place. 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. It would seem that Dallas became more aware of his identity as a Blackfoot learner and was able to locate himself in this place. His personal mathematics involved his ability to observe and explain location using both Indigenous and Western mathematics.

We hope the results of this study will inform future investigations into the impact of learning mathematics from place on larger groups of students and how it fosters their academic interests and abilities in mathematics. 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.

Learning Indigenous, Western, and Personal Mathematics from Place
Gladys Sterenberg and Theresa McDonnell
Final Research Report

Introduction

In Canada, Aboriginal[1] postsecondary enrolment and completion rates are significantly lower than those of non-Aboriginals (Canadian Millenium 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 et al, 1996; Council of Ministers of Education, Canada, 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 study, 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

[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.

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 study contributes to one such perspective.

This paper is a preliminary exploration into one student's experiences of learning mathematics from place. Two research questions are investigated: (1) What are one student's previous experiences of learning mathematics? (2) What are one student's experiences of learning Indigenous, Western, and personal mathematics from place?

Literature Review

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, 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 modem 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.

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

Researchers are beginning to better understand student learning from place. However, much of the literature emphasizes environmental or place-based education. Loveland (2002) describes principles of place-based education that emphasize school and community collaboration "to make the local place a good one in which to learn, work, and live" and for students to "do sustained academic work that draws upon and contributes to the place in which they live" (p. 2). Place-based education is often approached as cultural studies, nature studies, real-world problem solving, internships, or entrepreneurial opportunities (Smith, 2002) and is viewed as contributing to student motivation and interest in environmental studies as students make connections to local neighbourhoods or traditions (National Science Foundation, 2002).

Place-based research in Western mathematics often involves these same principles and approaches. Long, Bush, and Theobald (2003) describe place-based Western mathematics instruction as engaging students in activities that are relevant to their daily lives and provide examples of how this can be done through watershed studies and cash flow studies of a community. Lewicki (2000) emphasizes the importance of students working with community members on field studies in local places.

Boyer (2006) describes four rural programs aimed at increasing student achievement in Western mathematics for Native American students and claims that place-based learning had a significant impact on student learning. While test scores did improve, Boyer also notes the positive impact of these programs on empowering local leaders, raising expectations of parents, and shifting the school culture in fundamental ways. Other researchers also document increased student achievement in Western mathematics when Native American students engage in place-based education in Indigenous settings (Hill, Kawagley, & Barnhardt, 2006). It appears that student learning of Western mathematics can be impacted when implementing a place-based curriculum. However, what is evident in these studies is the complexity of the relationship between student achievement and place-based programs and the variety of factors that influence this relationship.

Learning from place is often viewed as similar to place-based education. Indeed, 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). Leroy 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 study to reflect this perspective.

Methodology

Research design

The Blackfoot community was the context of the study. Specifically, we worked with twelve Grade 9 students from a First Nation school located in what is now called Southern Alberta and situated within a Canadian Aboriginal context. One of the researchers, McDonnell, was the classroom teacher; the other researcher, Sterenberg, had been working with teachers and students in the school for two years. All Grade 9 students at the school (fourteen in total) were invited to participate in the study in two ways: (1) by volunteering to be part of initial and concluding focus groups, and (2) by allowing the researchers to collect artifacts of their learning (e.g. classroom work, mathematics problems, photographs generated for the project, written responses, assignments). Six students volunteered to be part of the focus groups. In addition to these participants, we also received consent from six students to allow us to photocopy and digitally scan their student work on classroom assignments.

The research was conducted in three stages: we investigated students' personal experiences of mathematics through an initial focus group, we created and implemented four lessons that intertwined Indigenous and Western mathematics, and we examined students' personal experiences of mathematics through a concluding reflective writing assignment.

Students participated in lessons that addressed 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 researchers.

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 study 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. 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, Kent Ayoungman, to provide us with insight into Indigenous mathematics. Ayoungman was consulted at various stages of the planning, especially during lessons 3 and 4. For these lessons, we arranged a field trip to the Big Rock, a sacred site we selected for our study (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[3]:

---

[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.

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

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

Figure 1

Ayoungman 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.

Data collection

The initial focus group was audio recorded and transcribed (see Appendix A for focus group questions). Student assignments for each lesson were collected (see Appendix B). At the conclusion of the project, reflective writing assignments were collected (see Appendix C). Two students were asked questions by a local newspaper reporter and the published article became another source of data for our study.

Data analysis

We chose to analyze data from one student and present this as a case study. This decision was based on the limitations of the study (see below). Our analysis involved using an adapted framework of mathematics from Ogawa's (1995) research. Identifying themes in the data, we read the interview transcript, the written comments on the reflective writing assignment, and the responses in the newspaper article in detail, noting specific responses that described this student's experiences of mathematics; that is, we selected phrases and sentences that the student used to describe his personal mathematics. Similarly, we noted how the student expressed his understanding and experiences of Western and Indigenous mathematics on the lesson assignments. The concluding reflective writing assignment and the newspaper article provided data about this student's experiences learning Indigenous, Western, and personal mathematics from place. Our analysis involved categorizing data according to the research questions and one student's experiences of personal, Indigenous, and Western mathematics.

Limitations of the study

This study was limited by the number of participants and the collection of data. The small number of students involved in the study provides preliminary descriptions of specific students' experiences but conclusions regarding the impact of learning mathematics from place on student interest, sense of relevance, and achievement cannot be made. Because of student absenteeism, we did not have a complete collection of data from most of the participants. The methodological approach was limited by non-participation because data was collected on specific dates and we did not allow many opportunities for students who were absent to participate later in the study. Indeed, we have chosen to present a case study of Dallas as this represents the most comprehensive set of participant data we were able to collect. Our methodology also limited our ability to claim changes in mathematics achievement, sense of relevance and interest. Future research projects will consider using pre- and post-tests with larger groups of students to help address this. At best, we can offer a glimpse of Dallas' experiences of learning Indigenous, Western, and personal mathematics from place in order to inform further research.

Results

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.

Dallas was absent the day we conducted the focus group but wanted to provide his perspective on learning mathematics. McDonnell did a follow-up interview where Dallas was asked to respond to the focus group questions. 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 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.

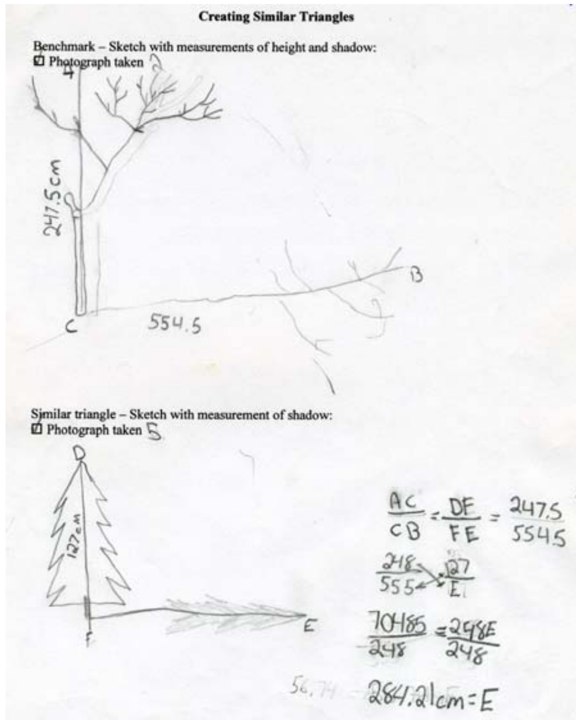


Figure 2

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).

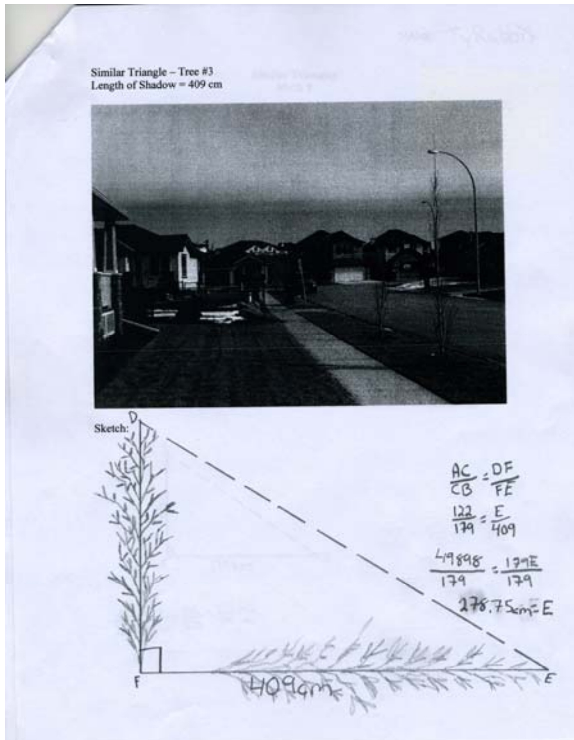


Figure 3

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.

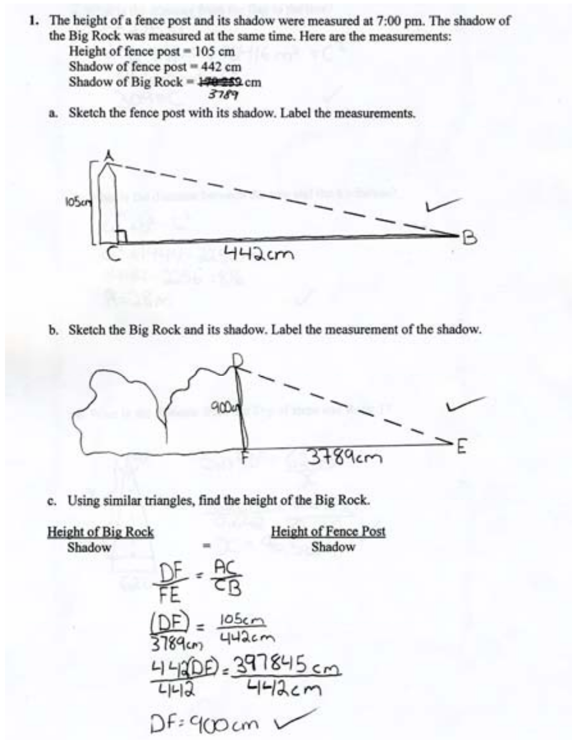


Figure 4

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.”

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. The data sources reflect 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.

Discussion

Our intent for this paper was to investigate one student's experiences with Indigenous, Western, and personal mathematics. Dallas engaged in learning from place through lessons that attempted to intertwine these three types of mathematics. His 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. It is important to note that these 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 Ayoungman 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 Ayoungman 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.

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 study by acknowledging the significance of place, Dallas was offered a different way of viewing mathematics. We believe that this study 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 study, 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 ways 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 study 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.

Conclusion

The purpose of this research paper was to consider one student’s experiences of learning mathematics from place. The results suggest that learning from place can be used to intertwine

Indigenous, Western, and personal mathematics. Dallas acknowledged the importance of Indigenous mathematics that reflected a worldview of Blackfoot peoples. He demonstrated a robust understanding of the Western mathematics concepts of similar triangles, coordinate geometry, and trigonometry. His personal mathematics involved his ability to observe and explain location using both Indigenous and Western mathematics.

We hope the results of this study will inform future investigations into the impact of learning mathematics from place on larger groups of students and how it fosters their academic interests and abilities in mathematics. 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.

References

Aikenhead, G. S., & Ogawa, M. (2007). Indigenous knowledge and science revisited. *Cultural Studies of Science Education, 2*(3), 539-620.

Alberta Education. (2007). *Mathematics Kindergarten to Grade 9 Program of Studies*. Edmonton: Alberta Education.

Bastien, B. (2004). *Blackfoot ways of knowing*. Calgary, AB: University of Calgary Press.

Battiste, M. (2002). *Indigenous knowledge and pedagogy in first nations education: A literature review with recommendations.* Ottawa, ON: National Working Group on Education and Indian and Northern Affairs Canada.

Bishop, A. J. (1994). *Mathematical enculturation: A cultural perspective on mathematics education.* Dordrecht, The Netherlands: Kluwer Academic Publishers.

Bourke, C.J., Burden, J.K., & Moore, S. (1996). *Factors Affecting Performance of Aboriginal and Torres Strait Islander Students at Australian Universities: A case study*. Canberra, Australia: Report of Commonwealth EIP program, AGPS.

Boyer, P. (2006). *Building community: Reforming math and science education in rural schools.* Fairbanks, AK: Alaska Native Knowledge Network.

Cajete, G. (2000), *Native science: Natural laws of interdependence.* Santa Fe, NM: Clearlight Publishers.

Canada Millennium Scholarship Foundation. (2004). *Aboriginal Peoples and Post-Secondary Education: What educators have learned*. Retrieved September 18, 2009 from http://www.millenniumscholarships.ca/images/Publications/aboriginal_en.pdf

Council of Ministers of Education, Canada. (2002). *Best Practices in Increasing Aboriginal Postsecondary Enrolment Rates*. Retrieved September 19, 2007 from http://www.cmec.ca/postsec/malatest.en.pdf.

Hayward, J. (1997). Letters to Vanessa: On love, science and awareness in an enchanted world. Boston, MA: Shambhala Publications.

Hill, F., Kawagley, O., & Barnhardt, R. (2006). *Alaska rural systemic initiative: Final report, phase II, 2000-2005.* Arlington, VA: National Science Foundation.

Humble, L. H. (2007). *The legend of Napi and the Rock: Napi on the run from the Big Rock of Okotoks.* Retrieved March 18, 2009 from http://canadian-first-nations.suite101.com/article.cfm/the_legend_of_napi_and_the_rock

Indian and Northern Affairs Canada. (2005). *Aboriginal Post-Secondary Education and Labour Market Outcomes Canada 2001*. Retrieved September 18, 2007 from http://www.ainc-inac.gc.ca/pr/ra/pse/01/01_e.pdf

Lakatos, I. (1976). *Proofs and refutations: The logic of mathematical discovery*. Cambridge, UK: Cambridge University Press.

Lewicki, J. (2000). *100 days of learning in place*. Westby, WI: Author.

Little Bear, L. (2000). Foreword to *Native science: Natural laws of interdependence*, G. Cajete, (pp. ix-xii). Santa Fe, NM: Clearlight Publishers.

Long, V. M., Bush, W. S., & Theobald, P. (2003). "Place" value: the rural perspective. Athens, OH: Appalachian Collaborative Center for Learning, Assessment, and Instruction in Mathematics.

Loveland, E. (2002). Connecting communities and classrooms. *Rural Roots Newsletter, 3*(4). Retrieved Feb. 4, 2008 from http://www.ruraledu.org/roots/rr304a.htm

Mankiewicz, R. (2000). *The story of mathematics.* London, UK: Cassell.

Mendelson, M. (2006). *Aboriginal peoples and postsecondary education in Canada*. Ottawa, ON: The Caledon Institute of Social Policy.

National Science Foundation. (2002). *A 10-year agenda for environmental research and education at NSF.* Arlington, VA: National Science Foundation.

Neel, K. I. S. (2007). Numeracy in Haida Gwaii, BC: Connecting community, pedagogy, and epistemology. Unpublished doctoral dissertation, Simon Fraser University, 313 pp.

Ogawa, M. (1995). Science education in a multiscience perspective. *Science Education, 79*(5), 583-593.

Peat, F. D. (2002). *Blackfoot Physics*. York Beach, ME: Red Wheel/Weiser.

Smith, G. (2002). Place-based education: Learning to be where we are. *Phi Delta Kappan*, *83*(8), 584-594.

Sparks, S. (2000). Classroom and curriculum accommodations for Native American students. *Intervention in school and clinic, 35*(5), 259-263.

Appendix A
Initial Focus Group Questions

Guiding questions:

How do you view yourself as a math student?

1. How did you learn math when you were younger?
2. What kind of math student were you?
3. Did you enjoy math?

What early experiences of math have shaped your views?

4. What do you remember about learning math? What are some of your experiences?
5. Do you remember something you enjoyed the most?

What is needed to help you learn math?

6. What do you like most about math?
7. If you were going to give advice to someone coming into Junior High School and how to be successful in math, what would you say?
8. What are some things Grade 6 students could be doing? What do Grade 6 students need to know?
9. How is math important in your own lives?

Appendix B
Lessons

NAME:

Creating Similar Triangles – Lesson 1

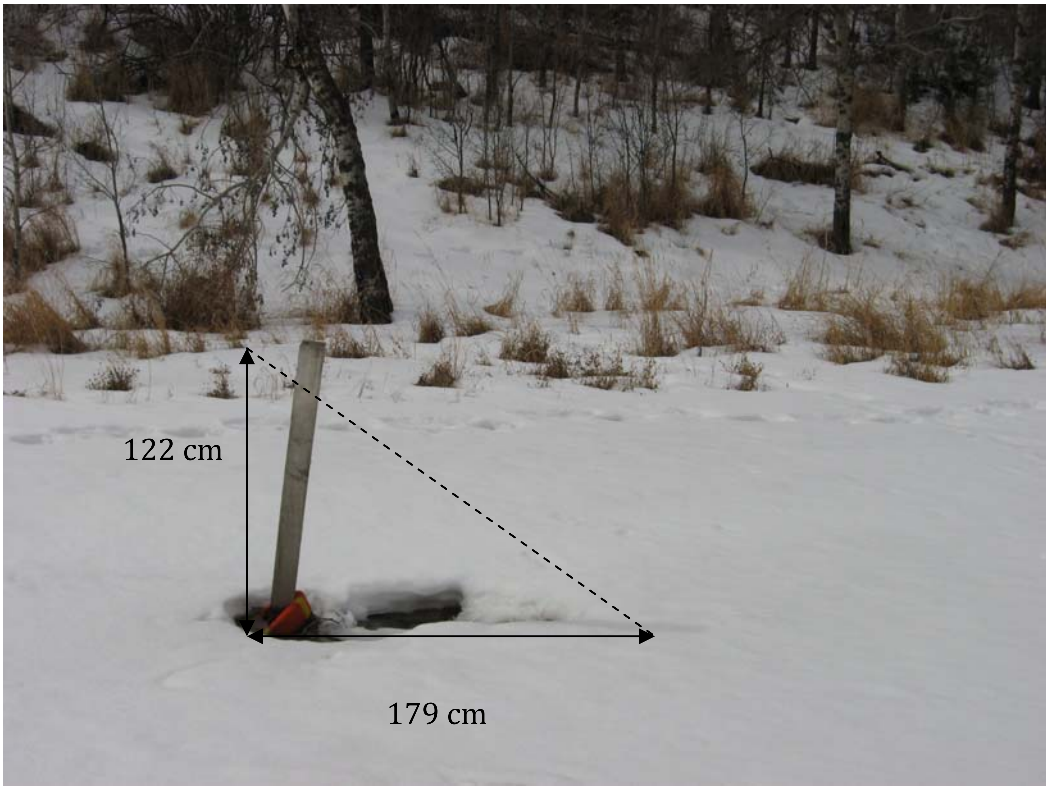
Benchmark – Sketch with measurements of height and shadow:
☐ Photograph taken

Similar triangle – Sketch with measurement of shadow:
☐ Photograph taken

NAME:

Similar Triangles – Lesson 2

Benchmark Object:



Sketch:

Similar Triangle - Evergreen Tree #1
Length of Shadow = 328 cm

Sketch:

Similar Triangle – Tree #2
Length of Shadow = 439 cm

Sketch:

Similar Triangle – Fence post
Length of Shadow = 191 cm

Sketch:

Similar Triangle – Tree #3
Length of Shadow = 409 cm

Sketch:

Additional Problems:

1. Given one triangle, magnify two of the sides by a factor of 2. Explore the relationships between the angles and sides of the original triangle and the enlarged triangle.

2. A person 180 cm tall casts a shadow 45 cm long. A nearby telephone pole casts a shadow 300 cm long at the same time of day. What is the height of the pole?

3. Shandra said that two triangles drawn on a page "looked" similar.
How can she find out for sure if they are, or are not, similar?
Find two different ways she can do this, and explain your reasoning.

4. Explain, giving examples, whether each of the following statements is true or false.
- All similar triangles are congruent.
- All congruent triangles are similar.

Similar Triangles and Trigonometry: Investigating the Big Rock – Lesson 3

1. The height of a fence post and its shadow were measured at 7:00 pm. The shadow of the Big Rock was measured at the same time. Here are the measurements:
Height of fence post = 105 cm
Shadow of fence post = 442 cm
Shadow of Big Rock = 3 789 cm

a. Sketch the fence post with its shadow. Label the measurements.

b. Sketch the Big Rock and its shadow. Label the measurement of the shadow.

c. Using similar triangles, find the height of the Big Rock.

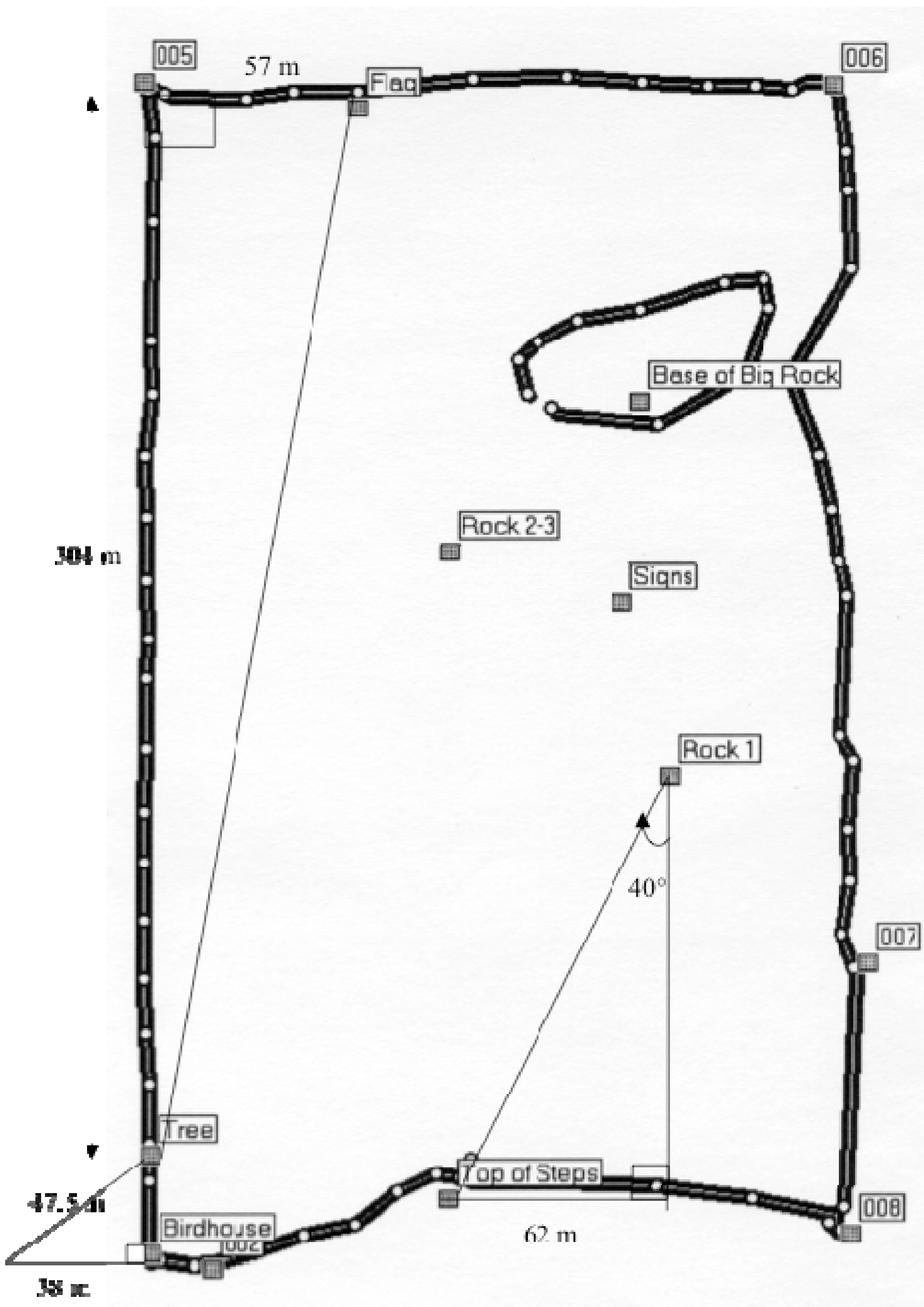
$$\frac{\text{Height of Big Rock}}{\text{Shadow}} = \frac{\text{Height of Fence Post}}{\text{Shadow}}$$

2. Use the map on the next page to find the following lengths. Be sure to use what you know about trigonometry and right triangles to solve each part.

a. What is the distance from the flag to the tree?

b. What is the distance between the tree and the birdhouse?

c. What is the distance from the Top of steps and Rock 1?



005
57 m
Flag
006
Base of Big Rock
Rock 2-3
304 m
Signs
Rock 1
40°
007
Tree
47.5 m
Top of Steps
008
Birdhouse
002
62 m
38 m

Scavenger Hunt - Lesson 4

Names:

____

____

____

GPS#: 308 _ _ _

Coordinates	Question	Answer
N50° 42.232 W114° 04.631	What is the elevation of the bottom step?	
N50° 42.224 W114° 04.701	What do you see on the fence post?	
N50° 42.237 W114° 04.701	How high is the tree directly East?	
N50° 42.398 W114° 04.653	What is on the fence post?	
N50° 42.334 W114° 04.633	Look down. What objects do you see?	
N50° 42.359 W114° 04.608	How many fence posts make up the circumference?	
N50° 42.369 W114° 04.558	What is the largest object between you and the Big Rock?	
N50° 42.330 W114° 04.584	What kind of rock is the Big Rock?	
N50° 42.305 W114° 04.598	What structure do you see at 220° SW?	
N50° 42.297 W114° 04.580	Face S. What direction is the Big Rock from you?	
N50° 42.266 W114° 04.532	What makes a 90° angle with the perimeter fence?	
N50° 42.243 W114° 04.532	What begins at this place?	

On the back of this sheet, sketch the shape formed by the track you walked throughout this scavenger hunt.

NAME: ____________

Appendix C
Reflective Writing Assignment

1. What did you enjoy the most (not including eating ☺)? Why was this fun?

2. What would you change?

3. List 2 math things that you learned.

4. Write 3 additional questions you might include for the scavenger hunt.

5. How can you use the GPS to help you find the circumference of the fence around the Big Rock?

6. What did you learn about yourself?