Learning the Yup'ik Way of Navigation: Studying Time, Position, and Direction

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Abstract

This paper is about the use of mathematics in Yup'ik navigation strategies, as practiced by Fred George of Akiachak, Alaska. Fred George travels by snow machine over snow covered frozen lakes and tundra in the Yukon-Kuskokwim Delta. In day light, he uses the position of the sun and time of day to determine his direction. On clear nights, he uses the position of the Big Dipper and time of night to determine his direction. In addition, he observes the frozen grass, isolated trees, and/or snow waves to reinforce his direction. The sun, Big Dipper, frozen grass, isolated trees, and snow waves function as natural compasses for Fred George.

Originally mentored by his father when he was a boy, Fred has continued to develop his navigational skills on the tundra for over 60 years to hunt and fish for his family of eight children and many grandchildren. He passionately wants to pass his navigational skills on to the young people in Akiachak. He knows young people are no longer being mentored by their families to navigate. Yet many young people drive snow machines, and many become lost on the tundra.

To help Fred George with this mission, this paper was written for the teachers in Akiachak and other native villages. The paper contains descriptions and explanations of the mathematics in navigation practices used by Fred George, plus appropriate classroom activities, which facilitate student understanding of natural compasses, available on the tundra. This valuable knowledge will help young people find their direction when they venture out on a snow machine over frozen lakes and snow covered tundra. In addition, the connection of mathematics to navigation and subsistence supports the cultural knowledge of Yup'ik students, and will contribute to their successful transition into adulthood throughout West Central Alaska.

The Need for Culture in the Mathematics Classroom

In the Alaskan schools, Alaskan Native students are being underserved (Dunham, 2000). Schools with high populations of Alaska Native students do not make Adequate Yearly Progress (AYP) as required in No Child Left Behind (Bush, 2001), and increasing numbers of Native students drop out of school and exhibit violent behaviors (Alaska Department of Education and Early Development [DEED], 2005; First Alaskans, 2005). Currently, Native students do not learn the skills needed to survive in the modern world, nor do they learn the skills needed to survive in their villages. Native elders claim that high school graduates do not have the skills needed to develop successful adult lives, physically or spiritually in the village (Klump & McNeir, 2005)

In the village school districts, Eurocentric teachers (e.g., 75% of teaching staff) are employed from outside the village communities (First Alaskans, 2005). Generally, the teachers are trained in traditional mathematics education, which reinforces Western culture and styles of thought. In village schools with high enrollment of Native students, there is a turnover of an average of 12% of the teaching staff and 28% of administrative staff each year (First Alaskans) As a result; the Western perspective of mathematics is continually reinforced in the classroom. Native students learn the implied message that mathematics is an artifact of Western culture; also, it is inferred that mathematics is not relevant to the Native culture and the community to which they belong (Klump & McNeir, 2005).

In Mountain Village, Alaska, subsistence education has been integrated into the school curriculum very effectively, and the entire community has benefited (Klump & McNeir, 2005). Elders are invited to participate in the education of the children and have a profound influence on the children. Youth crime rates have decreased, and test scores have improved.

The inclusion of the Yup'ik way of navigation into the school mathematics curriculum will enable teachers to use: (a) cultural knowledge, (b) prior experiences, (c) frames of reference, and (d) the performance styles of Alaskan Native students. This inclusion will make learning mathematics more relevant and effective for them (Klump & McNeir, 2005). Elders can be invited into the classroom to share their experiences of navigation on the tundra, especially since they are the traditional teachers of native people and know how to work with the students. In addition, because students are familiar with the environment, they will learn more, and realize the importance of navigation with snow machines over the tundra in order to travel to other villages and for subsistence. They will gain a respect for mathematics and its relevance to Yup'ik culture.

Cultural topics can be used in mathematics curricula to legitimize native knowledge (Powell & Frankenstein, 1997). Such topics are necessary for a global perspective of mathematics and navigation, for mathematical knowledge has been developed in every culture, for example: (a) numeration systems; (b) time calculation; (c) units of measure; and (d) navigation on land, rivers, or oceans. The inclusion of the Yup'ik way of navigation will broaden the Eurocentric perspective of the mathematics curriculum to incorporate mathematics from diverse cultures.

Use of these navigation activities will make the learning of mathematics more concrete for English Language Learners (ELL), such as the Yup'ik students in the village communities. The activities will be visual and hands-on, which will personalize mathematics for them. Therefore, the students will be able to incorporate details from their lives and community into the problem situations and activities (Reed, 2005). According to Reed, the literature on culturally relevant mathematics lessons supports the idea that, when mathematics is embedded in a familiar context, students' comprehension of the problem situation is enhanced, and the discussion of possible solutions is enhanced.

Also, the inclusion of culturally relevant activities in the mathematics curriculum supports the process standards of the National Council of Teachers of Mathematics (NCTM, 2000), specifically: (a) connection, (b) communication, (c) problem solving, (d) reasoning, and (e) representation. When mathematics is connected to culture, students' ability to communicate and comprehend problem situations is enhanced. Students can introduce new ideas into the discussions of possible solutions based on their cultural experiences. Also, in the social interaction of their shared experience about the problem situation, students can better solve problems and reason together (Bradley & Taylor, 2002). In the navigation activities, natural compasses will be introduced, such as: (a) frozen grass, (b) wind blown trees, (c) snow waves, (d) the shadow of the sun, and (e) the Big Dipper. In these activities, students will be able to look at nature in a new way, as an instrument of angle measure, and find new ways to represent mathematical concepts in nature.

Mathematics teachers should not teach the subjects of algebra, geometry, and data analysis as isolated subjects; instead, they should find ways to integrate mathematical knowledge. The former President of NCTM, Lott (2005), stated that precollege students should "do integrated mathematics where you weave in and out of those different topics" (p. 17). The extension of the concepts of angles and angle measurement to situations in nature introduces a variety of ways to explore angles in the concrete domain that can be transferred into the semiconcrete and abstract domains of learning. It is a practical application of mathematics, which interfaces with science knowledge in regard to: (a) weather prediction, (b) water physics, (c) astronomy, (d) global position, and (e) plant biology.

The inclusion of Yup'ik Navigation into the mathematics curriculum can provide numerous cognitive, social, and emotional benefits for the village students. When the Yup'ik mathematics is connected to community culture, the elders can be included in the teaching and learning process, and the mathematical and cultural knowledge will be important to students' future survival as individuals and as a people. The learning experience will help them to understand mathematics within and outside their cultural settings. The teachers, students, and community members will gain knowledge that will enrich their lives and increase their confidence as mathematical problem solvers.

Introduction to Fred George

On the North bank of the Kuskokwim River is the village of Akiachak, 32 miles Northeast of Bethel, Alaska. The population consists of nearly 600 people, 129 families, and 95% of the residents speak Yup'ik. Fred George is an elder and the father of 8 children and grandfather to many; he was born near Marshall Landing on the Yukon River. As a young boy, his family moved to Akiachak. Fred traveled with his father during the winter months to the Yukon River and back. The primary purpose was to ice fish, hunt ptarmigan, caribou, and occasionally moose. Fred has continued to travel 90 miles over the tundra and thousands of lakes every winter to support his family. His winter camp is near Horseshoe Lake, where he ice fishes for pike.

Fred is an expert navigator on the tundra. He delivers mail to people who camp or live in the remote areas of the tundra. Also, he is the leader of a search team of four Akiachak men who search for individuals, who have left Akiachak to travel on the tundra and become lost.

Explore the Map and His Trail

Fred George met on several occasions with other elders, teachers, and university faculty to discuss and demonstrate his navigation strategies. At some point during those discussions, the rivers of the Yukon-Kuskokwim Delta Region were drawn on tracing paper over a map of the region with a mark to depict the location of Akiachak. Fred was asked to draw his routes to travel to Horseshoe Lake, which is about 5 miles South of the Yukon River. He drew one route that was nearly a straight path to Horseshoe Lake. This route was about 30 degrees West of due North from Akiachak. The other route was due North from Akiachak for 60 miles, and it turns Northwest to Horseshoe Lake for 30 miles.

The distance from Akiachak to Horseshoe Lake is about 90 miles. Fred travels on the snow machine at 15-20 miles per hour and, typically, the trip takes 5-6 hours. Although Fred can travel faster, often, he stops along the way to shoot ptarmigan, take a break, or investigate the terrain.

Navigation with the Sun

The sun is a natural compass because it rises every day in the East and sets in the West traveling along a parabolic pathway in the sky. At local noon, the sun passes through its highest point (apex), which is directly over South on the horizon. In the winter months, the sun rises in the Southeast and sets in the Southwest. As the days of the month get closer to December 21, the winter solstice, the positions of rising and setting move Southward from the true East and West positions of the rising and setting on the equinoxes. Fred George knows the position of the sun with respect to the horizon at any given time of day. By viewing the sun position in the sky and looking at his watch, he knows where North, South, East and West are located on the horizon.

Fred George's Sundial in the Snow

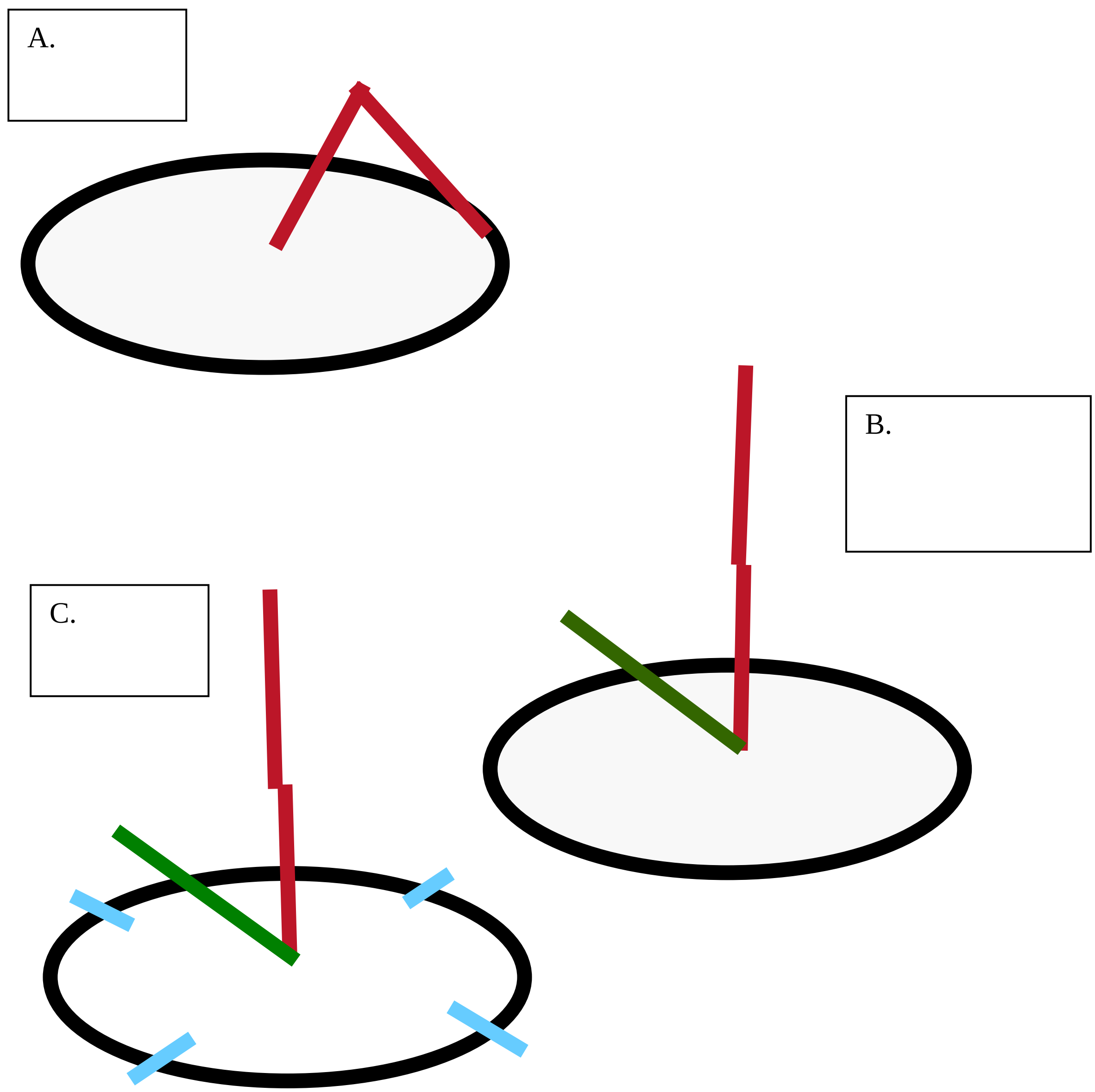
In March 1998, Claudette Engblom-Bradley, Fred George, and his nephew, James Moses, traveled on two snow machines over the snow covered tundra and frozen lakes. The sun was bright, and the winds were quiet, which was unusual because, generally, the winds howl, and the sky is overcast. They stopped by a lonely wind blown, aspen tree. For years, the powerful Southeast winds blew the tree in the northwest direction. The skinny tree survived the harsh winds, below zero temperatures, and blizzard conditions, alone without the presence of other trees nearby. After all those years, the skinny tree was bent over like an old man with its bare branches bent in the Northwest direction. The winds forced the tree to permanently bend toward the Northwest and prevented branches and summer foliage from growing on its Southeast side.

Fred George is a fluent Yup'ik speaker, and his English is limited. Fred George mentored his nephew, James, for many years to navigate across the tundra. James is a member of Fred's search team, who are called upon to find village people lost on the tundra. James was the translator for Claudette Engblom-Bradley, for Fred must speak Yup'ik to express his higher level thoughts. Many times, he communicated nonverbally with hand motions or drawings on paper or in the snow.

In March 1998, when the three tundra travelers stopped for a break, Fred demonstrated his understanding of the relationship between the position of the sun, time of day, and direction with the following sequence of behaviors. Fred pulled out his jack knife and opened it in a right angle position. In the snow, he drew a circle and used the jack knife as a geometry compass. He straightened the knife to a straight angle position and stabbed it in the snow at the center of his circle. He let go of the knife, which stood vertically in the center of the circle. Fred pushed his left sleeve above his wrist to see his watch and the time of day. The shadow of the knife crossed the circumference of the circle. Based on his knowledge of the relation between the position of the sun and the time of day, he bent over the circle to make four finger marks in the snow on the circumference to indicate the four directions: North, South, East, and West (see Figure 1).

Figure 1. The jack knife (drawings by C. Englom-Bradley).

A. Jack Knife (red) was used to draw a circle in the snow.
B. Jack Knife is straightened and placed in center of the circle. The shadow (green) of the knife passed over the circle.
C. After looking at his watch and a nearby tree, Fred marked (blue tick marks) the four directions (North, South, East, and West).



He walked over to the tree and saw the direction of the wind blown branches, then; he double checked his directions with the tree. He returned to the circle to make a correction in the position of his four finger marks. James told me that Fred was showing me the four directions and went to the tree to double check his determination.

The jack knife sundial helped Fred to determine the position of the sun. His watch gave him the time. Since he knew where the sun should be at a given time, he could determine the four directions.

As the earth revolves over a 24 hour period in each time zone, the sun appears to rise in the East and move higher in the sky until noon or local noon. For the remainder of the day, the sun lowers toward the West. At the equinoxes on March 21 and September 21, the sun rises due East at 6 a.m., is high in the sky at noon, and sets due West at 6 p.m. Then, at 9 a.m., the sun should be in the Southeast direction or halfway between the East and South direction. Likewise, at 3 p.m., the sun should be in the Southwest direction.

Sun-Time-Direction Experiments

The sun-time-direction relationship was tested in two events, when Dr. Engblom-Bradley flew to Denver, Colorado for a conference in Boulder. In the Denver airport, she asked a stranger for directions to Ground Transportation. The stranger said, “The ground transportation is on the East side of the terminal” and walked away leaving her to wonder which side was East.

She decided to use the sun-time-direction relationship. If the position of the sun and time of day is known, then the direction can be determined. She looked up at the teepee shape ceiling of the Denver International Airport. The sun was shining through the teepee flap openings in the ceiling. The sunbeams pointed away from the sun revealing its position. She looked at her watch and was delighted to learn it was 12 noon. She had set her watch to Denver time when the plane landed, for that is her practice when traveling. At 12 noon, the sun was in the South direction, and the sunbeams pointed North. Now she immediately knew where the East side of the building was and walked to the shuttle bus for Boulder, Colorado.

After she checked into the Boulder hotel room, Dr. Engblom-Bradley needed to find the East direction to set up her altar. She observed the sunbeam shining through the window and turned to face the direction of the sun. She checked her watch and learned it was 3 p.m.; therefore, the sun was halfway between South and West. She raised her arms so her left hand pointed South and right and pointed West. Each direction was 45 degrees from the sun direction, which made a 90 degree angle spread between her arms. She concluded East was in the opposite direction, 180 degrees, from her right hand.

Sun Dial

In order to teach fifth and sixth grade students to understand how the sun moves across the sky and to find the four directions, they must understand time zones in Alaska. The State of Alaska spreads over 4 time zones, but the State Legislators put all Alaskans on Juneau time. Hence, in Akiachak, the sun is not in the South at noon. At Akiachak, the longitude is 161 degrees West, and at Juneau, Alaska, it is 134 degrees West. The meridians are 27 degrees apart on the earth. Since there are 360 degrees around the globe and 24 hours each day, the natural time zones are 15 degrees apart. Since most of the Alaska is on Juneau time, Akiachak is 2 natural time zones away from Juneau. This means that, when local noon is at 12 noon during the winter months in Juneau, local noon is nearly 2 pm or 1:54 pm in Akiachak. Therefore, students would have to study the position of sun with respect to the South direction at 1:54 pm in Akiachak. To make this clear visually, students should use a sundial, which has its shortest shadow at 1:54 pm in Akiachak, Alaska (National Oceanic and Atmospheric Administration [NOAA], 2006)

A sundial can be constructed with a nut and 4 inch bolts, two large washers, and a white poster board. A hole is punched in the middle of the poster board, so one washer is placed on the 4 inch bolt, which is put through the hole from the bottom of the poster board. The second washer is placed over the bolt, and the nut is screwed in place. The washers keep the 4 inch bolt perpendicular to the poster board.

The poster board with the 4 inch bolt is placed outside on a sunny morning in a flat area that will not have shade any time during the day. The poster board should be placed a sufficient distance from buildings and trees so that a shadow can be cast on the board. Also, the board should be secured with heavy rocks, so that neither the wind, animals, nor people will move its position. When class begins at 8 or 9 a.m., the students should set up their poster board and trace the outline of the shadow of the bolt on the poster board with a pencil and write the exact time inside the outline. Every hour, students should return to the poster board to trace the outline of the shadow of the bolt on the poster board and write the time inside the outline.

As students trace the outline of the shadow of the bolt, they can observe that the shadow turns and becomes shorter, as the sun becomes higher in the sky. After the sun reaches its highest point, they can observe the shadow as it continues to turn but it increases in length. At the end of the day, the shadows will look like a fan. However, where was the point when the shadow was its shortest? Why would it be short at that point? How fast did the sun move across the sky?

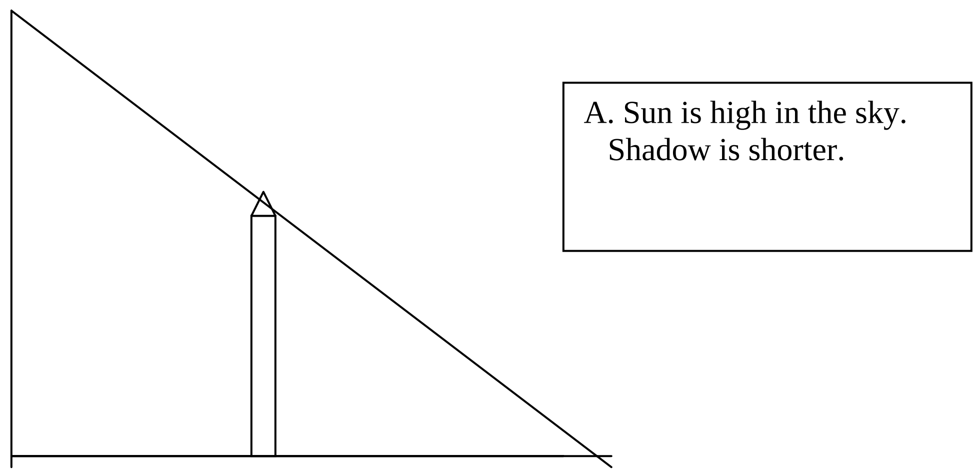
APTE Sundial

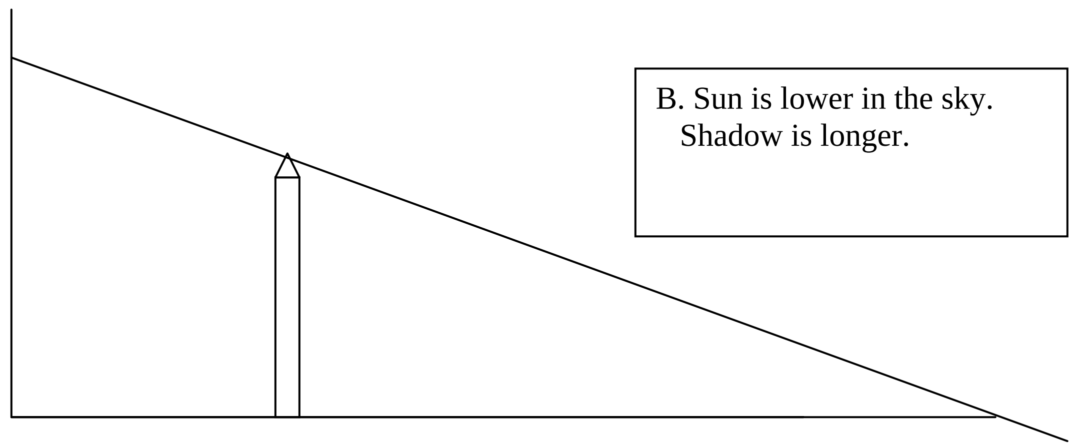
In July 2002, in Anchorage, Alaska, 18 teachers participated in the Alaska Partnership Teacher Enhancement (APTE) Summer Institute, and they made sundials with 4 inch bolts and poster board. They started at 9 a.m. on a sunny day during the Institute. Their poster boards were carefully set outside where the sun would not cast shadows from a building or tree during the day. Each hour they returned to the sundial to trace the shadow and write the time. Each hour, the shadow rotated from left to right and grew shorter. At 1 p.m., the shadow continued to become shorter. At 2 p.m., the shadow was very short. However, by 3 p.m. the shadow began to look longer. At 5 p.m., the program was concluded for the day so the teachers initialed their boards and brought them into the classroom after they outlined the shadow one more time.

Of the 18 participants, 14 were village teachers, and 4 were Anchorage School District teachers. Two teachers constructed one sundial of sticks and stones, for an alternative sun dial, which could be constructed with natural materials that are readily available in a village or fish camp setting. A twig of about three-fourth inches thick was pushed into the dirt to stand vertically to the ground; 2 inch stones were marked with the time with a Sharpie black marker and placed at the stick, the endpoint of the shadow.

After 4 p.m., participating teachers were asked to discuss: why the shadow of the sun was longer in the morning and grew shorter as the day progressed in the afternoon? They explained: when the sun was lower in the sky, it cast a longer shadow. The teachers explored this phenomenon with a flashlight demonstration. When the flashlight was lowered, the 4 inch bolt shadow grew long. As the flashlight was raised, the 4 inch bolt shadow grew short. The teachers concluded this phenomenon happened with the sun as it rises higher in the sky in the mornings and falls lower in the sky in the afternoons (see Figure 2).

Figure 2. Right triangles demonstration (drawings by C. Englblom-Bradley).





When would the shadow be the shortest? The response was, when the sun is highest in the sky. What direction would the sun point to when it is highest in the sky? The response was North. If the shadow points North, where is the direction of the sun? South! When should the sun be highest in the sky? The response was, at noon. Let's find out.

At 4: 30 p.m., the teachers ventured outside to the sundials. The shadows were not shortest at noon. The shadows were shortest near 2 p.m., and the teachers could determine the direction of North, which established the four directions. Why is the sun shortest near 2 p.m. on a sunny July day in Anchorage, Alaska? It was time to bring the sundials into the classroom.

The next day, the teachers looked in the newspaper for the times of sunrise (i.e., 4:46 a.m.) and sunset (i.e., 11:23 p.m.). Working in groups at tables with their sundials, they discussed when should the shadow of the sun be the shortest and why? They could predict how long the shadow would be at sunrise and how long it would be at sunset. They continued their discussion. When would the shadow be the shortest? They calculated the time half way between sunrise and sunset as 2:05 p.m. They compared that time with the time of the shortest shadow on their sundials (Thorsen, 1995/2005).

With pencils, the teachers connected the tips of the nail shadow outlines on their sundial poster boards. They measured the lengths of the nail shadows with centimeter rulers to locate the shortest length and estimated it to be near 2:04 p.m. The set of shadow outlines looked like a fan or a portion of a parabolic curve. The members of the table groups came to a consensus that their shadow outlines were the shortest near 2:04 p.m.

Local Noon

Local noon is the time when the sun is highest in the sky and the shadow of the sun points North. Why is local noon in Anchorage at 2:04 p.m. in July? Does 2:04 p.m. seem late in the day? Should local noon be at noon? In July, Anchorage is on daylight savings time, which moves the sunset 1 hour later to provide more sunlight in the evening. Therefore, the sunrise and local noon are 1 hour later. For most places, local noon is closer to 1:00 p.m. in the summer and 12:00 a.m. in the winter.

However, an investigation of longitude reveals some enlightening answers about local noon in Alaska. Alaska has four natural time zones, but the State Legislators decided to have all of Alaska on Juneau time (Benson, 1983). Since the earth rotates 360 degrees each 24 hours, or 15 degrees each hour, the earth is divided into 24 natural time zones where each zone is 15 degrees wide along the East/West direction. When one views the longitudes of Juneau, Anchorage, and Akiachak, it is clear that they are in separate natural time zones and the local noon differs by about 1-2 hours (see Table 1).

Table 1

Local Noon for Anchorage and Akiachak in Summer Months

Place	Latitude: Degrees	Latitude: Minutes	Longitude: Degrees	Longitude: Minutes	Difference from Juneau time	Local noon
Juneau	58	18	134	24	0	12:04 p.m.
Anchorage	61	13	149	54	15	1:06 p.m.
Akiachak	60	91	161	43	12	1:52 p.m.

Note. Thorsen (2005).

Speed of the Sun

This investigation of the local noon in Anchorage lead to the next discussion topic: How fast does the sun move across the sky? The teachers measured the angles between the adjacent nail outlines and used angle rulers to determine the time difference with calculators, then, they divided the angle measure by the time difference. They calculated degrees per minute, then degrees per hour. Their calculations revealed various speeds. They discussed in table groups how fast the sun moves across the sky vs. how fast the earth turns each day. The earth turns 360 degrees every 24 hours plus and shifts 1 degree about the sun. It turns 15 degrees per hour plus some for the shift of the earth about the sun.

Quiz and Standards

Being teachers, they developed a sun-time-direction quiz during the APTE Summer Institute. The parameters in the mathematical relationship were**:** (a) time, (b) direction, and (c) position of the sun. If two parameters are known, then the third one can be determined.

1. In Anchorage, local noon is 2:04 on July 12. In what direction does the shadow of the sun point at 2:04 p.m.?
2. If the shadow of the sun points East, what time is it?
3. If the time is 8 a.m., in what direction does the shadow point?
4. If the time is 5 p.m., in what direction does the shadow point?
5. How fast does the sun appear to move across the sky?

From Fred's sundial to the teachers' sundial, the mathematical relationship of the position, time, and direction of the sun are the same. Fred George learned these relationships from his father and from observations he made while he traveled for many years on the tundra. The students can learn these relationships easily and efficiently from the sundial in preparation for navigation during the daytime.

The sundial activities address the following Alaska State Performance standards:

A. In Measurement strand about time:
M2.1.4 Tell time to the nearest half hour distinguishing between morning, afternoon, and evening.
M2.2.3 Tell time using analog and digital clocks identifying A.M. and P.M., find elapsed time.
M2.3.5 Apply information about time zones and elapsed time to solve problems. (DEED, 1999, p. 4)

B. In Geometry strand about angles and rotation:
M5.1.3 Identify and create examples of line symmetry.
M5.2.5 Identify and model transformations of geometric figures describing rotations.
M5.2.6 Locate and describe objects in terms of their position with and without compass directions
M5.3.5 Draw and describe the results of transformations including rotations.
M5.3.7 Draw, Measure, and construct geometric figures with angles. (DEED, 1999, p. 7)

Navigation with the Stars

Just like the sun, the stars continually move in the sky. Akiachak is at the 61 degree parallel or latitude. Therefore, the North star, Polaris, is 60 degrees above the North horizon. The big dipper rotates around Polaris a full circle every 24 hours, like a mammoth clock in the sky. Since the seven Big Dipper stars have rotational paths, which are 30 and 40 degrees away from Polaris, the seven stars are 20 and 30 degrees above the North horizon, when they pass under Polaris. Being 20 and 30 degrees above the horizon makes the Big Dipper an ideal location for a tundra traveler who uses a dog sled or snow machine (Bradley, 2002; MacDonald, 1998).

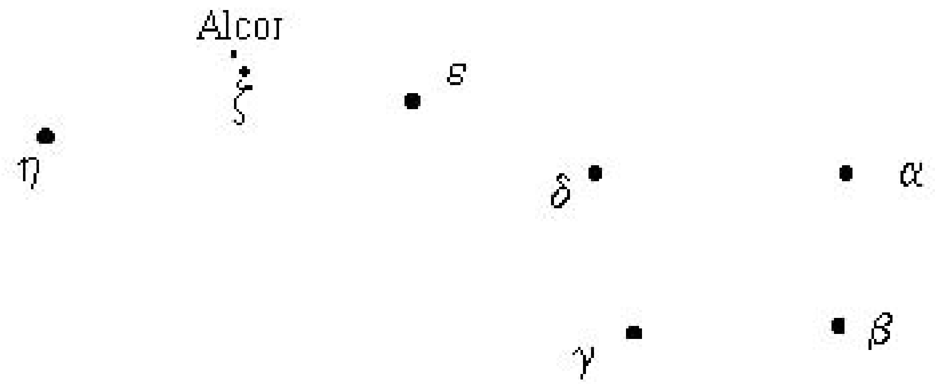
Breaking Trail at Night

On November 10, Fred George prepared his snow machine and camp gear for the long ride across the tundra. He had checked the weather at sunrise each morning and knew the weather would be good for his trip to Horseshoe Lake next to the Yukon River. Horseshoe Lake is about 90 miles Northwest of Akiachak. He prefers to travel at night, but each year the November 10th trip is his first trip for the season. On that day, he breaks trail for 6 hours all the way to Horseshoe Lake.

His gear is ready; he checks his watch. The time is close to 10:00 p.m. He must go now, so he can see the Big Dipper. The people in Fred's village call the Big Dipper, *Tunturyuk.*

Tunturyuk means caribou in Yup'ik. When the elders draw a picture of Tunturyuk about the seven stars, they draw a picture of its head around the dipper handle and its body with legs around the four stars at the right, which appear to be in a rectangular arrangement. The right most pair of stars is the pointer stars and represents Tunturyuk's hind legs. On November 10th, at 10:00 p.m., Tunturyuk looks like a caribou with a long neck that grazes over the horizon with its head in the West direction (see Figure 3).

Figure 3. Big dipper: Alpha, Beta, Gamma, etc. (Eglash, 2002).



Fred leaves the village on his snow machine and travels in a roving pathway through the brush, over the frozen stream, and through more brush. After a mile or so, the brush diminishes, and the open sprawl of the tundra is revealed. Fred stops his snow machine to observe Tunturyuk grazing over the horizon with its front feet (see the Gamma star in Figure 3) at due North and its head (see the Eta star in Figure 3) points Westward toward Horseshoe Lake. Fred checks his watch. It is a minute before 10:00 p.m.

He measures the distance from Tunturyuk's front feet (see the Gamma star in Figure 3) to the horizon. With his right hand, he makes a hand span with his little finger at the front feet of Tunturyuk and his thumb downward toward the horizon. His eye marks the position of his little finger on the front foot star and his thumb against the night sky. Carefully, he turns his right hand horizontally and away from him to see its palm. He holds the four fingers together with the index finger just under the previous thumb position and the little finger toward the horizon. His eye marks the position of little finger, and he carefully rolls his hand, turns the thumb toward him, until the index finger meets the horizon, and the ring finger is adjacent to the previous thumb position. The index finger marks the position of true North on the horizon. Fred wants to head his snow machine direction just under Tunturyuk's head (Bradley, 2002).

On November 10th at 10:00 p.m., Tunturyuk looks like it is grazing over the horizon. At 10:00 p.m., Fred says the dipper handle of Tunturyuk points West, which is as far West as he wants to go to reach Horseshoe Lake. Fred understands that the position of Tunturyuk moves continually. He knows that, by 12:00 a.m., the dipper handle of Tunturyuk will point North on the horizon. Hence, Fred determines the direction to drive his snow machine at night in a manner similar to his use of the position of the sun position and time on his watch during the day. The parameters he uses are the position of the sun or stars, time of day, and direction: North, South, East, or West (see Table 2).

Table 2

Tunturyuk Rotational Speed

Degrees	Number of Hours
360	24
180	12
90	6
30	2
15	1

As Fred travels during the night, Tunturyuk moves. Horseshoe Lake is 90 miles from Akiachak. Fred averages 15-20 miles per hour on his snow machine and makes stops along the way. In 6 hours, the Tunturyuk has become a dipper, and the elders say it is emptying. When the dipper empties, then Fred knows he should have reached his destination.

Map of the Yukon-Kuskokwim Delta

There are thousands of lakes that can be seen on the map of the Yukon-Kuskokwim Delta between Akiachak and Horseshoe Lake. These lakes carry the Yup'ik names of families who have used the lakes to camp and ice fish for generations. Fred's itinerary alternates over countless lakes and tundra.

The shape of the Yukon River meanders from Southwest from Aniak and begins to turn West to carve a *baby's foot* shape with the toe in the West direction. Then it meanders Northwest to Marshall and St. Mary's. Horseshoe Lake is at the toe of the baby's foot, which is approximately 30 degrees, as *the crow flies* West of North from Akiachak. If Fred were to travel 35 degrees West of North from Akiachak, he would miss Horseshoe Lake and travel parallel to the Yukon River toward the Bering Straight.

Selecting a Path to Horseshoe Lake

On nights when the sky is almost clear, Fred selects a path directly 30 degrees West of North to Horseshoe Lake. The Big Dipper has an angle that spreads from the Gamma star to the Eta star of just under 30 degrees or 2 hours of right ascension (Love, 2005). On November 10th at 10:00 p.m., the Gamma star is over the North, and the Eta star is 30 degrees West of North. (See Figure 3.)

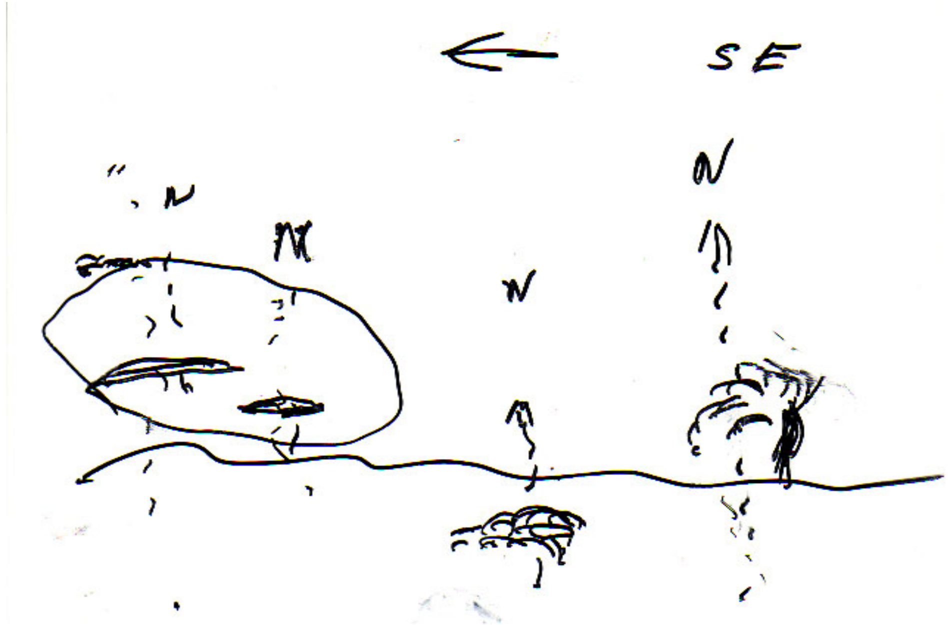
Fred does not know degrees, and the elders remind me that they do not know about degrees. However, he clearly understands the concepts of angle and direction. He will show me, with his hand, pipe cleaners, or watch, what angle or direction he plans to use. Since his apprentice has used the term, degrees, fairly often in discussion, Fred decided to investigate the meaning of degrees during the APTE Summer Institute.

Upon seeing Tunturyuk, Fred double checks the direction with his wristwatch. He places 12 in the North direction. He points to his watch and says "5 minutes," then points in the direction of Horseshoe Lake. Five minutes before 12:00 a.m. is when the minute hand points to

11, which is 30 degrees North of West. Fred has determined the direction to travel with his snow machine.

On cloudy nights, Fred selects a path in which he travels due North for 2 hours and changes West of North about 30 degrees. He relies on the snow waves, trees, and frozen grass to find his direction to Horseshoe Lake. Generally, the *warm* Southeast wind blows from the Southeast toward the Northwest direction. When conditions become stormy, the direction of the wind changes. Generally, the cold winds from the Northeast become very strong. The Southeast winds are most prevalent and blow the water in the Northwest direction. The lakes freeze in October, and the early snow freezes and thaws until it hardens to form frozen waves, like a frozen ocean. The tall grass of the tundra blows in the wind. The prevailing Southeast wind blows the frozen grass which points in the Northwest direction. In October, the first snow covers the grass, which is blown by the Southeast wind. The grass becomes trapped by the snow and frozen in the direction of the wind, Southeast to Northwest. Also, the few isolated trees are constantly blown by the Southeast wind. Since the trees bend over in the Northwest direction, the foliage grows on the Northwest side of the tree (see Figure 4).

Figure 4. Grass, trees, lakes, SE wind (drawing by Fred George).



Tunturyuk Is Constantly Moving

Fred understands that Tunturyuk moves counter clockwise in the sky. Discussion with the elders revealed that Tunturyuk *rests* when it hovers over the horizon on November 10th at 10:00 p.m. After that, Tunturyuk *turns*. Six hours later, Tunturyuk becomes a Dipper and is said to be *emptying out*. These three terms are the closest translations of angle measures in the Yup'ik language in regard to Tunturyuk.

The elders identify three positions for Tunturyuk: (a) resting, (b) turning, and (c) emptying out. On November 10th at 12, midnight, Tunturyuk has turned, and the Eta star is over the North on the horizon. Fred stops to check his watch and moves the number 12 on his watch in the North direction. He determines the direction of 5 minutes West, which is the direction of the number 11 on his watch. Since the angle measure between 12 and 11 on his watch is 30 degrees, Fred adjusts the direction of his snow machine to travel in the direction of the number 11 on his watch, which is 30 degrees West of North (see Figure 5).

Figure 5. Fred's drawing of Tunturyuk.

When Tunturyuk has turned for another 2 hours, the time is 2:00 a.m. on November 11th. Fred measures the angle difference with his hands. He estimates the angle measure with one hand in the direction of the Eta star and the other hand at some width West of that. He was not clear about how he estimates the angle measure with his hands. However, the width between his hands is his angle measurement and determines the direction he needs to travel toward Horseshoe Lake.

Creating Board Games

Fred George has observed Tunturyuk for over 60 years of travel on the tundra. However, navigation is dangerous for young people who do not have training. To support their training in the school setting, it is necessary for students to study the movement of stars in the night sky. They need to understand where Tunturyuk is at 2:00 a.m. on November 11th, but also where Tunturyuk is at 10:00 p.m. on November 24th, or December 10th, or January 30th.

The time of night, the position of Tunturyuk, and the four directions are the three parameters that work together in a mathematical relationship, just like the previous investigation with the sun. If a tundra navigator knows any two of these parameters, then he/she can determine the third. As a result of Fred's mentoring, Dr. Engblom-Bradley developed three games for the students to explore the Big Dipper-Time-Direction relationships.

Time has two components: the calendar time and the daily time. Even though the earth turns in 24 hours, also, it rotates around the sun, which causes a shift of 1 degree each day or 30 degrees each month. On November 10th at 10:00 p.m., Tunturyuk rests over the horizon; on December 10th at 10:00 p.m., Tunturyuk has shifted 30 degrees. On February 10th at 10:00 p.m., Tunturyuk has shifted 90 degrees. Fred navigates in March, but by March 10th at 10:00 p.m., Tunturyuk has shifted 120 degrees from the November 10th at the 10:00 p.m. position.

The first board game contains a large circle that represents the entire sky with a smaller circle that is one-third the diameter and whose circumference passes through the center of the larger circle. The smaller circle is the pathway of Tunturyuk in the sky, and it contains the 12 positions of Tunturyuk. North on the horizon is the place where the circumferences of the two circles are closest together (see Figure 6). The 12 positions are used as references for the players to position their Tunturyuk player piece at even numbered hours. For each day, Tunturyuk turns 30 degrees every 2 hours. On the 10th of each month at 10:00 p.m., Tunturyuk has shifted 30 degrees. Hence, the 12 positions were used for the position of Tunturyuk on the 10th of each month at 10:00 p.m. There are two sets of cards next to the board; one set has the Calendar time and the other has Daily time. Students select the Calendar time card and a Daily time card and must determine the position of Tunturyuk. Where is Tunturyuk on April 10th at 8:00 p.m.? The student determines the position of Tunturyuk on April 10th at 10:00 p.m., and then determines the position of Tunturyuk at 8:00 p.m. This game teaches the relationship of time and position of Tunturyuk.

First Game: Title: What is the Position of Tunturyuk?

Designed for two players: A player selects a Calendar Time card and a Daily Time card, and then tries to find the position of Tunturyuk (i.e., the Big Dipper) in the sky. The blue circle is the sky, which has the 12 positions of Tunturyuk in a circular pathway. When a player is successful the player receives a yellow chip. When a player is unsuccessful, the second player has a chance to find the position of Tunturyuk with the same calendar and daily time. Engblom-Bradley designed the game. Teachers in the 2004 Alaska Partnership Teacher Enhancement Math Institute at University of Alaska Anchorage constructed the game board and pieces in the photograph. An electronic version of this game is available snd can be used for the classroom. (Eglash, 2002)

Figure 6. First game.

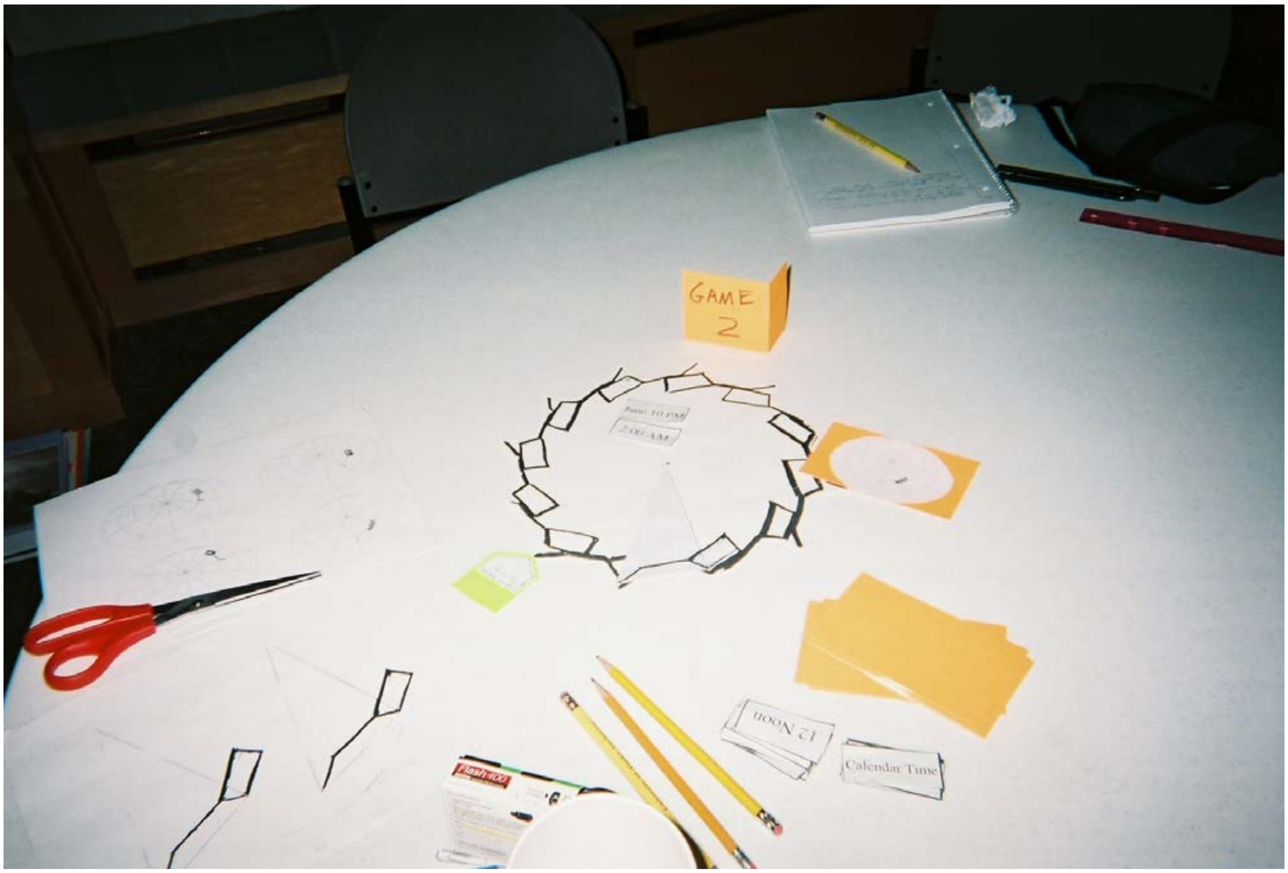
Tunturyuk is hovers over North on the horizon on November 10th at 10:00 p.m. North is under the Gamma Star.(See Figure 3.) On the playing board the dot located in the center of the 12 positions of Tunturyuk represents Polaris. Moving vertically under Polaris is the position of Tunturyuk on November 10th at 10 pm. Players use this position as their reference to determine other positions for Tunturyuk. For example: when a player needs to find the position of Tunturyuk on January 1Oth at 6 a.m., the player places his/her Red or Blue Tunturyuk marker over the November 10th at 10 p.m. position; Moves his/her Tunturyuk marker counterclockwise to the December 10th at 10 p.m. positions, which is the next position at the right.; then continues to move the Tunturyuk marker counterclockwise to the January 10th at 10 pm position; This position is the reference for January, so now the player must find the position for 6 am. Since Tunturyuk moves 30 degrees every two hours, the player continues to move Tunturyuk marker counterclockwise 30 degrees to Midnight; then 30 more degrees to 2 a.m.; then 30 more degrees to 4 a. m.; and finally 30 more to 6 a. m. Tunturyuk is located in the zenith of the sky on January 10 at 6 a.m. The players are learning how the stars move in relation to time and North on the horizon.

Second Game: Title: Where is North?

Designed for two players: A player selects a Calendar Time card and a Daily Time card, and then selects a yellow card with the position of Tunturyuk. There is no blue sky only the 12 positions of Tunturyuk in a circular pathway. The play must determine the direction of North around the circular pathway using a pointer to show the North direction. When a player is successful, the player receives a yellow chip. When a player is unsuccessful, the second player has a chance to find North with the same calendar, daily time, and position of Tunturyuk.

Engblom-Bradley designed the game. Teachers in the 2004 Alaska Partnership Teacher Enhancement Math Institute at University of Alaska Anchorage constructed the game board and pieces in the photograph (see Figure 7). Two electronic versions of this game are available for use in the classroom (Eglash, 2002).

Figure 7. Second game.

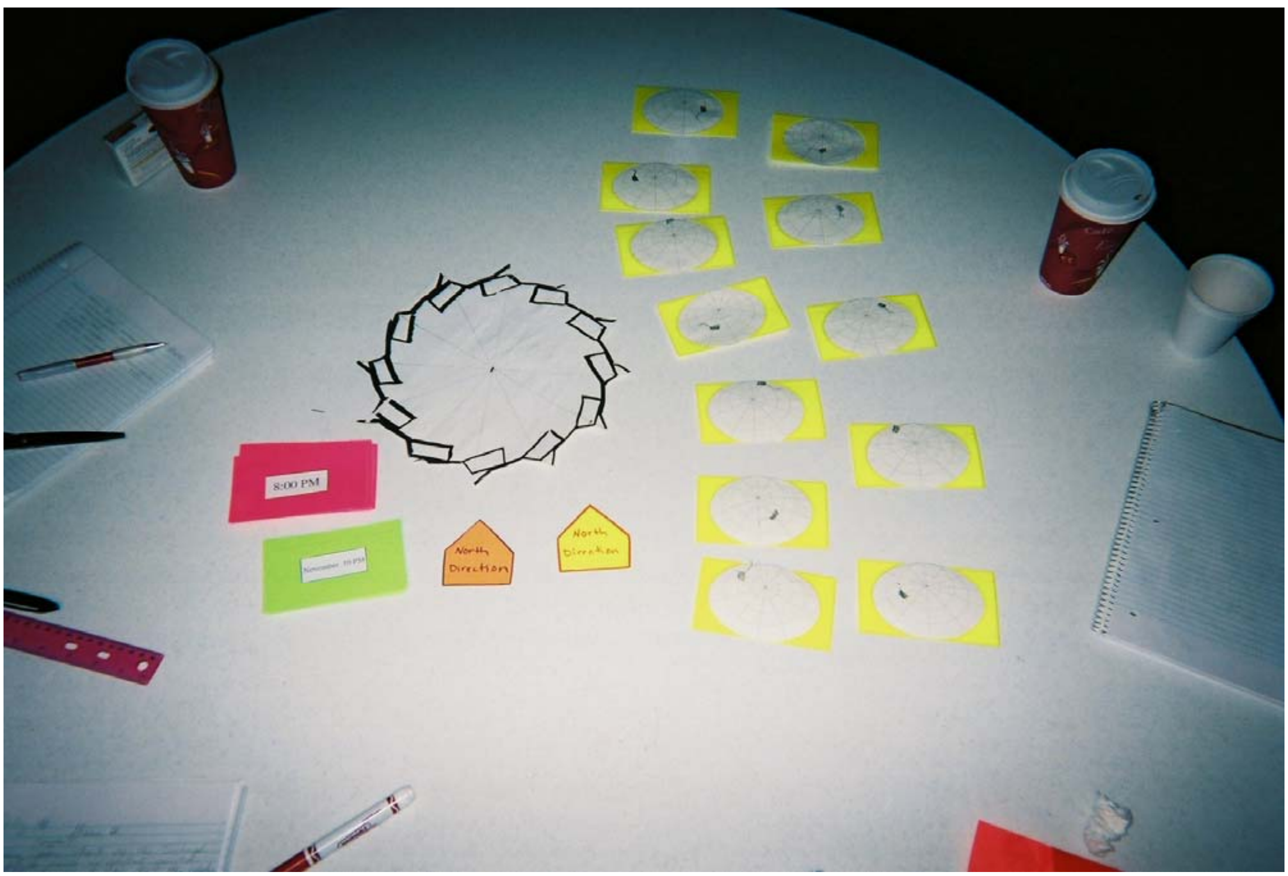


In the third game, the direction of North, the position of Tunturyuk, and the Calendar time are provided. The player must determine what time it is. The player selects the Tunturyuk position cards and a Calendar card. The player determines where Tunturyuk is at 10:00 p.m. for the month then determines the time at the position given in the card. Before elders had watches, they could look at Tunturyuk, know the calendar time, and the direction of North and determine the time.

Third Game – Title: What time is it?

Designed for two players: A player selects a Calendar Time card, and a yellow card with the position of Tunturyuk (i.e., the Big Dipper) in the sky. The blue circle is the sky, which has the 12 positions of Tunturyuk in a circular pathway. The player must determine the daily time. When a player is successful, the player receives a yellow chip. When a player is unsuccessful, the second player has a chance to find the daily time with the same calendar and position of Tunturyuk. Engblom-Bradley designed the game. Teachers in the 2004 Alaska Partnership Teacher Enhancement Math Institute at University of Alaska Anchorage constructed the game board and pieces in the photograph (see Figure 8). An electronic version of this game is available for use in the classroom (Eglash, 2002).

Figure 8. The third game.



Internet games.

Three games are available on the Internet. Eglash (2002) reported that the FIPSE grant to Rensselear Polytechnic Institute (RPI) was used to fund graduate students to develop Culturally Situated Design Technology. There are three games: (a) Tunturyuk Position, (b) Tunturyuk Navigation, and (c) Tunturyuk Time. The games were intended to have three levels of difficulty:

1. Has reference lines and positions Tunturyuk at 2 hour intervals.
2. Has reference lines and positions Tunturyuk at 1 hour intervals.
3. Has no reference lines and positions Tunturyuk at 1 hour intervals.

Each of the three games on the website is at Level 1. Only Tunturyuk Navigation has two levels. Eglash and Engblom-Bradley plan to include the other levels in the future. The following button menu appears on the left side of the screen: (a) Cultural Background; (b) Training; (c) Setting; (d) Navigating; (e) Games: How to Play; (f) Tunturyuk Position; (g) Tunturyuk Navigation, Navigation Level 2; (h) Tunturyuk Time, and (i) Credits. In the playing of these games, mathematics problems are developed for students to practice their navigation skills in order to: (a) understand the position of Tunturyuk, (b) determine the four directions, and (c) know the time (see the URL in Eglash, 2002).

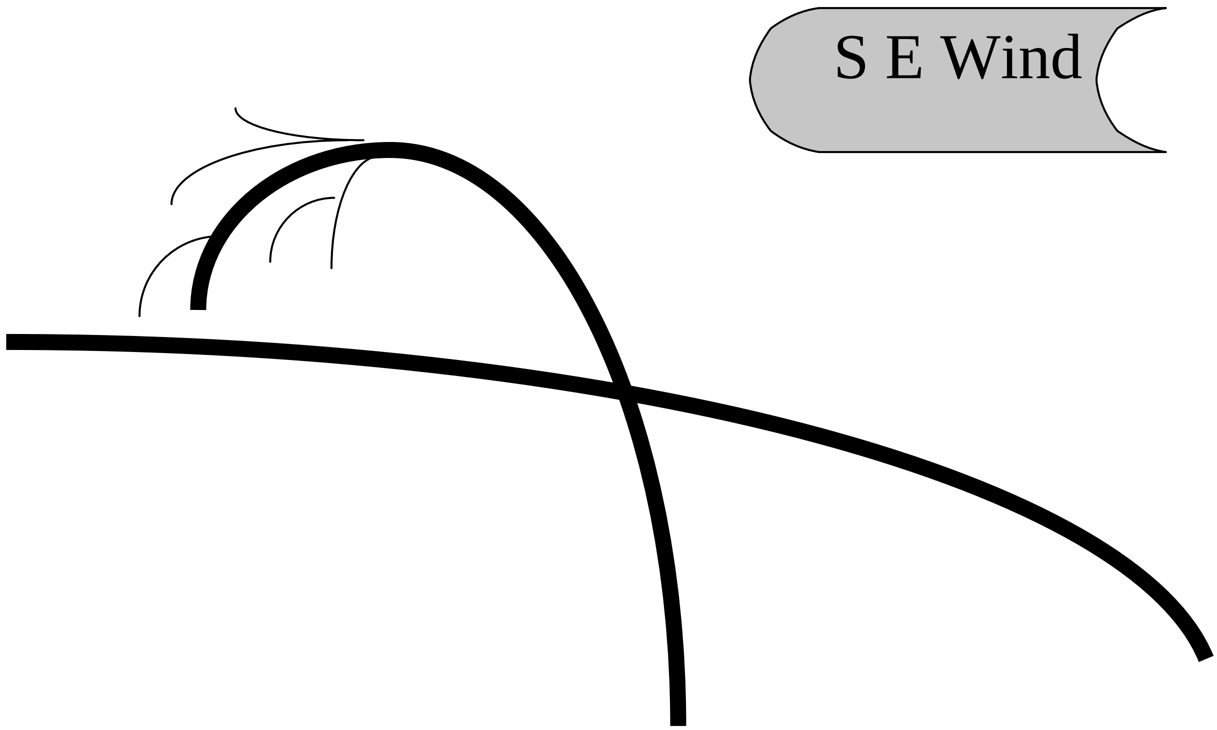
Maintaining Trail

When traveling with Fred on the tundra in March 1998, the three navigators stopped to rest, and Fred pointed to the frozen grass, which was partially exposed. The grass tips and stems close to the roots were covered with ice and snow which left its brown-tan middle exposed to the sun. Fred bent over to place his black, glove covered hand in the direction of North. His black, glove covered hand and the brown-tan exposed grass formed an X over the white frozen snow (see Figure 9).

Figure 9. Frozen grass (photographed by Engblom-Bradley).

Fred can use an isolated tree as a compass to determine his direction. When he made a snow compass with his jack knife, he looked at a nearby isolated tree to reinforce his determination of the four directions. The tree leaned toward the Northwest direction and had no branches on its Southeast side. Fred ran his glove covered hand over its Southwest side to illustrate its lack of growth bumps or broken pieces (see Figure 10).

Figure 10. Isolated tree (drawing by Englom-Bradley).



The Southeast wind carves an axis on the tundra in the lakes, trees, and grass (see Figure 4). Fred can maintain his trail to Horseshoe Lake or locate other places in other directions because he knows the direction of snow waves, trees, and grass. Fred showed me the snow waves on several occasions. They are subtle and difficult to see up close. On his snow machine, Fred can see the snow waves, as elongated (e.g., about 6 feet) gray mountains on the frozen lake. Bouncing around in the sled behind the snow machine, Engblom-Bradley could feel the sled hurl upward and pounce down over the frozen snow waves.

When studying navigation in Fred's home, Engblom-Bradley was browsing over a map of the Kuskokwim Delta region with markings indicating the position of Akiachak and the Yukon River. A collection of pipe cleaners were lying on the kitchen table. Quietly, Fred selected three pipe cleaners from the collection. He placed two parallel pipe cleaners on Engblom-Bradley's map to depict two snow waves. He placed a third pipe cleaner in the direction of his snow machine pathway to Horseshoe Lake, which was about an 80-85 degree angle measure between the pathway of the snow machine and the parallel snow waves (see Figure 11).

Figure 11. Snow waves and pipe cleaners.

Figure 11 is a reproduction of Fred George's placement of three pipe cleaners on the map of the Yukon-Kuskokwim Delta. Two parallel pipe cleaners indicate the snow waves. The third is the direction he travels using the snow waves to find his way to Horseshoe Lake.

When he discussed the snow waves, grass, and trees with the teachers in the APTE Summer Institute, Fred drew the lake with waves, frozen grass, and isolated tundra tree on paper with a directional arrow for the Southeast wind (see Figure 5)

Ice Fishing

On a rainy day in March 1998, Fred George and his six person crew traveled over the tundra to camp near Horseshoe Lake. The next morning after breakfast they snow machined to Horseshoe Lake about a mile or two away from camp. The crew searched over the frozen lake to find places to drill holes for ice fishing. They separated in pairs to drill, and two of the men used a 6 foot battery powered drill. The other four used the more traditional Yup'ik way with the use of 6 foot broom sticks with metal picks attached at one end to chip away the ice for a hole. When the holes were completed, they mounted hooks and fish bait onto the end of a string that was attached to a 3 foot stick. Bait and hook were dropped into a hole. The men shook the stick up and down to attack fish to their bait. Over 200 pike fish were caught the first day. After the third day of fishing, everyone began to pack gear to prepare to return home.

Returning Home

The crew had slept, but awakened before sunrise to dismantle the tents and finish packing. During the return to Akiachak, the Tunturyuk is behind Fred George. He starts his journey back, mounts his snow machine, and faces South. To check his direction, Fred looks up to the sky and twists his body to the right to see Tunturyuk. In this position, Fred can select the stars that are 5 minutes West of North. Holding his right hand vertically with his thumb toward the horizon, he moves his hand upward in an arched pathway in the sky, which passes through zenith and heads toward Akiachak.

However, it was unclear which star he selected. Just prior to leaving Horse Shoe Lake, Fred demonstrated this action without talking: He made certain to capture Dr. Engblom-Bradley's attention and proceeded to twist his body; pointing with his right hand, Fred George drew an arch in the sky; then, pointed his snow machine in the direction of Akiachak to lead the way home. Knowing the direction, he continued his journey home using snow waves, frozen grass, and wind blown trees (see Figure 4.)

Fred's crew was confident that Fred would lead them back to Akiachak. They had their rifles ready for hunting. Their watchful eyes searched for ptarmigan, moose, or caribou, although caribou and moose did not appear that day. White feathered ptarmigan, with their brown feather tips, are difficult to see on a white tundra surface dotted with occasional trees and far off mountains. However, 16 ptarmigan were caught on the return trip. Everyone was happy to get home.

Summary

Fred understands sun-time-direction relationship. When he knows the position of the sun and time of day, he can determine the four directions and the direction of Horseshoe Lake. Fred understands the stars-time-direction relationship. During a clear or nearly clear night when he knows the position of Tunturyuk and the time of night, Fred can determine the four directions and the direction of Horseshoe Lake. The position of Tunturyuk, in relation to time, shifts 30 degrees each month or approximately 1 degree each 24 hour period. This shifting of the earth around the sun adds to the challenge of finding direction using Tunturyuk each month.

Generally, the wind blows from the Southeast direction. Therefore, the Southeast wind carves an axis on the tundra. The Southeast wind blows the grass until it freezes in the winter months. The Southeast wind blows across the water in the many lakes of the Yukon-Kuskokwim Delta region.   The lakes freeze over for the winter, like a frozen ocean.   Fred feels the snow waves kinesthetically, as he drives his snow machine drives over the lakes. The Southeast wind blows the skinny, isolated trees which bend over like old men toward the Northwest. The importance of these natural compasses increases, as the clouds cover the sky during the day or night.

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