the natural creative process of nature is the hallmark of Native science" (p. 20, italics in original). Cajete describes a broad perspective of Native science that includes metaphysics, philosophy, art, architecture, agriculture, and ritual and ceremony practices by Indigenous peoples. This view of science involves studies related to the earth and extends to include "spirituality, community, creativity, and technologies that sustain environments and support essential aspects of human life" (p. 2). He suggests:

> Native science is born of a lived and storied participation with the natural landscape. To gain a sense of Native science one must participate with the natural world. To understand the foundations of Native science one must become open to the roles of sensation, perception, imagination, emotion, symbols, and spirit as well as that of concept, logic, and rational empiricism. (p. 2)

Western science, using a Western paradigm of mathematical measurements, may not coincide with how nature is experienced by the Aboriginal peoples. Nature cannot be superimposed by Western mathematics and examined from a mathematical grid. Little Bear (2000) suggests that Aboriginal science is a pursuit for knowledge and is not based on measurement because Native Americans never claim regularities as laws or finalities; the only constant is change. This can be related through the tradition of Native American storytelling because it is not the actual words but the living experience that gives a holistic treatment of "livingness" and "spirit" (p. xii). This is the fundamental gap in the mathematics of Western science. Western science, according to Hayward (1997), leaves out the sacredness, the livingness, and the soul of the world. He states, "It does get troublesome when some scientists tell us, often with a voice of authority, that the part they leave out is really not there." This lack of relevancy emphasizes the difficulty with the Aboriginal experience of science and mathematics as taught solely from a Western perspective.

Throughout this paper, we use Ogawa's distinctions to clarify the type of mathematics we are describing. In much of the education literature, the term *mathematics* is taken to mean *Western mathematics.* However, mathematics can be described in many ways. In this particular context, we retain the notion of science as a superordinate concept that subsumes Western, Indigenous, and personal mathematics (Aikenhead & Ogawa, 2007).

We use the term *Indigenous mathematics* to describe the mathematics of Aboriginal peoples. Bishop (1994) believes that mathematics is embedded in all cultural groups and describes six fundamental mathematical activities all people engage in: counting, measuring, locating, designing, explaining, and playing. Here, we refer to Indigenous mathematics as these types of activities that are engaged in by Blackfoot peoples. Mathematics understood in this way is a subcategory of the superordinate science. It does not exist as a separate body of knowledge but is integrated into a rational perceiving of reality.

We use the term *Western mathematics* to refer to the Western modern discipline that is taught in schools. Mankiewicz (2000) suggests, "[Western] mathematics is not about impenetrable symbols. It is about ideas: ideas of space, of time, of numbers, of relationships. It is a science of quantitative relationships" (p. 8). Aikenhead and Ogawa (2007) describe this view of reality as materialistic with objective mathematical relationships. They suggest the quantification of nature tends to "objectify an entity or event by stripping it of qualitative, human, or spiritual attributes (i.e. stripping it of intelligible essences)" (p. 550). Observations of the world and our experiences in it are ignored. Lakatos (1976) explains:

> In deductivist style, all propositions are true and all inferences valid. Mathematics is presented as an ever-increasing set of eternal, immutable truths. Counterexamples, refutations, criticism cannot possibly enter.

> An authoritarian air is secured for the subject by beginning with disguised monster-barring and proof-generated definitions and with the fully-fledged theorem, and by suppressing the primitive conjecture, the refutations, and the criticism of the proof. Deductivist style hides the struggle, hides the adventure. The whole story vanishes, the successive tentative formulations of the theorem in the course of the proof-procedure are doomed to oblivion while the end result is exalted into sacred infallibility. (p. 142)

For the purposes of this paper, *personal mathematics* involves personal understandings of the world through activities of counting, measuring, locating, designing, explaining, and playing (Bishop, 1994).

We believe these three types of mathematics can help us understand the experiences of Aboriginal students in the context of learning from place.

Learning from place: Students' sense of relevance and interest

Learning from place offers an opportunity to provide relevance to Western mathematics education for Aboriginal students. However, learning from place is more than environmental education and working with community members. It is not necessarily solely concerned with improving achievement in Western mathematics. Rather, it recognizes the importance of Indigenous mathematics that is connected to Indigenous knowledges and worldviews. Battiste (2002) links Indigenous knowledges to particular "landscapes, landforms, and biomes where ceremonies are properly held, stories properly recited, medicines properly gathered, and transfers of knowledge properly authenticated" (p. 13). Little Bear (2000) describes the land as integral to the Native American mind. He writes:

> Events, patterns, cycles, and happenings occur at certain places. From a human point of view, patterns, cycles, and happenings are readily observed on and from the land. Animal migrations, cycles of plant life, seasons, and cosmic movements are detected from particular spatial locations; hence, medicine wheels and other sacred observatory sites. Each tribal territory has its sacred sites, and its particular environmental and ecological combinations resulting in particular relational networks. All of this happens on the Earth; hence, the sacredness of the Earth in the Native American mind. The Earth is so sacred that it is referred to as "Mother," the source of life. (p. xi)

Learning from place emphasizes a relationship with the land, something deeply respected in Indigenous communities and something absent from much of Western mathematics instruction.

In this project, we experimented with intertwining Indigenous, Western, and personal mathematics through learning from place. The term *cultural infusion* has been used to describe the process of integrating Indigenous and Western knowledges (Sparks, 2000). To us, however, the metaphor of infusion suggests a pouring of liquid into a vessel, and in the context of education, this may infer an addition of content to the existing body of knowledge. We offer an intertwined image where Indigenous, Western, and personal mathematics encircle one another as they embrace, twist, or wrap each other. This implies that each type of mathematics is preserved and the twisting together adds tensile strength to the learning. We designed our lessons to reflect this perspective.

Our Lessons

The Blackfoot community was the context of the project. Specifically, we worked with twelve Grade 9 students from a First Nation school located in what is now called Southern Alberta. One of the authors was the classroom teacher, the other author had been working with teachers and students in the school for two years.

Lessons were designed to address two specific objectives of the provincial Western mathematics curriculum. Students were expected to (1) recognize when, and explain why, two triangles are similar, and use the properties of similar triangles to solve problems, and (2) relate congruence to similarity in the context of triangles. We expanded the Western mathematics objectives in lessons 3 and 4 to include using the Pythagorean theorem to find missing lengths of a triangle, using trigonometry to calculate sides of a triangle, and using coordinate geometry to map the topography. Two lessons involved locating benchmarks and objects on the school grounds and recording shadows and similar triangles using digital cameras; the other two involved using Global Positioning Systems (GPS) to map triangles in the landscape at a sacred site. Each lesson was 1.5 hours long and was team-taught by the authors.

We began lesson 1 by reviewing the Western definition of congruent triangles and reminding students of an activity they did the previous year creating similar shapes by enlarging magazine images. We told a historical Greek story of how shadows and similar triangles were used to calculate heights of objects. Then we provided students with digital cameras and instructed them to go outside and locate a benchmark and an object. They measured the benchmark's height and shadow (base), and sketched the triangle formed by these two measured sides and the resulting hypotenuse. After this was completed, they took a photograph of the benchmark. Similarly, they found an object on the school grounds whose height was too high to measure. They measured the shadow, sketched this object and the resulting triangle, and photographed the object. Then they calculated the height of the object using similar triangles.

For lesson 2, we provided students with digital photographs of a benchmark and four objects. While the benchmark photograph was taken from a perspective consistent with most textbook diagrams (vertical height forming a right angle with the horizontal base to the right of the height), the object photographs were taken from different views to encourage students to create sketches of similar triangles by mentally manipulating and rotating the object. Part of our project engaged students in learning Western mathematics through place using GPS technology. We chose to use a technological tool that would help the students map the land using Western Cartesian mathematics. For lessons 3 and 4, we arranged a field trip to the Big Rock, a sacred site we selected for our project (see Figure 1). This choice was shaped by historical connections of the Blackfoot community to the place. Located west of Okotoks, Alberta, the Big Rock is the largest glacial erratic[2] in the world and is part of a series of boulders stretching from Jasper to Montana. This site was significant to the Blackfoot community and the splitting of the Big Rock by Napi's actions is a story still told today:

> Napi is the supernatural trickster of the Blackfoot. In this particular story everybody knew Napi had cheated someone out of the nice buffalo robe he was wearing as he trekked northward with his pal Coyote. Napi had played tricks on so many other creatures the Sun and the Wind thought that they would play a trick on him. The Sun shone very brightly making Napi hotter and sweatier and the robe heavier. When the robe got too heavy to wear Napi asked Coyote what he should do with it. "Why don't you give it to the Big Rock?" said Coyote. So that is what they agreed to do. They went over to the Rock, praised the Rock, and Napi made a gift of the robe to the Big Rock. No sooner had Napi and Coyote headed off again when the Wind started blowing very cold air. Napi began to think he should have kept his robe. He tells Coyote to run back and take the robe from the Rock. Coyote doesn't want to have anything to do with taking back the robe. So Napi goes back and tells the Rock that he has come for the robe. To which the Rock replies, "You gave the robe to me." Napi responds, "What are you going to do? You have always been here and are going to stay here. I am going to be on my way." Napi takes the robe and heads off again with Coyote reluctantly by his side. All of a sudden Coyote hears some noise and looks back and sees the Rock rolling after them. Coyote and Napi become quite startled at what is going on and the two of them start to run.
>
> Napi and Coyote run past all the animals which Napi had played tricks on. Napi asks the animals to help him. The animals are quite amused to see Napi finally getting a taste of his own medicine and will not help. Coyote realizes the Rock is only chasing Napi and so he runs away from Napi. Napi runs along prairies, coulees and rivers, staying just ahead of the rolling Rock. Napi is getting very tired. Some swallows finally decided to help him. The swallows swoop down and start pecking off pieces of the Rock. Some stories even say they use their droppings to break the Rock apart. The swallows see Napi is getting too tired to run much longer. They swoop down on the Rock one more time and stop the Rock by breaking it in two. Napi was

[2] A glacial erratic is a rock that is different from the rock in the area and is believed to have been carried and deposited by glacial ice.

safe. The Rock still sits on the spot near Okotoks, Alberta where it broke in two.[3]

Figure 1. The Big Rock

Lesson 3 involved locating a benchmark at the site (we chose a fence post) and calculating the height of the Big Rock using similar triangles. Students mapped the site by recording coordinates throughout the site. Students used these diagrams to calculate triangular lengths on the map using trigonometry and the Pythagorean theorem. Lesson 4 involved a scavenger hunt where students used the GPS coordinates to locate themselves in the landscape and answered questions based on their position.

If we consider one type of mathematics as Indigenous, then counting, measuring, locating, designing, playing, and explaining (Bishop, 1994) will reflect a collective worldview of this particular Blackfoot community. For this project we focused on locating. In order to offer students an experience of learning mathematics from place, we asked the school-based cultural Elder to provide us with insight into Indigenous mathematics. The Elder was consulted at various stages of the planning, especially during lessons 3 and 4. The Elder participated in the field trip, beginning our visit at the site with an offering and prayer, and observing community protocols for telling stories of Napi. These stories emphasized the relationship of Blackfoot peoples to the land. Using place names, the Elder told stories of what is now called Southern Alberta and described the vastness of the land visited by the ancestors and Napi. Stories of the trees and rocks were told that focused on the animate nature of these objects, thus further describing to the students their relationship to the place. This was intended to explicitly engage students in Indigenous mathematics through stories involving locating.

What follows is an example of one student's experiences of learning personal, Western, and Indigenous mathematics from place.

Dallas' experiences of personal mathematics

The First Nation school that Dallas attends has 250 students in Grades 7 – 12. His family is well known in the community; his father is a member of the First Nation and his mother is a member of a neighbouring Blackfoot Nation. He is the youngest of three children. Dallas is an average student, well liked by his peers. His school attendance is consistent and he has expressed to his teachers that he enjoys mathematics.

When asked about his early experiences of learning mathematics, Dallas commented that he struggled with algebra and "gave up and just decided to get it out of the way." His strategy for learning algebra was to read the examples in the textbook and ask friends

[3] This is a version of the story as told by Blackfoot Elder Stan Knowlton and recorded by Humble (2007).

for help. He felt most frustrated with learning mathematics when he was sitting down working with the calculator and a pen at his desk. While he identified that he learned both by doing things physically and using paper, he "liked it better when I was actually doing the things." He enjoyed learning about circumferences of circles because the lesson involved measuring different circles (such as juice lids) and figuring out a pattern.

Dallas' experiences of Western mathematics

For lesson 1, Dallas correctly measured and sketched the benchmark and object. He set up the ratios for the similar triangles and accurately calculated the missing height (see Figure 2). While this data shows that he was able to get the correct answer, what is not evident in his written work is how he interpreted the photographs of the similar triangles when sketching. The sketches mirror the format found in most textbooks (he drew them so that the height was vertical and the base was horizontal out to the right); however, many of the photographs were not taken from this perspective. Dallas was able to mentally reflect, slide, and rotate what he was viewing into a conventional sketch.

Mentally rotating, sliding, and reflecting objects is an important part of mathematical reasoning and representation. We designed lesson 2 to explicitly present students with a variety of triangle perspectives. Dallas completed all questions correctly, drawing accurate sketches and creating ratios for similar triangles (see Figure 3).

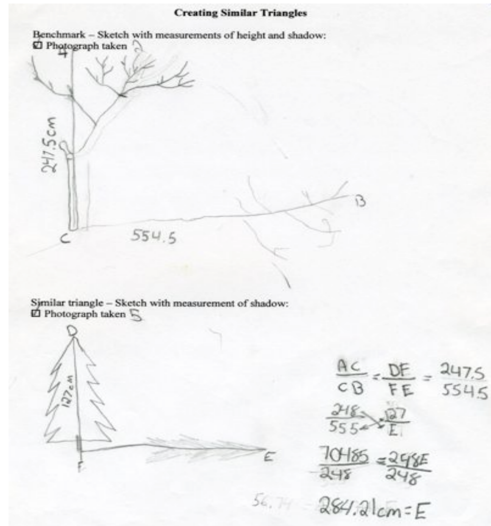

Figure 2. Dallas: Lesson 1

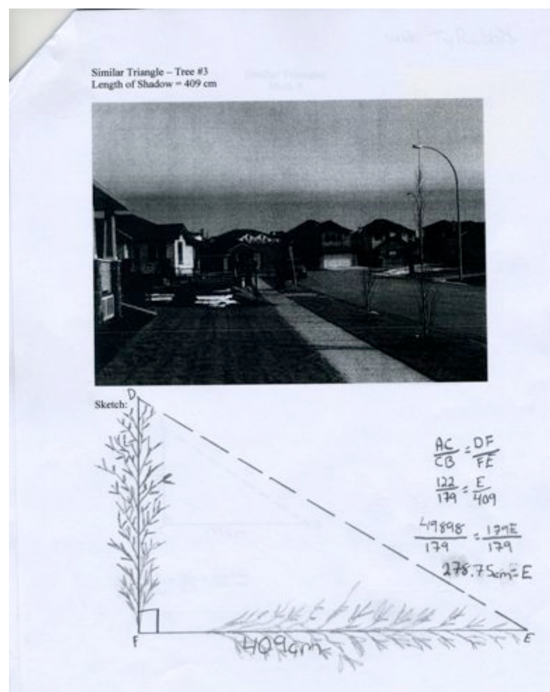

Figure 3. Dallas: Lesson 2

Dallas was able to use similar triangles to correctly calculate the height of the Big Rock. He applied the Pythagorean theorem to find distances on the map and used trigonometry to find the missing side of a triangle (see Figure 4). He was also able to use the

GPS to locate points in the field for the assignment for Lesson 4.

On the reflective writing assignment, students were asked to list two things they learned about mathematics. Dallas wrote that he learned that “math can be learned in all ways. You can make math fun or boring.”

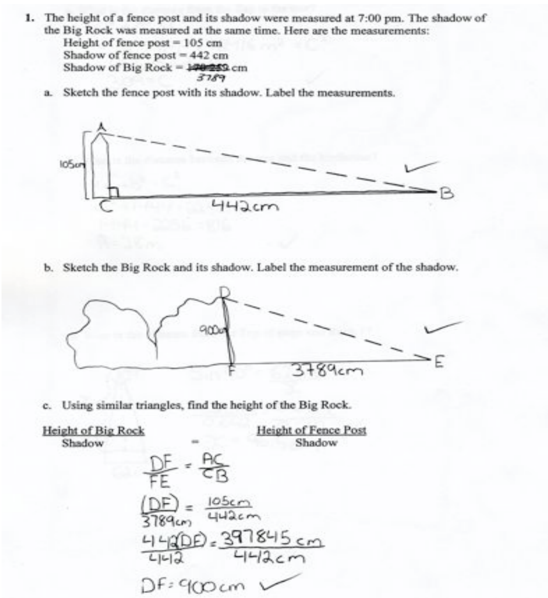

Figure 4. Dallas: Lesson 3

Dallas’ Western mathematical learning was robust as he exceeded the outcomes prescribed in the provincial curriculum. This was especially evident in his work with similar triangles. Teachers often present problems with similar triangles by drawing the models on the board and expecting students to know how the triangles represent reality. For the first lesson, Dallas was asked to work outside. He had to measure and find a benchmark, and then he had to find something he could not measure the height of and calculate it using similar triangles. Then we asked him to draw and label the triangle. What was interesting to us was that his drawings did not reflect his perspective. Rather than drawing according to how he was standing in relation to the shadow, he flipped that triangle back to the way that it was typically represented in the textbook. He did this mentally and tended to draw the triangles so that the height was vertical and the base was horizontal out to the right, but that was not how he was looking at the actual object. Spatial reasoning is an essential part of Western mathematics. This involves visualization and mental imagery and enables students to interpret their environment through two- and three-dimensional representations (Alberta Education, 2007). Clearly, Dallas was able to demonstrate spatial reasoning through these assignments. Dallas also related to the land through Western mathematics. By overlaying a Cartesian grid and using technology to map the land, he gained an understanding of one way to describe the location of the Big Rock.

While we had planned lessons that focused on learning from place, it seems that Dallas perceived the mathematical tasks for lessons 1 and 2 as environmental and hands-on activities and his responses on assignments were solely reflective of Western mathematics and place-based learning. This did not seem to correspond with our notion of learning mathematics through place. For lessons 3 and 4, we deliberately emphasized Indigenous mathematics through learning from place.

Dallas’ experiences of Indigenous mathematics

Locating, one of the mathematical focuses of this project, reflects Indigenous mathematics. Of primary importance to the Blackfoot community is the locating of self within place. This notion of locating involves the fundamental question, “Who am I?”

Providing students with experiences of Indigenous mathematics was done through storytelling, prayers, and offerings. Locating is a relational act as one comes to know oneself. Dallas identified the most enjoyable part of the visit to the sacred site as learning about the importance of the Big Rock to Blackfoot peoples and hearing the stories about Napi. His written reflection shows his consistent emphasis of the importance of this:

> "I did not know the Rock was a part of us."
>
> "I didn't know that it was a part of our First Nations culture. But now I know, so it is part of me. I know our territory is huge."
>
> "I would bring my kids to go see what is a part of the culture and I would tell the story that goes with the Rock."

It would seem that Dallas became more aware of his identity as a Blackfoot learner and was able to locate himself in this place.

It is important to note that lessons 3 and 4 were not merely activities of experiential or hands-on learning. The lessons unfolded in a context of stories of the Big Rock and Napi. Dallas became more aware of the history of his people and this impacted his sense of identity as an Aboriginal youth. The stories told by the Elder emphasized a relationship with the land, an animate relationship with entities viewed by Westerners as inanimate. For example, the Rock was seen as animate and our understanding of the location of the Rock through the stories told by the Elder reflected the importance of knowing the land in relational ways. Indigenous mathematics emphasizes such relationships. When we explained how GPS technology worked using triangulation, we talked about the history of how Dallas' ancestors would have travelled and used these sites as benchmarks. He was introduced to the rich history in the First Nations of using the land and sacred sites to help his people navigate across the land. To his ancestors, the angles of triangulation became an intuitive way of living with the land.

Conclusion

Both Western and Indigenous mathematics can contribute to a more intertwined way of locating and can contribute to a deeper understanding of personal mathematics. Ogawa (1995) provides an example of Nepalese people who were able to account for natural phenomena such as earthquakes using Indigenous (folk-oriented) and Western (school-oriented) explanations. He emphasizes that the people can understand more than one worldview simultaneously and that these understandings prompt the individual to create a personal view of science. However, this can only happen if each worldview is respected and acknowledged as having equal status.

Unfortunately, Dallas encountered Indigenous and Western mathematics as opposing worldviews. When we arrived at the site, vandalism was evident. The interpretive sign contained two stories: a scientific description of the movement of the erratic and a Blackfoot story of how the Big Rock had come to rest at this place through the actions of Napi. The Blackfoot interpretation had been spray-painted. In addition, graffiti was evident on the Big Rock itself. Dallas stated that the vandalism on the Big Rock was disrespectful and something he wished he could change: "I would clean off the spray paint off the rock." In another place, he commented, "It was wrong to do that because the person that did that was racist to us and that in my culture the person would be punished for what he did to that Rock." The pride Dallas felt in his heritage was evident and this impacted his personal mathematics. When asked what he learned about himself, Dallas wrote, "[I learned] that math can be used in all ways and that the culture is strong to us plus that people should respect that". Dallas was able to locate himself as a learner of Western and Indigenous mathematics.

We believe mathematics learning was prompted within this intertwined context. Because we began the project by acknowledging the significance of place, Dallas was offered a different way of viewing mathematics. We believe that this project is an example of how Aboriginal curriculum can be rooted in Aboriginal understandings of the world, in response to Battiste's (2002) call, "To affect reform, educators need to make a conscious decision to nurture Indigenous knowledge, dignity, identity, and integrity by making a direct change in school philosophy, pedagogy, and practice." (p. 30)

Learning mathematics from place offers a way to intertwine Indigenous and Western knowledges in a personal manner. Battiste (2002) suggests that Indigenous peoples have a complete knowledge system different from a Eurocentric system and that this knowledge is holistic and fundamentally important to Indigenous peoples. For Indigenous peoples, knowledge is a process, not a commodity. Customs for acquiring and sharing knowledge exist, thus emphasizing the responsibility and importance of knowledge keepers.

In a Blackfoot context, balance and harmony with the environment are recognized as part of the knowledge system. Bastien (2004) writes, "Ontological responsibilities of *Siksikaitsitapi* are the beginning of affirming and reconstructing ways of knowing. These fundamental responsibilities must be renewed by coming to know the natural alliances" (p. 4). She suggests that Indigenous knowledge is linked to intricate interrelationships within nature. The environment is understood as "the source from which all life originates and from which all knowledge is born" (p. 39). Writing about Blackfoot physics, Peat (2002) emphasizes the importance of the web of interrelationships in nature and suggests

> Indigenous knowledge comes through direct experience of songs and ceremonies, through the activities of hunting and daily life, from trees and animals, and in dreams and visions. Coming-to-knowing means entering into relationship with the spirits of knowledge, with plants and animals, with beings that animate dreams and visions, and with the spirit of the people. (p. 65)

In this project, we created lessons based on learning mathematics from place through a visit to a sacred site. Starting from Indigenous knowledges of the land, we designed locating tasks informed by stories and teachings of the cultural Elder at the school. This provided opportunities for considering alternative ways of thinking about mathematical knowledge. Through these lessons, we have seen glimpses of how one student can experience Indigenous, Western, and personal mathematics. All are important dimensions of learning, as stated by the Council of Ministers of Education, Canada (2002): "We believe that strong cultural identity and equally strong individual academic performance will create First Nations citizens who walk with ease and confidence in two worlds" (p. 1).

The impact of this experience on Dallas was evident. His understanding of similar triangles, trigonometry, and coordinate geometry was robust and his enthusiasm and confidence was evident as he began to see himself as a learner of mathematics. Learning from place in this project helped this student feel more connected to his land and community. He expressed concern for the care and treatment of traditional sites and was certain of his place and belonging in the Blackfoot territory and culture. He was able to express himself mathematically, confident in his knowledge and skills in mathematics. He seemed to engage in the mathematics lessons with a positive attitude.

What holds promise for us is the potential for viewing Western and Indigenous mathematics as having complementary strengths. Recognizing the strengths of each type of mathematics could maximize mathematical learning. To date, very little has been done to intertwine these knowledge systems and the reciprocity of cultural strengths in Indigenous and Western mathematics is not fully understood. This paper has attempted to initiate and engage in that dialogue.

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ETHNOMATHEMATICS IN THE CLASSROOM

Aileen Nienaber

Mathematics is the universal language and it is consistent and understood by all cultures. This is one of the long-held beliefs that surrounds the teaching and understanding of mathematics in the classroom, but is it true? The style of mathematics that is taught in schools has evolved from many different cultures, Egyptian, Greek, Arabic, and Hindi to name a few, but it has been widely accepted to have developed within European traditions. This European mathematics has continued to evolve into what many practitioners now call “academic mathematics.” But is this the only type of mathematics out there, and is it truly universal and understood by all cultures? Ethnomathematics can be thought of as the study of social mathematics, or the study of how mathematical concepts and awareness were developed and understood by different cultures. It is the belief that there are universal properties that are similar to all cultures, but because there are different modes of thought in every culture the mathematical processes will be different as well (D'Ambrosio, 1997). The mathematics that is taught and studied within schools has developed from Eurocentric thought processes, which uplifts certain types of mathematics and makes them culturally superior to others. This separation and elevation makes it harder for some cultures to understand or integrate themselves into the cultural mainstream because their perceptions and understandings are different, but not inferior, from the mainstream understandings. The inclusions of these different understandings of mathematics will allow students to grow an awareness and appreciation for the diverse mathematical understandings of the world.

The study of mathematics, from its Greek descent, has always been in two distinct branches, "scholarly" and "practical." The scholarly mathematics were used in educating the upper classes; whereas, practical mathematics was understood to be necessary for manual labourers (D'Ambrosio, 1997). This distinction continued, for the most part, through the Roman era, the trivium, the quadrivium, and into the Middle Ages, where the distinct mathematical approaches began to converge. (D'Ambrosio, 1997). The mathematical knowledge continued to change and combine into a more "academic math" which is now taught in schools.

This "academic math" stems from a "scholarly math" which was once taught to elites to expand their knowledge and comprehension of their surrounding world. Elitism in math, the thought that one section or category of math is superior to another, is thought to have occurred because of this classification system (D'Ambrosio, 1997).

When mathematics is studied within broader categories, practices such as "counting, ordering, sorting, measuring, and weighing" (D'Ambrosio, 1997, p. 14) can be seen to have occurred in all civilizations, but not necessarily in the same way as it is taught in school.

When we begin to look at Native cultures, both in the Americas and elsewhere, we can see each culture has produced a mathematical understanding of the world surrounding them, based upon that world. For example, hunting societies such as the Ojibway and Inuit would measure distances based on temporal units, days, sleeps, and lunar phases, rather than use a standard unit of measurement such as a kilometre or mile (Denny, 1986). These hunting societies would have a more accurate measurement of the time needed to travel a certain distance, from one village to another or to their seasonal hunting grounds, because their temporal measurement takes into account travelling across difficult terrain; whereas, a standard unit of measurement does not. Linear measurement in these communities were based on body parts; for instance, in the building of birch-bark canoes, a main mode of travel in Ojibwa communities, the length of the forearm or hand, and variations upon these lengths, were used for measurement rather than centimetres or inches (Denny, 1986). These different forms of measurement were determined by the surrounding environment, and were based on the cultural understanding of that environment.

The Base 10 number system is derived, so the assumption goes, because of the 10 digits on our hands, eight fingers and two thumbs. It is the easiest way to keep track and tally, and once we form one group of ten we can continue to form groups based on these groups, which in itself a cyclic representation based on groupings of ten. Other cultures, such as the Nahuatl in Central Mexico, base their groups system on cycles of twenty, with significance on five, ten, and fifteen. That is the number fifty-six implies a group of twenty, two groups of fifteen, a group of five, and a single ($56 = 20 + (2 \times 15) + 5 + 1$) (Ascher, 1991). The Yuki of California also based their grouping system on the hand digits, but instead of counting the digits they counted the spaces between the digits and grouped in bunches of eight instead of ten. (Ascher, 1991). Some other societies, such as the Yoruba from Nigeria, group in bunches of twenty, but instead of adding singles to make a larger number, they subtract singles from a larger number. For example the name for forty-five in Yoruba means, "take five and ten from three twenties" ($45 = (3 \times 20) - 10 - 5$). (Zaslavsky, 1997). The amount of items each culture is counting remains the same, but they perceive the formation of the number differently. When students begin to learn about different numerations systems such as these they will be able to recognize that not all cultures construct their meaning of numbers the same way, but they are just as reasonable solutions to the same problem, all equal in their own understanding of their environment (Zaslavsky, 1997).

When teachers of mathematics begin to involve culture, and the various influences it has on mathematical assumptions, students will then begin to determine their own understanding of mathematical concepts based on their personal experiences. This will allow the students to learn mathematics in a more effective and meaningful way (Fasheh, 1997). The effects culture has on the understanding of mathematics can be perceived in the contrasting discussions of two geometric shapes, a line and a circle, by individuals of two different cultures, modern mathematicians and Black Elk, a Sioux Elder, respectively. Each discussion is equally passionate in their conviction that the geometric shape they describe is the intrinsic shape necessary for human development. The mathematicians believe a straight line is a necessary element for life and it has applications in style, building purposes, and distances; whereas, Black Elk believes the circle is necessary because all your surroundings are cyclic or round, for example the days, seasons, or sun, and based on these teachings native cultures embraced the circle into their everyday life. The mathematicians believe the straight line makes everything more symmetric, easier, and quicker, but Black Elk believes all life and power stems from the circle (Ascher & Ascher, 1997). Neither of these discussions are wrong, or better than the other, but they are just different perceptions based on the ideals and beliefs that are incorporated into a person's life. By connecting cultural meanings to mathematical concepts teachers can begin to relate these concepts to student's everyday lives. These relations can have applications in other disciplines as well, such as art, design, history, and social studies, and the students will have a deeper knowledge and better understanding of these concepts (Joseph, 1997).

Teachers can, and should, incorporate Indigenous understandings into their math curriculum. When discussing number systems of different bases include as an example the Yuki cultural view of counting the spaces between the digits, rather than counting the digits. Students will then realize that given the same tools other people can perceive a different understanding than their own. When studying patterns use Indigenous arts and crafts to incorporate further examples and explanations. Students will be able to perceive and visualize where mathematical concepts apply to their everyday life, rather than just believing math has no importance to their lives. Students can discuss which form of measurement is better, temporal or linear, and have them support their answers with further research. By uniting content with additional context teachers are giving their students a greater ability to visualize and understand mathematical concepts in different cultures. By studying a culture`s understanding of mathematics a person can then understand more about that culture and their way of life, as well as our own (Ashcer, 1991).

The incorporation of ethnomathematics into a classroom setting is beneficial for students and teachers. The student will realize where our mathematical concepts and ideals have emerged from, and they can contrast those with concepts and ideals from other cultures. Students will begin to question what they believe and accept as knowledge, and the students will become more accepting of other cultures and ideals. Mathematics is not, as it is commonly believed, universally accepted and understood by all cultures. Each culture has its own understandings and belief, and these beliefs must be welcomed, incorporated, and explored within the classroom to meet the needs of all students. If students are expected to learn the curriculum, teachers must be able to modify the curriculum to fit the needs and understandings of the students. This will benefit both teachers and their students, for each will understand and question the world surrounding them.

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A CHANGE OF PEDAGOGY: SUCCESS FOR ABORIGINAL STUDENTS IN THE MATHEMATICS CLASSROOM

Tracy Shields and Ann Kajander

This study was funded by the NSERC University of Manitoba CRYSTAL grant: *Understanding the Dynamics of Risk and Protective Factors in Promoting Success in Science and Mathematics Education.*

This paper describes case studies of Aboriginal teacher candidates at-risk in mathematics. It is argued that our lack of appropriate focus on at-risk students in general, particularly in the early grades, is resulting in the low success rates of Aboriginal students in general, and in this case has impacted the success of these students at the post-secondary level.

Each student comes to the classroom with a unique set of values and a unique lived culture. A student success report from Ontario acknowledges, "The reality is that mathematics is deeply embedded in the modern workplace and in everyday life. It is time to dispel the myth that mathematics is for some and to demand mathematics success for all" (Government of Ontario, 2004, p. 9). Further, it is essential that we now concentrate our research on the teaching of Aboriginal students rather than on so called Aboriginal learning styles. To concentrate on "learning styles" is to consider Aboriginal students as victims of their own existence.

The education system can prepare mainstream students for the rich array of mathematically related choices offered in post-secondary programs. Evidence of its success is provided in the graduation numbers of mainstream students from math related college and university programs such as computer science, electronics and engineering. Exciting changes have taken place in math programs over the past twenty years; changes which provide solutions to schools struggling with at-risk students in their mathematics classes. Why then, are Aboriginal students continuing to shy away from mathematics-related university and college programs (Eggertson, 2004)? Why are Aboriginal students showing low performance in mathematics, particularly in the upper elementary and secondary levels of their education (First Nations Math Education, 2009; Fraser, 2010)? This study describes the experiences of two Aboriginal teacher candidates as they work to overcome obstacles from their earlier mathematics experiences in order to understand the elementary mathematics content they will need for teaching. Based on these data, we argue that to assume that a *different* mode of thinking is needed and embodied by Aboriginal students may be without justification.

Background

Mathematics curriculum as adopted in Ontario embodies a mathematics pedagogy that teaches conceptual understanding of concepts, operations and relations (Ministry of Education, 2005). Conceptually based mathematics presents a wonderful opportunity for educators to reach their at-risk student population in general. Freire has long written about our responsibility to do more than to "fill" students with the contents of lectures (Freire, 2000, p. 71). Indeed, we need to do more than to treat students as empty vessels instead of active learners and conceptual problem solvers. Kajander, Zuke and Walton (2008) agree that the movement toward conceptual based mathematics is certainly encouraging for at-risk students. In their study of upper elementary and early secondary students, they determined that “procedural work was often not accompanied by conceptual understanding” (Kajander, Zuke, & Walton, 2008, pp. 1057-1058), which makes problem solving difficult for the at-risk student. The study further argues for the acceptance of conceptually based mathematics in the classroom. Comprehension should emerge with the extensive use of manipulatives, as topics are being introduced. This helps to take the mystery out mathematical concepts. In this paper we argue that conceptually-based mathematics has the potential to help at-risk math students grasp mathematics for the first time in their lives. It is the at-risk students in particular that need to understand mathematical concepts before they are able to put them into practice (Kajander et al., 2008). This must happen in the early grades (Government of Ontario, 2004). We will show that direct instruction and home support are also crucial in helping at-risk students comprehend mathematics. Some Aboriginal students, in particular, must deal with what they view as all-consuming social problems at home and in the community. We are convinced that with such help, provincial schools have the ability to graduate Aboriginal students with strong math foundations.

Rolands and Carson (2004) view conceptually taught mathematics in school as a gateway into the more pleasurable and satisfying aspects of the thinking of human-kind. “Formalized mathematics … is in and of itself one of the great achievements of the human mind, a potentially empowering intellectual discipline, and one of the practical keys to material wealth and well-being. This will be true on any planet in the universe where civilizations have emerged.” (Rolands & Carlson, 2004, p. 331). Emphasizing the beauty of mathematics is important. It draws students in and it uses conceptual math as its tool. “Conceptual mathematics helps to let more people in on this appreciation” (p. 331).

Although conceptually based mathematics helps us to reach out to at-risk students in our school system, clearly there are other factors at play which are preventing us from doing so. Recent mathematics curriculum changes in Ontario indicate an awareness of the issues which need addressing. It is important to question whether the recommendations concerning conceptually based math at the curriculum level are actually being implemented in the classroom. In the Kajander et al. (2008) study of four at-risk students and their teachers who were interested in better understanding the needs of these students, it was determined that the teachers were abandoning conceptually-based math because of the perceived challenges involved in implementing it in the classroom. The authors conclude: “Based on the diversity of the observed students’ characteristics and learning needs, and the challenges these impose on classroom dynamics, we suggest earlier intervention for at-risk students as well as more substantial professional development for teachers” (Kajander et al., 2008, p. 1039).

In Ontario for example, the mathematics curriculum has been re-written to fully incorporate conceptually-based mathematics learning. There is an attempt to back up its implementation with the required support through free on-line tutoring for students in the later grades. Is this tutoring too late for Aboriginal students? How many are even on-line? According to the Expert Panel on Early Math in Ontario, "Success in mathematics in the early grades is critical. Early mathematical understanding has a profound effect on mathematical proficiency in the later years" (Government of Ontario, 2004, p. 22). This is confirmed by a recent Educational Quality and Accountability Office (EQAO) study which concludes that "students who meet the provincial standard early in their schooling are most likely to maintain that high achievement in secondary school … students who do not meet the provincial standard early in their schooling are most likely to struggle in later grades … identifying struggling students early and providing support makes a difference" (EQAO, 2010, ¶ 7).

In a University of Alberta literature review of at-risk students, it is their interpretation that John Dewey's vision of a close cultural match between home and school has resulted in a match between the schools and the wealthy cultures of society, not those deprived of socio-cultural benefits. "Research suggests that it is also generally true that minorities benefit the least from the educational system" (University of Alberta, n.d.). Certainly schools in this country delivering curriculum based on Eurocentric ideologies are not without their issues. Stories of success are emerging, which is encouraging to those who see the massaging of the current system as the best means of fully addressing the needs of at-risk students, including those of Aboriginal descent.

In their recent book, *Disrobing the Aboriginal Industry: The Deception Behind Aboriginal Cultural Preservation*, Widdowson and Howard (2008) cite examples of improvements in an Indian run school noting that "these improvements were not made by instituting "culturally sensitive programs, but through a focus on … academics, and objective assignments" (p. 259). Prior to these improvements, the students had no demands on them and were out of control. Instead of experiencing strong self-esteem, they felt like failures. The principal and her staff largely used careful implementation of Eurocentric educational methods to dramatically improve the educational achievement within the school (Widdowson & Howard, 2008, p. 258). The view that Eurocentric educational methods such as conceptually based math, offer the answers we are looking for is supported by Rolands and Carson, "we simply do not agree with an educational strategy that blocks any child's access to the world's rich heritage of scientific culture, however that culture may have originated, and however many injustices have attended its misuse down through the ages" (Rolands & Carlson, 2004, p. 337). Research out of the University of Alberta also indicates that "One cannot read the research without coming to the conclusion that schools that worked well for every student would also work well for those students who were typically labeled 'at-risk'" (University of Alberta, n.d., p. 3).

Although our school system has the potential to meet the needs of Aboriginal students in math, as noted above, recent studies indicate that we are not doing so. Sheila Fraser (2010), Office of the Auditor General of Canada, found that

Aboriginal students are 28 years behind the Canadian norm. This is the time it will take to close the gap between 15 year old First Nation children and of the overall Canadian population with a high school diploma. What then, are the problems? Let us start with an examination of the problems of at-risk students in general as indicated by Kajander and Zuke (2007). According to their teacher interviews, at-risk student in general are most affected by attendance issues, behavior issues, lack of home support, reading ability, and gaps in knowledge. The effectiveness of the teachers themselves may be a primary factor in regard to the failure of Aboriginal students.

Despite the tremendously crucial role of teachers in the academic achievement of Native students, research on teachers in the classrooms is scant when compared to other aspects of Aboriginal education. In studies that have taken place, narrow mindedness, lack of awareness, and prejudiced attitudes have revealed that teachers do in-fact, share in the “problem” (Deyhle & Swisher 1997, p. 121). In a study by Deyhle and Swisher, almost 40% of Indian students who dropped out of school stated their teachers did not care about them and did not assist them enough with their assignments (Deyhle & Swisher, 1997). “I didn’t care to finish high school. It was not that important. You see, I was just learning the same thing over and over. Like the teachers didn’t expect anything of you because you were an Indian. They put you in general education, basic classes, and vocation. They did not encourage college bound classes” (Deyhle & Swisher, 1997, p. 131).

Are we willing to put the lion's share of responsibility for Indian retention rates on the backs of the front line educators? Or are such teachers even able to do the job given that they are confronted with a number of modified students and little or no teaching assistants? The method of funding seems to force them into this situation. “At all levels – provincial, regional, and local – the regular and special education models operate under separate bureaucracies, policies and procedures, and funding frameworks” (Dunleavy, 2008, p. 1). If teachers are giving up on students because too much is being asked of them, they are likely giving up on those having the most difficulty; which may happen to be Native students struggling with the social problems they are forced to contend with outside of the school environment.

In our study, we examine the influence of these various factors on two Aboriginal teacher education students completing their Bachelor of Education program. In particular, we focus on their knowing and learning of mathematics as needed for teaching.

The Study

Our study takes place in the context of a five-year project on mathematical understanding of pre-service teachers. Students in our program must pass a mandatory examination in conceptually-based elementary mathematics content as needed for teaching with a grade of 60% in order to pass the methods course and thus graduate. We describe our work with two Aboriginal teacher candidates who did not pass this required mathematics content exam in the Bachelor of Education program. The mathematics methods course was taught by the second author, while Tracy, the first author, provided the tutoring.

Both study participants were individually tutored after failing the initial mathematics content exam in order to help prepare them for the supplementary examination. Over 20 hours were spent with each teacher in order to fill in the gaps in their mathematical development and move them into the more conceptual content exam material. Tracy tutored both students in standard methods of mathematics as well as the much more conceptual methods required for teaching to the Ontario curriculum, keeping field notes and audio-tapes of the meetings which formed the data sources for the study.

It was interesting to observe as the sessions progressed that although both students improved at using the more standard methods of learning math, they became much more interested and involved in their own learning when they were able to use conceptual learning of each topic area. Both students asked in-depth questions and tended to demand more of their understanding when working with conceptual based mathematics. They often took hold of the manipulatives when asked to explain a concept. They both made full use of colours to represent their conceptual understanding on paper. They often laughed when working with conceptually-based math concepts. When working procedurally, they would sometimes forget 'which step came next'. Tracy felt like they were mimicking with little or no comprehension emerging when working with standard math procedures. We did not attempt to address language issues or "Aboriginal ways of knowing" despite the fact that one candidate spoke fluent Ojibwa. Our respect for their mathematical abilities ran deep and Tracy focused on keeping expectations high. Her genuine confidence in their abilities to succeed remained solid and was conveyed to them at each point of their success. Her observations of their abilities to succeed using European educational tutoring styles indicate a broad ability base which could be true for all Aboriginal students.

Other factors also emerged during the tutoring sessions. One of the teacher candidates expressed concern about a situation that she had observed on her placement. She said that in her classroom, students were being taken out of the class to be taught Ojibwa. What she found disturbing was that they were being taken out of math class for this supplemental language program. I asked her if she knew Ojibwa. She said she did; that she took it all the way through school along with French. I then asked her which classes she was taken out of to make that happen. She put her hand up to the side of her face, looked at me then looked away. "All different classes" she replied. "Including math classes" I asked? "Yes. I missed a lot of math classes" she answered quietly. One wonders about the funding agreements that are involved in Ojibwa being taught in provincial schools. Given that education is a provincial funding matter and Indians are covered under federal jurisdiction, are boards being supplemented for the attendance of Indian students in their classrooms through tuition agreements? Are Indian students with special needs providing provincial boards with additional funding even beyond tuition? Are Provincial at-risk programs meeting the needs of Aboriginal students in general?

As argued above, the data says they are not.

The data sources in our current study indicate that while the participants were weak overall in their understanding of conceptually-based mathematics, they were able to significantly benefit from the individual tutoring in ways similar to their colleagues who were also at-risk mathematically. We did not observe any differences in learning style or preferences in the study participants from other students deemed at-risk that we have both worked with. In fact overall we concluded that both students were entirely capable of learning as well as any other students we have worked with. The only obstacles to their success that were observed were social obstacles over which they had varying degrees of control. In fact, we believe that in the case of these two students, social obstacles were their greatest hurdle.

Discussion And Recommendations

The data in our case studies support the position that Aboriginal pre-service teachers are able to learn mathematics as needed for teaching in ways similar to other teacher candidates. We did not find evidence of a culturally-specific learning style or way of knowing in the context of our study. However, references were made by the participants to a number of social factors which had, and continue to, influence their learning in formal educational programs. These factors have implications for the learning of all Aboriginal students, whose needs should be better identified and addressed at all educational levels.

The testing of students for special needs in math should be all-inclusive, reaching out to include study habits, teaching effectiveness, medical history, social as well as academic information (Kajander & Zuke, 2007). One might suggest that stimulus provided in the home environment should be included in these tests. "Many Aboriginal children are under-stimulated at home and arrive at school ill-equipped to adjust to the demands of a modern education" (Widdowson & Howard, 2008, p. 167). This raises the question, whose responsibility is it to address these problems?

Returning to the question of appropriate teaching methodologies, we have long maintained in our teaching and tutoring practices that math is inherently fun. We have tried over the years to highlight the mysteries and puzzles to be solved in each math concept in order to draw students into the engaging and playful world that we are so attracted to. Lunney-Borden suggests in her dissertation (2010), that numbers are seen among the Mi'kmaw as something for play. Lunney-Borden has discovered after living amongst the Mi'kmaw and learning some of the language spoken, that traditional and more modern games that are played amongst the people have used numbers. It could be argued, however, that mathematics is fun in its own right, that students enjoy mathematics because of its inherent capability for pleasurable diversion in a pure and unattached form, as well as for the fun it affords in solving the problems of the world. Teachers need to understand math concepts well in order to convey enthusiasm for each mathematical topic taught to the student body. How will students ever understand the useful role that mathematics plays in their lives without a persuasive case made by the teacher as to how that might occur? The mathematical perspectives which math teachers carry into the classrooms play a significant role in the attitudes adopted by their students.

The attitude of all math teachers is important in order to keep expectations high and to assist with motivational factors, especially with at-risk students. Teachers should not over-praise students, particularly at-risk students. Over-praise has been shown to be detrimental to the over-all learning experience of at-risk mathematics students (Kajander & Zuke, 2007). Providing students with a false notion of where they stand in their mathematical comprehension might address motivational issues, but will shut students down completely when the truth about their actual level of comprehension comes to light. Many at-risk students are unmotivated and often lack meaningful levels of participation in the classroom (Kajander & Zuke, 2007). On the other hand, motivational issues may arise when students are not having their emotional needs met within their home environment. Such students, including many Aboriginal students, may be looking to have these needs met within their schools and with their teachers. "Direct teaching seems to be key, although it is difficult to tell whether it is the relationship with the student or helping the student understand the content that is a key – probably good teaching for at-risk students is a combination of both" (University of Alberta, n.d., p.3).

We argue, based on evidence from the current study, as well as the literature, that motivation with (particularly Aboriginal) at-risk students is best addressed by working one-on-one with educational assistants or other tutors in order to meet both the educational and emotional needs of students. We further suggest that providing sufficient number of educational assistants will help with behavioural issues, gaps in knowledge and reading abilities.

As noted above, a deeper look into the homes of some students reveals that the definition for students at-risk must include those whose parents' educational levels are low (Kajander & Zuke 2007). As such, we recommend that workshops, designed to introduce parents to the conceptually based mathematics that we are currently teaching their children, are the most cost effective way to "leave no student behind" in mathematics. Workshops would provide a strong message to parents of Aboriginal students that the education of their children is all inclusive reaching out to every aspect of their child's learning experience. Not only could the teacher-documented at-risk problem of home support discussed above be addressed by this approach, but also that of problems such as attendance and behaviour. Without the provision and success of such adult workshops, we suggest that a major increase in educational assistants, who are well trained in conceptual math, will be essential to reach all at-risk students, including those who are Aboriginal.

Mathematics lessons that make use of value- driven problems may reach at-risk students who are often confronting, what are to them, all-consuming social problems in their daily lives. Gutstein (2008), who has taught at-risk students for many years, believes that developing solid cultural and social identities is essential in order for at-risk students to develop the freedom to be who they are. Gustein contends that value driven mathematics should be used to fight injustice and improve society. Gustein routinely uses mathematics in the classroom to reveal social inequalities such as those that occurred in the aftermath of Hurricane Katrina. To illustrate, mathematics was used to discover who suffered most in the tragedy and why. The students looked at pictures of all the African American people who had nowhere to stay but the “Superdome”. The students were then asked if that meant that only African Americans lived in New Orleans, and other similar questions. “They used a very confusing graph from the New York Times to answer a series of questions” (Gutstein, 2008, p. 8). Rather than the current standard math problem approaches, Gutstein would like to see 85% to 90% social justice mathematics where students examine their social realities.

Imagine for a moment, being an educator in a country that entrenches value-based conceptual mathematics. We would be able to teach the youth of this country mathematics in a way they can comprehend it, and also provide them with the knowledge of how to implement it to better our world. Imagine such knowledge spilling over into Aboriginal communities in future generations. Providing quality math education to Aboriginal students will be ground-breaking. It was not attempted through church controlled residential schools where Indian students were not even taught rudimentary math and, as discussed, it has not been properly addressed by recent provincial government run schools either. In taking over the education of Indian students from the churches, we have not yet fully addressed the social issues plaguing Aboriginal communities in spite of government apologies. We need to do that now. We do not need to wait for more research on abstract issues such as “Aboriginal ways of knowing” in an attempt to distinguish the differences between mainstream society and Aboriginal cultures. It is apparent that we are currently attempting to address a Hollywood version of traditional differences rather than contemporary culture; as Widdowson and Howard (2008) say, “Due to a generally sympathetic attitude toward the plight of Aboriginal peoples, Canadians lean to the romanticization of native culture as a way of righting past wrongs and thus have not challenged these dubious (and racist) assertions” (Widdowson & Howard, 2008 p. 47).

In conclusion, we argue that we do not need to investigate “Aboriginal ways of knowing” or Native languages in order to provide and support Aboriginal students with a conceptual math framework. Everything is in place within mainstream schools for Indian students to thrive in mathematics. We have the responsibility to make that learning happen through our funding decisions. More educational assistants and increased home support are needed for at-risk students if we want to graduate Aboriginal students from schools who are able to continue on to pursue math related post-secondary programs. We must remember that one day we may be seen as culpable for our actions as some of those who were responsible for implementing the Indian residential school programs. What will be our legacy? We do have many answers to Aboriginal issues in our current system. A few of them are discussed in this paper. But the one most crucial is that we concentrate our efforts on the teaching of Aboriginal students rather than waiting to discover Aboriginal learning styles.

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RACISM BY NUMBERS

Gale Russell

Perhaps it is due to the shock that I experienced when I first heard the statement: *Mathematics is culturally biased*, but I cannot remember who said it to me or where. Perhaps I even read it somewhere. It is funny how four common words, when strung together can be the starting point of a new and ongoing set of reflections and actions that can change one or more of your most prized and deep-set beliefs. *Mathematics is culturally biased* are four of those words for me. They annoyed me. How dare someone try to question the oneness, the inherent beauty, the universality of my mathematics? I was determined to prove those words wrong, if only for myself. Fortunately, it didn't work out that way.

I started to read works from the field of ethnomathematics. I found myself nodding in agreement with the ideas that I first noticed in these writings because they were reminiscent of my beliefs about the teaching of mathematics. I was familiar with the ideas that the procedures and representations of mathematical ideas that I was taught, memorized, regurgitated, and passed on to my students were not the only way mathematics could be "done". Those ideas were and still are foundational to my beliefs about the teaching and learning of mathematics.

So that is what the unknown spokesperson of those four words meant by culturally biased – we weren't letting students solve the problems in their own ways. Instead we were demanding one type of representation and one set of steps that were determined by someone (most likely Greek – or was he? Greek?) at some time. *I had found place to sit on the 'mathematics is culturally biased' bandwagon.*

As I read more, however, I started to encounter other ideas that went beyond pedagogy. The researchers of ethnomathematics were also questioning what mathematics we teach and why. My thinking was that of course there is other mathematics, but it is the mathematics of the very specialized. Not everyone needs to know about triangular numbers, no matter how *cool* they are. Nevertheless, emerging from what I read were examples of mathematics that had been dismissed or ignored, as being an indication of intellectual inferiority, that were really quite powerful, meaningful, and useful. Why was the Egyptian way of determining surface areas of cylinders ignored so that the Greek (or was it really Greek?) use of formulas could reign supreme (Powell & Frankenstein, 1997a), or why were African solutions to 'non-standard problems' (and why are they non-standard?) dismissed as a fluke and not viewed as examples of true mathematics (Lumpkin, 1997)? Even the questions raised by feminists caught my eye. Why is it that the knitting of socks for families, with the ever changing lengths, widths, and foot shapes, is relegated to non-mathematics (it is women's work), while aspects of pipe fitting and pipe design that use the same mathematical ideas and are recognized as "real" mathematics (Harris, 1997)? Ahhh...mathematics IS culturally biased. It is biased in that decisions are being made based upon beliefs and values (subjective, not objective) of the "powers" who be.

So, there you have it. Mathematics is culturally biased in the way we teach it, in the content that we choose to include in the school system, and in the way anything else that comes to our attention is NOT mathematics. Done.

Sorry, I don't think so. I've now started to grapple with notions of cultural bias that are the absolute foundation of mathematics in our schools. Our very concept of number and numerals, the heart and soul of mathematics, are also in question.

What are numbers? Thesaurus Maths, a website developed and maintained by Cambridge University, defines numbers as telling: "How much or how many of something" (Cambridge University, n.d.). I imagine we are all nodding our heads in agreement, so where is the cultural bias? That will become clearer when we consider a few of the ways that the number systems of Indigenous cultures differ from each other and from the base-ten Eurocentric number system taught in our schools and consider the impact of the exclusion of these alternative number systems from the teaching and learning of mathematics.

Origins and Meanings of Number Names

As the editor of *Native American Mathematics*, Closs (1986) includes a series of essays that consider the mathematical thinking, reasoning, and knowledge of a survey of American Indigenous groups. In the opening essay, Closs discusses the great variance in the number systems used by different Indigenous peoples throughout North and South America. In particular, he notes that the naming of numbers by "the Algonquian, Siouan, Athabascan, Iroquoian … Salish… and … the Quechua" (p. 3) is based upon groupings of 10. For many Inuit tribes, as well as Indigenous peoples from Mexico, Central America, and parts of California, a base 20 system is used, and in most cases a subgrouping of 5 or 10 is also used (Closs, 1986). Poirier (2007) confirms the use of a base 20 system by the Inuit of the territory of Nunavik in Northern Quebec. In addition to base 10 and base 20, Closs also notes that there are some Indigenous groups whose number systems have no base, or use a completely different base or multiple bases.

Indigenous number systems also differ from the Hindu-Arabic number system used in Western-based schools in ways other than the base used. Frequently, Indigenous number words up to 10, and quite often beyond, reflect a physical context for the quantity. As an example, Inuit in Greenland say *arfinek-mardluk* for the quantity '7' which translates into English as "on the other hand, 2". The quantity of '9', *mikkelerak*, translates as "fourth finger", and '13', *arkanenpingasut'* translates to "on the first foot, 3" (Closs, 1986, p. 5). Unlike the English words for the same numbers, seven, nine, and thirteen, these words convey a visual of the quantity and how it could be represented physically. Similar examples of this type of relationship between physical representation and oral naming can be found throughout the languages of many Indigenous cultures and some include a description of physical movement as well. For example, the Unalit word for '11', *atkahakhtok,* translates into "it goes down" (Closs, 1986, p. 6), indicating that as the quantities get larger, the physical representation is moving from the hands to the feet.

In describing the message of a print that shows a "grinning Inuit with two upraised hands" (Closs, 1986, p. 5) that is by an Inuit artist from Cape Dorset in the late 1950s, an elder explained:

> It shows the indication for ten caribou … this way of counting came from the first Eskimo people. How did we count to 100? We went by hands then by feet. Two hands are 10 and one foot is 15. The other foot makes 20. When you have 20, that's one person. One person plus five fingers is 25 and so on. Five people make 100 and 100 means a bundle. Often the foxes and sealskins were bundled into 100 (Closs, 1986, p. 5).

This explanation demonstrates how the Inuit, like many Indigenous cultures, used oral language, visualization, physical, and pictorial representations within their repertoire of communicating about quantity.

Indigenous peoples also created number words that were culturally and historically significant. The Meskwaki (or Fox), an Algonquian tribe, have two words used for 1000, *medaswakw* which translates to "ten hundreds" and *negutimakakw* which translate to "one box". Closs (1986) writes of these two words:

> The latter comes from negut, 'one', and makakw, 'box'. It is the more usual of the two and the more resent. Apparently in some of their earlier sales of lands to the government, the Fox received payment partly in cash. The money was brought in boxes, each box containing a thousand dollars (p. 12).

Through the incorporation of this new word into their language, the Meskwaki meaningfully preserved their remembrance of this part of their history in a mathematical word.

The naming of numbers in many Indigenous cultures also involves the "use [of arithmetic principles] to construct numbers less than 10" (Closs, 1986, p. 11). There is no arithmetic connection found within the numbers less than 10 in English, but "the additive principle is very often used to express 6, 7, 8, and 9 in the form 5 + 1, 5 + 2, 5 + 3, and 5 + 4" (Closs, 1986, p. 11) in Indigenous languages. Different Indigenous cultures also used subtraction – "found in 40 percent of more than 300 languages examined" (Closs, 1986, p. 11) – multiplication, and division, as well as a combination of the operations to name quantities.

The Yanoama, Indigenous people from Venezuela, also present a different way of knowing quantity. In their language, the Yanoama only have words for 1, 2, and 3. Closs (1986), however, notes that

> There still remains a sense of whether a quantity has become larger or smaller, though there is no way to express it numerically. … ' if 20 arrows are standing together and one increases or reduces the bundle by only one during the owner's absence, he will notice this change at once upon a his return'… [and] 'A man who has a hundred ears of corn hanging on a pole … will note the lack of one ear immediately' (p. 17).

This ability to recognize such changes in large quantities would seem to be in opposition to Western research, which asserts that we can only subitize, or identify at a glance, small quantities (five or less is usually the limit given) without counting (Van de Walle & Lovin, 2005).

Eurocentric View of Indigenous Number Systems

When the colonization of America began, as was the case all over the world, an imperative of the process was for the European colonizers to position themselves in superiority over the Indigenous peoples they encountered (Battiste, 2000). This is one reason why Indigenous number systems were ignored by Western mathematics. Lack of understanding and an assumed hierarchy of representation and use also influenced the exclusion of Indigenous mathematical ideas and concepts. (Powell & Frankenstein, 1997) Even the influence of Darwin's evolutionary theory impacted the way historians and mathematicians critiqued and valued Indigenous mathematics (Ascher & Ascher, 1997). Even more disheartening is the claim by many ethnomathematicians that these early misunderstandings and racist beliefs continue to be accepted within many historical and mathematical communities today (Asher & Asher, 1997; D'Ambrosio, 1997; Powell & Frankenstein, 1997a).

Colonizers and researchers alike pointed to differences between Indigenous understanding and use of numbers and that of the European-influenced schooling as examples of the inferiority due to a lack of complexity and abstractness. One such argument made, by researchers such as Lèvy-Brühl and Taylor, was that by naming quantities after body parts the term could not take on the abstract nature of numbers in Western mathematics (Ascher & Ascher, 1997). In addition, it was felt that by using such an association, the number was being confused with the body part and not actually understood. In response to these claims, Ascher & Ascher (1997) write:

> If a word is adopted from an already existing word, it soon takes on a meaning appropriate to its new context. For example, when an English speaker says "a foot" in the context of measurement, no English hearer thinks he is thinking of a body part. If in an [Indigenous] culture, we hear a word for a body part in the context of number, there is no reason to presume otherwise (p. 27).

Is a sign of "real" mathematics that its vocabulary does not have a connection to the concrete? What makes this a more intellectual stance? Perhaps within the ancient Greek belief that mathematics is meant for the elite (D'Ambrosio, 1997) that such an argument could be made, but this does not align with our current Goals of Education or the K-12 Goals of Mathematics in Saskatchewan (Ministry of Education, 2009).

Researchers have noted that many Indigenous number systems have an upper limit of counting. The Yamoama, as noted earlier, only name quantities to 3. Other cultural and linguistic groups have names to 5, 20, 100, or 1000, and then nothing beyond. For some Indigenous peoples it was argued that they were suspicious of larger numbers. The Crow, for example, are reported as saying "honest people have no use for higher numerals" (Closs, 1986, p. 16). Is this a sign of intellectual inferiority? I hope not, as I find it reminiscent of many of the water cooler and coffee row discussions pertaining to government and big business spending and deficits that I have overheard and taken part in over the last decade.

The researcher Prescott, wrote of the Dakota, who have number words up to 1 000 000 000:

> The Indians themselves have no kind of an idea what these amounts are; the only way they could form any kind of an idea would be to let them see the amount counted out. One thousand is more than or a higher number than some of them can count. We hear some of them talk about thousands, and sometimes a million, but still they can give no correct ideas how much of a bulk it would make.

This is a case of an Indigenous number system vocabulary where the upper limit is much higher than others, so instead of it being ignored because it is not in some way rigorous enough, it is invalidated by the assumption that the words have no real meaning for the speakers. Interestingly, Paulos (1988) makes a similar argument regarding European-influenced mathematical understanding of large numbers.

Ascher & Ascher (1997), like Closs (1986), argue against the dismissal and devaluing of Indigenous understanding of number based upon the limit of the vocabulary found in the Indigenous languages.

> How high number words go reflects only how high people in a language community wish to count and is unrelated to intelligence or ability to formulate abstraction. The flexibility and expandability of all languages permit the addition of higher number words as and if they are needed. … New names are created when they are needed, but their presence or absence implies nothing new about the number concept (Ascher & Ascher, 1997, p. 27).

This highlights an important worldview difference between many Indigenous cultures and the world view which informs what is taught in Western schools: the role of place in knowledge construction and use. For many Indigenous people, such as native Hawaiians, "knowledge for knowledge's sake is a waste of time" (Meyer, 2003, p. 57), while it is desired by Western education. How often is our answer to the student's question of "why do I have to know this?" based upon the superior intellect that abounds from knowing more rather than the relevance to the individual student?

Related to this notion of knowledge for knowledge's sake, Indigenous mathematics was also considered inferior because it often focuses on the practical rather than the theoretical. The following story of a western researcher and an Indigenous sheep herder demonstrates this difference in approach and understanding of mathematics: "… the herder agrees to accept two sticks of tobacco for one sheep but becomes confused and upset when given four sticks of tobacco after a second sheep is selected" (Ascher & Ascher, 1997, p. 29). The conclusion reached by mathematicians and Western researchers who hear this story is typically that "the herder cannot comprehend the simple arithmetic fact that 2 + 2 (or 2 x 2) = 4", but the real problem is "…that the scientist… doesn't understand sheep. Sheep are not standardized units" (Ascher & Ascher, 1997, p. 29). What is assumed by the researcher to be a sign of mathematical inferiority on the part of the Indigenous herder actually serves to highlight some of the inherent biases that many researchers bring to understanding, and assigning validity and value to Indigenous mathematical ideas.

The mathematical understandings of Indigenous peoples have also been devalued and ignored by Western mathematics because of their connection to contexts of religion, rituals, and legends. For instance, Vedic mathematics allows for the substitution of 3, 7, and 9 for each other in specific instances. Of this practice, Lèvy-Brühl wrote: "…this equivalence, an absurdity to logical thought, seems quite natural to prelogical mentality, for the latter, preoccupied with the mystic participation, does not regard these numbers in abstract relation to other numbers, or with respect to the arithmetical laws in which they originate" (Ascher & Ascher, 1997, p. 31). Others, however, speak of Vedic mathematics':

> striking and beautiful methods are just a part of a complete system of mathematics which is far more systematic than the modern 'system'. Vedic Mathematics manifests the coherent and unified structure of mathematics and the methods are complementary, direct and easy (Vedic Mathematics, n.d.).

Which is the correct way to describe and view Vedic mathematics, as "prelogical" or "striking and beautiful", moreover, who decides and how? Of course, the Western view of the use of mathematics would never allow for mysticism or superstition to interfere with numerical values. *What floor do I want? 13th please. What do you mean there isn't one – isn't this building 20 stories high?*

The Kèdang also received a less than favourable review from Lèvy-Brühl who noted their association of odd numbers with life and even numbers with death, and the allowing of substitutions within these classifications of the numbers if contextually needed. For example, if a ritual or ceremony is to last a "period of four days…, but cannot be met, two days will do but three would be a serious infringement" (Ascher & Ascher, 1997, p. 31). Is this type of substitution so foreign in the world of Western mathematical thinking? Do not contexts, such as the number of pages in a book (even or odd), allow for such class substitutions? Does a spiritual or ritual context make the mathematical ideas less intellectual, and if so, why?

Some Indigenous cultures also have multiple words for the same quantity, depending upon the context that the quantity is being used in. For example, the Inuit of Northern Quebec have six different words for the quantity of three, depending on the context: three inside, an abstract pattern of three, a collection of three objects, the playing card three, groups of three, and the digit '3' in an abstract sense. Three of these contexts, the playing card, the digit, and the pattern, are newer settings for the quantity of three that the Inuit developed due to the influence of the Western new-comers at the start of colonization (Poirier, 2007). This type of naming by context is one that earlier researchers, such as Lèvy-Brühl, found to be demonstrating an inferiority of mathematical understanding. However, in education we speak of the importance of context in learning, so why has this Indigenous way of contextualizing by number name not been recognized or incorporated into Western mathematics education?

Contemplating Some Answers, Problems, and Solutions

How are these for answers to the questions of why Indigenous mathematics is not found in our mathematics curriculum: "There is not room for any more in the mathematics curriculum. Choices had to be made and whether done so from a racist stance or not, they were made. It's time to move on and focus on getting the students mathematically smart", "All these variations in the way Indigenous cultures view, represent, classify, and use numbers are intriguing and thought provoking, but they are not the mathematics students will need in the 'real' world", or "All of these examples would make a great optional course at the high school level"? To these responses, I now ask the question: "What is the impact of leaving out Indigenous mathematics on students (Indigenous and non-Indigenous)?"

First, consider the impact on Indigenous students. Poirier (2007) writes of how the Nunavik Inuit students are living in "two separate and distinct universes … the world of day-to-day life and the 'southern' mathematical world" (p. 54) . In Nunavik, students are taught all subjects in their native language, an Inuit dialect, until the end of grade 2, at which point they continue their studies in English or French. The one exception is mathematics, which has seen the native language use extended to grade 3 because the English language and the related ways of conceiving of Western mathematics is so fundamentally different from the language and ways of their Indigenous mathematics. To facilitate the transition into English or French language in mathematics, the Elders of the Nunavik communities have been working to develop culturally appropriate words that will assist the students in learning the Western, base-ten, decontextualized number system (Poirier, 2007), while still valuing their native culture's understanding and use of number through the use of their native language.

But what of our First Nations and Métis students in Saskatchewan? How are they being supported in the bridging of their cultural understandings and that of Western mathematics? Or do we assume that since so many of those students, especially those in the south of Saskatchewan or who are not living on a reserve, do not know their native language and thus do not know or are not influenced or even aware of the cultural understandings of mathematics? Just like you cannot know how to make perogies if you do not speak an Eastern European language.

When Meyer (2003) writes:

> Inherent within this discussion of correlation with culture and poor SAT scores is the assumption that our current system is the ideal and that students who do not aspire to that goal are 'at risk'. Surely someone can stand up to that weakest of arguments: 'If you're not like us, then you are deficient' (p. 55).

I am reminded to ask what is the system problem that is causing so many reports to indicate that First Nations students in Saskatchewan are at risk in school? Development of identity and culture are often cited as the missing factors for those students. By teaching mathematics, laden with Eurocentric facts and procedures, in sterile and culturally biased settings (through at least omission), how are we helping the situation? How does a student who understands “equal” as meaning “fair, or for the good of the community” succeed in a mathematics class that is built upon the “truth” of equal being “the same” (personal communication, January 1, 2009).

What do we as teachers of First Nations and Métis students in Saskatchewan know about how their Indigenous cultures understand, represent, and use numbers? I suspect that “nothing” is a pretty good descriptor for many of us – I know it is for me. If we really feel it is important for all students, Indigenous or non-Indigenous alike, to succeed in mathematics, then it is time that we did something about this. However, this does not mean that we need to learn the mathematics of every First Nations tribe in Saskatchewan, as well as the mathematics of those Indigenous students who are continuing to immigrate to Saskatchewan. Instead, I believe we can welcome the Indigenous mathematical knowledge of our students through the changing of pedagogy. By taking the stance that all students come to us with knowledge, and creating an environment which invites and supports the sharing of that knowledge, all ways of “knowing mathematics” that students have can serve as the foundation for mathematical learning, Western or otherwise.

But this type of stance towards teaching and learning does not just make the classroom more inclusive, inviting, and supportive to the students with Indigenous backgrounds. It also provides all students the opportunity to understand the connection between mathematics, place, and need. It engages students in rich and deep meaning making, providing students with alternative representations and ways of knowing and understanding ideas from a mathematical perspective. It provides students with experiences that demonstrate how different perspectives and ways of knowing can be brought to bare upon a situation or idea, and that each one contributes to a deeper and more meaningful understanding and solution.

Racism by numbers exists in Western mathematics education. By omission, alternative ways of viewing, representing, and using numbers that are found within cultures around the world, including within Saskatchewan, have been denied significance, value, and a place among “real” mathematics. By only focusing on the Western use of the Hindu-Arabic number system, and by emphasizing assumed superior intellectual capability as being associated with the use of its symbolic numerals, we are unintentionally telling students with other backgrounds, other beliefs, and other thoughts that they are wrong, inferior, and incapable of attaining superior intellect. As educators we need to reexamine our beliefs that Indigenous students suffer from cultural intelligence deficits and, by changing our pedagogical approaches, start to address the instructional deficits that have allowed the illusions of intellectual deficits to persist for so long. Teaching and learning about numbers is one arena where this change can begin.

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TEACHING NUMERACY IN A COMMUNITY CONTEXT: THE ROLES OF CULTURE AND IMAGINATION

Kanwal Neel and Mark Fettes

Numeracy isn't just about mathematics, which is an abstract construct; it is about mathematics situated in culture. Numeracy has multiple layers and should be linked and contextualized. Numeracy is a term encompassing a range of social activities that involve both mathematical thinking and communication skills (Withnall, 1995). Different definitions emphasize different aspects of the term numeracy. For the purposes of this article we will use the following definition of numeracy:

> Numeracy is the set of mathematical skills needed for one's daily functioning in the home, the workplace, and the community. It is the willingness and capacity to solve a variety of situated and contextual problems that could be functional, social, and cultural. (Neel 2007)

Familiar contexts can make mathematics more accessible to those who have been alienated from it. Relevant learning experiences should be designed to challenge the learner's understanding and extend his or her knowledge to a personal context. Learning activities should be culturally valid and educationally sound. Teachers need to select culturally oriented learning activities that can be used in the study of appropriate topics in mathematics.

For effective numeracy development, it can therefore be beneficial to embed mathematics in cultural activities that involve everyday tasks and solve everyday problems (Nunes, 1992). Yet in order to engage students' imaginations, it is often necessary to present them with ideas and examples that are far from everyday (Egan, 1997; 2005). This article explores how this apparent contradiction might be resolved through the approach to culturally inclusive teaching pioneered in the LUCID project.

The performance and participation rates of Aboriginal students in mathematics in BC, as elsewhere in Canada, are significantly lower than those of non-Aboriginal students (Ministry of Education, 2005). This is not due to a lack of numeracy practices In Aboriginal communities, these cultures, like all human cultures, have developed a wide range of activities that rely on various kinds of mathematical thinking (Ascher, 1991; Bishop, 1988; D'Ambrosio, 1985; Zaslavsky, 1991). However, mathematics teaching in school does not usually make any use of this community knowledge (Davison, 1992). In order to explore how this might be done, a series of interviews was conducted in the communities of Haida Gwaii, BC, with members of the school district's Haida Role Model Program, to determine how they use mathematics in their daily lives.

Haida Gwaii Study

Haida Gwaii is a collection of islands situated off the northern coast of British Columbia and south of Alaska. Of the 5200 people living on the islands, approximately 2000 belong to the Haida Nation, the Aboriginal people of this territory. Caution is needed when attempting to generalize from study of one particular Aboriginal group or community, as there is a vast range of cultural differences among First Nations or Aboriginal people more broadly. Nonetheless, the kinds of issues addressed by this study (Neel, 2007) are likely to arise in many settings where the participation and performance of Aboriginal students in mathematics education are at issue. Likewise, we suggest that the approach to mathematics teaching that we advocate in this paper may prove beneficial in a great variety of contexts.

The Haida Gwaii study (Neel, 2007) confirmed that some of the mathematical concepts that people practiced in their daily lives were not congruent to the mathematics taught in school. For example, the artist who draws different geometric shapes such as Ovoids and U-shapes has intuitive knowledge as to what the final piece of art will look like. Somehow the artist has a sense as to what shape will be most appealing to the eye of an observer. The art may integrate mathematical concepts such as symmetry, congruency, and transformations without the artist implicitly or intentionally knowing that they are doing it. Thus a significant pedagogical challenge is to connect such implicit mathematical understanding with the explicit ways in which mathematics is presented in classrooms. Similar conclusions have been reached by Aikenhead (2002), Davison (2002), Nichol and Robinson (2000), and Nunes, Schlieman, and Carraher (1993), among others.

This also reflects what members of the Haida community think schools should be doing. Many of those interviewed were adamant that their children should learn mathematics that is "authentic". They wanted to see their culture acknowledged and represented in the curriculum, but not as some kind of "watered down" curriculum for their children. To their way of thinking, the Haida people's knowledge of problem-solving, spatial relationships, estimation, and measurement, and their interpretation of physical phenomena have enabled them to live for thousands of years in Haida Gwaii, and should be directly related to their formal, conventional school mathematics (Neel, 2007).

How might this be accomplished in practice? One approach that seems worth exploring in depth is to deliberately incorporate both traditions of numeracy – one based in community practice and personal experience, the other in a Western tradition of systematization and formalization – in teaching mathematics, and to look for the imaginative qualities or creative processes underlying both. This paper explores this possibility using examples of numeracy practices from Haida Gwaii and tying them to the WNCP mathematics curriculum, using a curriculum framework developed in the LUCID project that incorporates the principles of imaginative education (Egan, 1997; 2005) and cultural inclusion (Fettes, 2005a; 2005b).

Designing Engagement

One can begin the process at either the Western end or the Indigenous end, knowing that either may lead to a number of false starts before a satisfactory unit emerges. In this case, we will start with a Haida cultural practice familiar to any student from these communities: the making of button blankets. Why, then, should blanket making be a source of imaginative engagement, and how might it be authentically tied to the math curriculum?

Button blankets have been used by a number of First Nations in the Pacific Northwest for over 200 years as a representation of family lineages and crests. The crests are highly stylized representations of various animals such as Raven, Killer Whale, Beaver, and Eagle, as well as certain natural phenomena such as the sun and moon, clouds, and rainbows. Each is tied to the history of a particular lineage and implicitly proclaims the rank or social status of the owners and their hereditary rights, obligations, and powers. In Haida culture, lineage is matrilineal, so women pass their crests to their children along with their family's status and privileges. Button robes are generally only worn at special events such as the raising of a totem pole, a feast, or a graduation ceremony.

Evidently, then, button blankets exert a special fascination because of what they communicate about the person wearing them, and about the event at which they are worn or for which they were made. The design carries a story, perhaps several stories. But the stories are to be told using the precise language of Haida design, with its characteristic use of positive and negative space, its ovoids and U-forms, its motifs of repetition and transformation.

Here, then, is a possible connection to the mathematics curriculum. Transformations occupy a significant place in the BC (WNCP) mathematics curriculum for Grade 9: students are required to study line and rotational symmetry as well as translation on the Cartesian plane (Appendix 1). Instead of choosing arbitrary or abstract shapes for such an exploration, one might look for symbols that evoke some of the same associations of identity, pride, power, and display as the crest designs do. Take sports logos, for instance: An inspection of the logos of NHL teams (Appendix 2) yields elegant examples of rotational and bilateral symmetry. This provides support for the idea that an imaginative and culturally inclusive mathematics unit might be fashioned around this deep source of emotional engagement.

Once this core “transcendent” quality for a unit has been found, one needs a sense of the overall narrative that will be experienced by the students. Drawing on the work of Pueblo educator Gregory Cajete, the LUCID framework identifies four main phases to a typical curriculum narrative: First Encounter, Going Deeper, Creating/Inventing/Re-Imagining, and Integrating/Celebrating. These phases are not necessarily of equal length: the first and last are often quite short, the second and third often quite long. What matters is that a fundamental tension or question be worked out in the course of the unit, much along the lines of a classic narrative form: something happens at the beginning to create a problem, the situation becomes increasingly complex and our understanding of it becomes increasingly detailed, some kind of action is undertaken to resolve the problem, and at the end the situation (along with the actors) has been altered in some significant way.

In this transformation unit, the central tension is that between a definite public identity, symbolized by a crest or logo, and the relative powerlessness and uncertainty of an indefinite private identity. This is a tension experienced directly, on a daily basis, by our Grade 9 students, and we will be using it as a source of emotional energy for learning mathematics. At the same time, we can look for ways of developing the creative or imaginative potential of each student that will allow them to take some ownership of their own ways of expressing identity, and perhaps work through some of the contradictions of their own social positioning.

Thus in First Encounter, students' attention will be drawn to the strong symmetries that are pervasive in commercial and professional logos, as well as the subtle asymmetries that are used to communicate departure from dominant norms (the Apple logo, for example). These design principles will be compared with those in Haida crests, as displayed on button blankets and hats. In Going Deeper, they will start to play with the properties of different transformations and produce variations on existing designs. In Creating/Inventing/Re-Imagining, they will undertake their own design projects, working in the Haida or Western traditions or a combination of the two. And in Integrating/Celebrating, they will display their work with an explanation of the underlying mathematical principles and the meaning of the design.

With the overall narrative arc of the unit in mind, we can now think about the scope and sequence of activities as they unfold. At this level of the design process, many different resources can be drawn on, including more traditional approaches to mathematics education, provided they are integrated within the overall theme. Thus, the introduction of key vocabulary, the use of graph paper and "miras" (semi-transparent plastic devices commonly used to experiment with reflections and translations), the integration of small group projects and whole-class discussions, will all be influenced by the teacher's familiarity with the relevant teaching methods. The particular sequence of activities outlined here is only one possibility. What is essential, however, is that the activities be continually related back to the "why" of the unit – the search for a harmonious visual identity that expresses pride and confidence.

In LUCID, a set of circular planning frameworks is used to assist in the development of these activities. Appendix 3 displays one of these. At the centre of the circle is the "heroic quality" or transcendent value that drives the entire unit. Around this are a number of key categories of "cognitive tools" (Egan, 1997) that tend to be engaging for school-age children in our kind of society, in which language, media, and education connect us with distant and diverse realities. Considering the "tools" (in LUCID sometimes called "tools of imaginative engagement," or TIEs) can be helpful for coming up with ideas for projects or shorter activities that get students thinking in new ways about the topic. The planning framework in Appendix 3 suggests, for example, that one might include an activity in which students collect, classify, and display logos and/or crest designs according to the kind of symmetry they display; this could be done as a scavenger hunt (students are asked to find designs that fit particular criteria), as a research project (students are asked to find all items of a particular set), or in a number of other ways.

Wiggins and McTighe (1998) have created *Understanding by Design*, a way of planning sequence for curriculum in three stages. In Stage one desired results are identified by asking the following questions: What should students know, understand, and be able to do? What enduring understandings are desired? In Stage two, acceptable evidence is determined. How will we know if students have achieved the desired results and met the standards? What will we accept as evidence of student understanding and proficiency? In the last stage, the planning of the learning experiences and instruction is outlined which would promote understanding, interest, and excellence. A unit on shape and space (transformations) created with the *Understating by Design* template is included in Appendix 4.

Conclusion

Today's mathematics curriculum from pre-kindergarten to Grade 12 is in most cases limited to the major successes of the Eurocentric world. Students of Indigenous and multicultural heritage frequently face the challenge of learning in an environment that may undervalue or ignore their cultural backgrounds. Principles and Standards for School Mathematics (NCTM, 2000) calls for a common foundation of mathematics to be learned by all students. It also advocates the need to learn and teach mathematics as a part of cultural heritage and for life. Achieving this goal requires a paradigm shift in the way mathematics is taught and the introduction of culturally inclusive curricula and pedagogy. Learning activities should build upon a student's prior knowledge and present mathematics in an exciting and inclusive way. Context combined with content should direct teaching in the ongoing cultural quest for knowledge. Partnerships need to be developed with educators, elders, parents, policymakers, and others in the community to promote numeracy and change societal attitudes towards mathematics.

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Appendix 1:

Curriculum Learning Outcomes on Mathematical Transformations

NCTM <u>Geometry 9-12</u>

- Understand and represent translations, reflections, rotations, and dilations of objects in the plane by using sketches, and coordinates.
- Use various representations to help understand the effects of simple transformations and their compositions.
- Use geometric ideas to solve problems in, and gain insights into, other disciplines and other areas of interest such as art and architecture. (NCTM, 2000, p. 308)

WNCP Specific Outcomes

- Classify a given set of 2-D shapes or designs according to the number of lines of symmetry.
- Complete a 2-D shape or design given one half of the shape or design and a line of symmetry.
- Determine if a given 2-D shape or design has rotation symmetry about the point at the centre of the shape or design and, if it does, state the order and angle of rotation.
- Rotate a given 2-D shape about a vertex and draw the resulting image.
- Identify a line of symmetry or the order and angle of rotation symmetry in a given tessellation.
- Identify the type of symmetry that arises from a given transformation on the Cartesian plane.
- Complete, concretely or pictorially, a given transformation of a 2-D shape on a Cartesian plane, record the coordinates and describe the type of symmetry that results.
- Identify and describe the types of symmetry created in a given piece of artwork.
- Determine whether or not two given 2-D shapes on the Cartesian plane are related by either rotation or line symmetry.
- Draw, on a Cartesian plane, the translation image of a given shape using a given translation rule, such as R2, U3 or label each vertex and its corresponding ordered pair and describe why the translation does not result in line or rotation symmetry.
- Create or provide a piece of artwork that demonstrates line and rotation symmetry, and identify the line(s) of symmetry and the order and angle of rotation.
- Draw and construct representations of two- and three-dimensional geometric objects using a variety of tools.
  [C, CN, PS, V] (WNCP, 2006, p. 156).

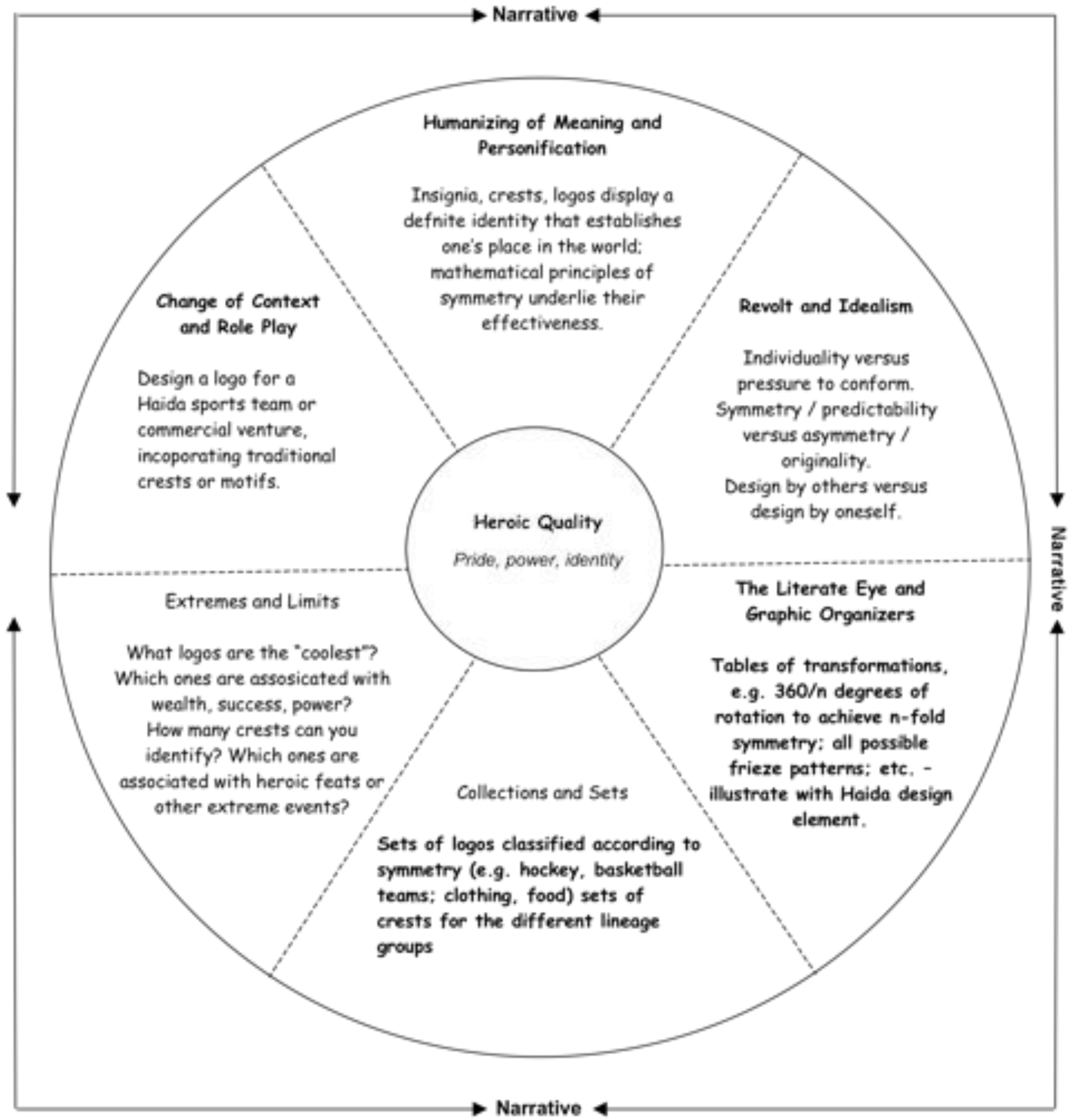
BC Social Studies Grade 7

- Connections between ancient and contemporary cultures
- Cultural adaptation and preservation (http://www.bced.gov.bc.ca/irp/ssk7/planning.htm).

Appendix 2:
Symmetry in Sports Team Logos

1.__________	2.__________	3.__________
4.__________	5.__________	6. __________
7.__________	8. __________	9. __________
10.__________	11.__________	12.__________

Appendix 3:
Romantic Imaginative Education Brainstorming Chart (The Cognitive tools of Literacy)



Appendix 4:
A Culturally Inclusive Imaginative Unit on Transformations

Title of Unit	**SHAPE AND SPACE (TRANSFORMATIONS)**	**Grade Level**	7-9
Curriculum Area	Mathematics	**Time Frame**	7 lessons
Developed By	Kanwal Neel and Mark Fettes		

Identify Desired Results (Stage 1)

Content Standards

NCTM Geometry 9-12

- Understand and represent translations, reflections, rotations, and dilations of objects in the plane by using sketches, and coordinates.
- Use various representations to help understand the effects of simple transformations and their compositions.
- Use geometric ideas to solve problems in, and gain insights into, other disciplines and other areas of interest such as art and architecture.

(NCTM, 2000, p. 308)

WNCP Specific Outcomes

- Classify a given set of 2-D shapes or designs according to the number of lines of symmetry.
- Complete a 2-D shape or design given one half of the shape or design and a line of symmetry.
- Determine if a given 2-D shape or design has rotation symmetry about the point at the centre of the shape or design and, if it does, state the order and angle of rotation.
- Rotate a given 2-D shape about a vertex and draw the resulting image.
- Identify a line of symmetry or the order and angle of rotation symmetry in a given tessellation.
- Identify the type of symmetry that arises from a given transformation on the Cartesian plane.
- Complete, concretely or pictorially, a given transformation of a 2-D shape on a Cartesian plane, record the coordinates and describe the type of symmetry that results.
- Identify and describe the types of symmetry created in a given piece of artwork.
- Determine whether or not two given 2-D shapes on the Cartesian plane are related by either
- rotation or line symmetry.
- Draw, on a Cartesian plane, the translation image of a given shape using a given translation rule, such as R2, U3 or label each vertex and its corresponding ordered pair and describe why the translation does not result in line or rotation symmetry.
- Create or provide a piece of artwork that demonstrates line and rotation symmetry, and identify the line(s) of symmetry and the order and angle of rotation.
- Draw and construct representations of two- and three-dimensional geometric objects using a variety of tools.

[C, CN, PS, V] (WNCP, 2006, p. 156)

BC Social Studies Grade 7

- connections between ancient and contemporary cultures
- cultural adaptation and preservation

(http://www.bced.gov.bc.ca/irp/ssk7/planning.htm)

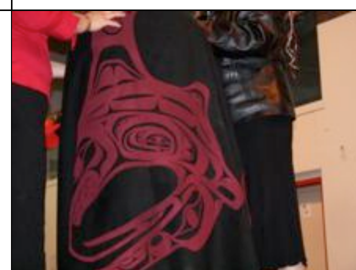
<table>
<tr><th>Enduring Understandings
Students will understand that:</th><th>Essential Questions</th></tr>
<tr><td>• Transformations (translations, reflections, rotations, and dilations) are all around us.
• Transformations provide the framework for artistic representation in many cultures.
• Transformations are imbedded in the design of blankets, and other art in many different cultures, including the Haida Button Blanket.
• Mathematical properties of rotations, reflection, and symmetry are found in many designs in everyday life.</td><td rowspan="3">• How are logos and crests linked to the sense of identity?
• How would life be different if there were no transformations?
• What information must be given in order to define a translation?
• What does a pattern look like that has been created using translations?
• What is the result when a shape is translated twice?
• What information must be given to describe a reflection?
• How can you describe the process of reflecting an object or shape?
• What shapes look the same after they have been reflected?
• What is the net result when we reflect something twice across the same mirror line?
• How can a rotation be described?
• Draw or describe some shapes that look the same after they have been transformed.
• What is the net result when you rotate something twice by two different angles?</td></tr>
<tr><th>Related Misconceptions</th></tr>
<tr><td>• Transformations are used only in a mathematics classroom.
• Indigenous cultures do not use transformations in their art.
• Transformations describe sizes, positions, and orientations of shapes under informal transformations such as flips, turns, slides, and scaling.</td></tr>
<tr><th>Knowledge
Students will know…</th><th>Skills
Students will be able to…</th></tr>
<tr><td>• Transformations (translations, reflections, rotations, and dilations) are all around us.
• There are different types of transformations, informally they can be referred to as: flips, turns, slides, and scaling.
• Similarity, symmetry, congruency are the basis of many transformations.</td><td>• Identify and classify translations, reflections, rotations, and dilations in figures and patterns.
• Reproduce a given transformation on grid paper.
• Make connections between mathematics and artistic endeavors of Indigenous artifacts, particularly Haida Button blankets.
• Create their logo design that would include a variety of transformations.
• Create their own blanket design that would include a variety of transformations.</td></tr>
</table>

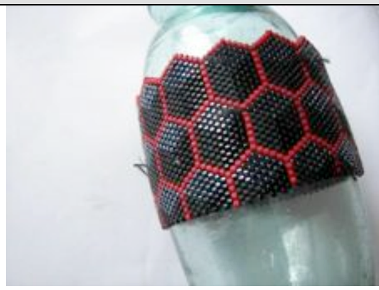
Assessment Evidence (Stage 2)					
Assessment Rubric					
Level	Problem Solving	Reasoning and Proof	Communication	Connections	Representation
Novice	• No strategy is chosen, or a strategy is chosen that will not lead to a solution.	• Arguments are made with no mathematical basis. • No correct reasoning nor justification for reasoning is present.	• No awareness of audience or purpose is communicated. • Little or no communication of an approach is evident.	• No connections are made.	• No attempt is made to construct mathematical representations.
Apprentice	• A partially correct strategy is chosen, or a correct strategy for only solving part of the task is chosen.	• Arguments are made with some mathematical basis. • Some correct reasoning or justification for reasoning is present with trial and error, or unsystematic trying of several cases.	• Some awareness of audience or purpose is communicated, and may take place in the form of paraphrasing of the task.	• Some attempt to relate the task to other subjects or to own interests and experiences is made.	• An attempt is made to construct mathematical representations to record and communicate problem solving.
Practitioner	• A correct strategy is chosen based on the mathematical situation in the task. • Evidence of solidifying prior knowledge and applying it to the problem-solving situation is present.	• Arguments are constructed with adequate mathematical basis. • A systematic approach and/or justification of correct reasoning is present.	• A sense of audience or purpose is communicated. • Communication of an approach is evident through a methodical, organized, coherent, sequenced, and labeled response.	• Mathematical connections or observations are recognized. •	• Appropriate and accurate mathematical representations are constructed and refined to solve problems or portray solutions.
Expert	• An efficient strategy is chosen and progress toward a solution is evaluated. • Adjustments in strategy, if necessary, are made along the way, and/or alternative strategies are considered.	• Deductive arguments are used to justify decisions and may result in more formal proofs. • Evidence is used to justify and support decisions made and conclusions reached.	• A sense of audience and purpose is communicated. • Communication at the practitioner level is achieved, and communication of arguments is supported by mathematical properties used.	• Mathematical connections or observations are used to extend the solution.	• Abstract or symbolic mathematical representations are constructed to analyze relationships, extend thinking, and clarify or interpret phenomenon.

Key Vocabulary
Transformation, Rotation, Reflection, Translation, Enlargement, Dilation, Slide, Turn, Flip, Scale, Congruency, Similarity, Symmetry, Line or symmetry, Point of Rotation, Logo, Crest, Design.
Learning Plan (Stage 3)
Unit Overview **Lesson 1: Connections and Activating Prior Knowledge** a) The teacher introduces a variety of everyday and sports logos to show the use of transformations. b) The teacher introduces a variety of relevant cultural artifacts (Haida artifacts and blankets). c) The students use their imagination and write a story, song or poem that is central to the artifact. d) The students, led by example from the teacher, describe the cultural artifact in mathematical terms. **Lesson 2: Translations** a) The students draw a triangle on graph paper to review coordinate graphing. b) The teacher introduces relevant terms: translation, pre-image, image, and congruent. c) The students, led by example from the teacher, perform translations on their graphing paper. d) The teacher leads a discussion on translations with the students. **Lesson 3: Reflections** a) The students investigate what happens to objects when viewed through a mirror. b) The teacher introduces relevant terms: reflection and line of reflection (mirror). c) The students investigate reflections through Scott Kim's 'Half words. d) The students use miras to reflect their names on a piece of paper. e) The students use miras to do a reflection of Haida crests and art. f) The teacher leads a discussion on reflections with the students. **Lesson 4: Reflection Symmetry** a) The teacher introduces relevant terms: reflection symmetry, line of symmetry, and symmetric. b) The students investigate the reflection symmetry on Haida crests and art using miras. c) In pairs or triples, the students investigate the lines of symmetry in various shapes using miras. d) The teacher leads a discussion on reflection symmetry and how it relates to reflections. **Lesson 5: Rotations** a) The students investigate what happens to objects when they are rotated with the use of clear paper. b) The teacher introduces relevant terms: rotation, and rotational symmetry. c) The students investigate rotation on Haida artifacts using clear paper. d) The students draw a rotation using clear paper. **Lessons 6/7: Creating a Design or Button Blanket** a) In the form of an assessment, the students design a transformation to be performed by another student. b) The students then give their transformation to another student to perform. c) The students investigate transformations in Haida artifacts and blankets. d) The students create their own blanket design that would include a variety of transformations. e) The students create their logo design that would include a variety of transformations.

Template adapted from: Wiggins, Grant and J. McTighe. (1998). *Understanding by Design*, Association for Supervision and Curriculum Development ISBN # 0-87120-313-8 (ppk)

Logos		
1.________________	2. __________________	3.__________________
4.____________________	5.___________________	6. _____________________
7.____________________	8.____________________	9.______________________
10.______________________	11.___________________	1 2.______________________

HAIDA BLANKETS		
 1.________________	 2.__________________	 3.__________________
 4.____________________	 5.__________________	 6. ____________________
 7.____________________	 8.____________________	 9.______________________
 10.______________________	 11.___________________	 12.______________________

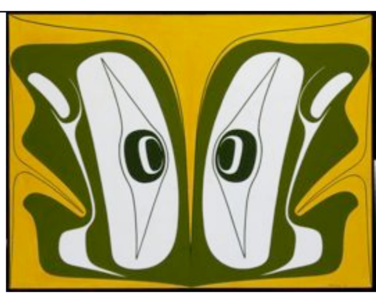
HAIDA ARTIFACTS		
 1.________________	 2.__________________	 3.__________________
 4.____________________	 5.___________________	 6. _____________________
 7.____________________	 8.____________________	 9.________________________
 10.________________________	 11.___________________	 12.________________________

SCOTT KIM'S HALF WORDS

HALF WORDS

Each design on this page is really half of a word. Can you figure out what each design says? To read a design, take two copies of this page, place one copy on top of the other, and slide them around until the two copies of the design meet. Hold the papers up to a light so you can see through both sheets. You may have to rotate or flip over one of the pages. For instance, the second design makes the word "mirror".

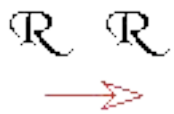
Source:
http://www.scottkim.com/inversions/halfwords.html

HAIDA CRESTS AND ART		
 1.________________	 2.__________________	 3.__________________
 4.____________________	 5.___________________	 6. _____________________
 7.____________________	 8.____________________	 9.______________________
 10.______________________	 11.___________________	 12.______________________

TRANSFORMATIONS

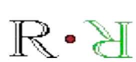
A transformation is a one-to-one mapping on a set of points. The most common transformations map the points of the plane onto themselves, in a way which keeps all lengths the same.

There are four transformations in the plane: translations, rotations, reflections, and glide reflections.



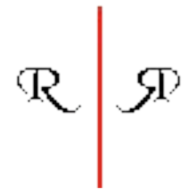
Translations

A *translation* slides all the points in the plane the same distance in the same direction. This has no effect on the sense of figures in the plane. There are no invariant points (points that map onto themselves) under a translation.



Rotations

A *rotation* turns all the points in the plane around one point, which is called the center of rotation. A rotation does not change the sense of figures in the plane. The center of rotation is the only invariant point (point that maps onto itself) under a rotation. A rotation of 180 degrees is called a *half turn*. A rotation of 90 degrees is called a *quarter turn*.



Reflections

A *reflection* flips all the points in the plane over a line, which is called the mirror. A reflection changes the sense of figures in the plane. All the points in the mirror contain all the invariant points (points that map onto themselves) under a reflection.

Glide reflections

A *glide reflection* translates the plane and then reflects it across a mirror parallel to the direction of the translations. A glide reflection changes the sense of figures in the plane. There are no invariant points (points that map onto themselves) under a glide reflection.

Source: http://plato.acadiau.ca/courses/educ/reid/Geometry/Symmetry

Education Building
EDUC1022 4:00pm

Tuesday, January 11, 2011

Mathematical Giftedness: Elitism or egalitarianism?

Bharath Sriraman, known in the mathematics education community for his Erdös-like wandering ways across researchers and institutions across the world, maintains an active interest in mathematics education, educational philosophy, history and philosophy of mathematics and science, creativity; innovation and talent development. Bharath is also a Professor of Central Asian Studies at UM.

He has published over 240+ journal articles, commentaries, book chapters, edited books and reviews in his areas of interest, and presented over 110+ papers at international conferences, symposia and invited colloquia. For a full list visit: http://www.math.umt.edu/sriraman/presented.html

Professor Bharath Sriraman
Department of Mathematical Sciences
The University of Montana

In this lecture, an overview of issues and practices in gifted education will be presented with an emphasis on cultural norms and a focus on "mathematical" giftedness. Political, sociological and cultural issues in gifted education in the U.S. and elsewhere is provided. In particular the issue of elitism associated with identification and/or addressing the needs of highly able students is addressed. Time permitting, we will also examine programs devised for identification and meeting the needs of mathematically gifted students such as the landmark Johns Hopkins Study of Mathematically Precocious Youth.

University of Saskatchewan
College of Education

Pacific Institute for the Mathematical Sciences

University of Saskatchewan The Gwenna Moss Centre for Teaching Effectiveness
Transforming Teaching • Fostering Learning

College of Arts & Science

University of Saskatchewan

vinculum

Journal of the Saskatchewan Mathematics Teachers' Society

VOLUME 3, NUMBER 1 (APRIL 2011)

PROBLEMS AND REFLECTIONS

Do you have a problem that you want to share? Here is your opportunity! (No, not that kind of problem.) This special issue of *vinculum* will focus on problems for the mathematics classroom and, further, the trials, tribulations and successes associated with their implementation. We are interested in you sharing, with the mathematics teachers of Saskatchewan (and beyond), problems that *you* use in *your* mathematics classroom and, more importantly, *your* reflections upon them.

The Journal of the Saskatchewan Mathematics Teachers' Society, *vinculum*, is seeking **Articles** and **Conversations** for the upcoming April 2011 edition. Given the wide range of parties interested in teaching and learning mathematics, we invite submissions for consideration from any interested persons, but, as always, we encourage Saskatchewan's teachers of mathematics to be our main contributors. All contributions must be submitted to egan.chernoff@usask.ca by **March 1, 2011** to be considered for inclusion in the April issue.

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