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Teaching Mathematics and the Inuit Community

Louise Poirier
Université de Montréal

Abstract: In the spring of 2000, the Inuit community and the Kativik School Board were pondering the difficulties encountered by students in mathematics and the measures that could be taken to help these students. One significant fact that it seemed might help explain these difficulties was that Inuit students learn Inuit mathematics (for example, a base-20 numeral system) in their own language in the first three years of their schooling and then go on to study in either French or English. A collaboration between researchers, teachers from the Inuit community, and curriculum developers was established. In this article, we present facets of the environment, language, and culture of the Inuit that influenced the development of the Inuit numeration system, their ways of measuring (length, distance, time, etc.), and their great aptitude in spatial representations. We then discuss the current collaborative project that aims at the development of teaching situations adapted to Inuit classrooms.

Résumé : Au printemps 2000, la communauté Inuit et la commission scolaire Kativik s'interrogeaient sur les difficultés qu'éprouvent les élèves en mathématiques et sur les actions à prendre pour aider les élèves. Un facteur important pour expliquer de telles difficultés tient au fait que les élèves inuit apprennent durant leurs trois premières années d'école, les mathématiques traditionnelles inuit dans leur langue (par exemple, ils ont recours à un système de nombres en base 20) puis poursuivent leur apprentissage en français ou en anglais. Un projet de recherche collaborative a été mis sur pied impliquant des enseignants inuit, des responsables du développement de programme et des chercheurs. Dans cet article, nous présentons quelques éléments de leur environnement, de leur langue et de leur culture qui ont amené les Inuit à développer leurs mathématiques. Des exemples en arithmétique, en mesure et en relations spatiales sont présentés. Nous terminons par une discussion autour du projet de recherche collaborative qui a pour but le développement de situations d'enseignement adaptées au contexte Inuit.

Knowledge is the condition of knowing something with familiarity gained through experience or association. The traditional knowledge of northern aboriginal peoples has roots based firmly in the northern landscape and a land-based life experience of thousands of years. Traditional knowledge offers a view of the world, aspirations, and an avenue to 'truth' different from those held by non-aboriginal people whose knowledge is based largely on European philosophies. (as cited in Bielawski, 1992)

Please note:

I am not an Inuk and I do not pretend to know and understand the Inuit's culture. My perception and understanding of the situation in the North will colour this report. I would like to sketch, in an impressionistic fashion, the mathematics built by the Inuit to answer their needs and also expose the challenges that this community faces in going from their traditional mathematics to, as they call them, the 'southern mathematics.'

History of this project

This project consists of ongoing collaborative research with several women from the Kativik School Board (teachers, teacher trainers, curriculum developers, etc.). In the spring of 2000, the Inuit community and the Kativik School Board were wondering about the reasons behind the students' difficulties in mathematics: How could these difficulties be explained and what could we do to help the students? To help the reader, the Kativik School Board presides over a territory named 'Nunavik' in the most northern part of the province of Québec. Nunavik includes 14 villages from west to east, spread out on the banks of Hudson's Bay, in Hudson Strait and in Ungava Bay. In all, 11 000 people live in Nunavik, a vast majority of them being Inuit.

In the spring of 2000, I was offered the opportunity of a series of visits in Inuit villages. I visited classrooms, meeting with the teachers and their students. Several observations can be made:

- *Mathematics and language:* Inuit children's first language, Inuktitut, is also the only language they learn in kindergarten, Grade 1, and Grade 2. Although they learn mathematics first in Inuktitut, from Grade 3 onwards to the end of high school, they have been learning mathematics in either French or English only. As a result of our work, since 2005, they now learn mathematics in their own language in Grade 3 as well.
- *Mathematics and culture:* Until recently, mathematics was looked at as a universal language. After all, no matter where we are, 'two plus two equals four.' This conception of mathematics as universal language is being challenged. Different cultures have developed different mathematical tools according to their needs and their environment, and the Inuit community is no exception. As for their learning of mathematics, Inuit children learn mathematics in their mother tongue during the first three years of schooling. Furthermore, Inuit mathematics is quite different. For example, theirs is a base-20 numeral system. It seems that, for these students, two separate and distinct universes cohabit: the world of day-to-day life and the 'southern' mathematical world. Furthermore, their everyday world has nothing to do with the mathematical world

studied in school. They do not perceive mathematics as something that can help them solve everyday problems. This situation can be explained by the processes identified by Bishop (1988). On the one hand, there is a process of 'enculturation' integrating the children into their own culture, and, on the other hand, there is a process of 'acculturation,' an effort to integrate the children into another culture, that of 'southern' mathematics. Entangled in these competing processes, the instructional situation becomes highly complex: How can these two cultures be combined and accommodated in mathematics teaching situations? In fact, as the gap widens between the two worlds, the difficulties in mathematics of Inuit students are getting more important. This situation is not unique to the Inuit community. A similar situation has been observed with Australian Aboriginals (Graham, as cited in Bishop, 1988). We will present later in this article some aspects of Inuit mathematics.

- *Spatial relations:* The students that I have met are particularly good at spatial representation and at geometry. Take, for example, a 12-year-old student raised by a traditionalist grandfather who did not send him to school. He was now attending school but was failing dramatically. When I taught the class how to play a strategy game, 'Nine Men's Morris,' he was the first to understand the rules and how to move the pawns on the board. He also won every single game he played. But sadly enough, the current curriculum does not put much emphasis on these strengths. Pallascio (1995) made the same observations: Inuit children develop spatial representations that are different from those of children who live in a city like Montréal.
- *Teaching methods:* The teaching methods used by most teachers in the North (paper-and-pencil exercises) are not based on the 'natural' ways of learning of Inuit children. Traditional Inuit teaching is based on observing an elder or listening to enigmas. These enigmas can be clues for problem solving in mathematics. Furthermore, Inuit teachers tell me that, traditionally, they do not ask a student a question for which they think that student does not have the answer. We can easily see the necessity to adapt our southern ways.

To help the Inuit community explain their students' mathematical difficulties and decide how to overcome them, a collaborative research project was undertaken (the reader will find this project's structure in a later section). The project—involving members of the Inuit community, Inuit teachers, pedagogical councillors, and curriculum developers—aims to understand both Inuit mathematics and the Inuit language in order to adapt teaching activities, since it is in Inuktitut that mathematics is first learned. In the section that follows, we present our first findings with respect to Inuit mathematics.

Inuit mathematics

The social dimension of mathematics has grown in importance in the last decades (Bauersfeld, 1998; Voigt, 1994). Lakatos (1976) said that 'mathematics is a dialogue between people who have math's problems to solve.' Taking from the work of Wittgenstein and of Lakatos, Ernest (1991) explains that, for socio-constructivism, mathematical knowledge is a social construction where the social processes of dialogue and critique are necessary. If mathematical knowledge is a social construction, then the learner's culture and community will play an important role in learning. According to Bishop (1988), we are more and more preoccupied by what he calls the 'cultural interfaces' in the teaching of mathematics:

> In other countries, like Papua New Guinea, Mozambique and Iran, there is criticism of the 'colonial' or 'Western' educational experience, and a desire to create instead an education that is in tune with the 'home' culture of the society. The same concern emerges in other debates about Aborigines, of Amerindians [*sic*], of the Lapps [*sic*], and of Eskimos [*sic*]. In all of these cases, a culture-conflict situation is recognized and curriculum are [*sic*] being re-examined. (Bishop, 1988, p. 179)

The Inuit community of Nunavik is in a similar quandary, but we know little about their mathematics: not surprisingly, this project also aims to discover more about Inuit mathematics!

Bishop (1988) recognizes that mathematics is a cultural product that takes many different forms. However, through his work, he came to realize that six different domains of mathematical activity are found in all cultures. These six domains seem necessary for the development of mathematical knowledge, even if each different culture has its own way of dealing with them:

- *Counting:* the systematic use of methods to compare and order sets of objects
- *Localization:* the exploration of one's spatial environment and the symbolization of that environment with the help of models, diagrams, drawings, words, or other means
- *Measuring:* the use of objects or measuring tools to quantify dimensions
- *Design:* the creation of forms for an object or for decorating an object
- *Games:* the development of games and the more or less formal rules that the players must follow
- *Explanation:* finding different ways of explaining a phenomenon, whether religious, animist, or scientific

We will now present the three domains that we investigated first because all three are taught to Inuit students in Inuktitut: Inuit counting, localization, and measuring. Since this is an ongoing project, we intend to study the other three domains in the near future.

Counting

Inuit children learn to count in their language, and, until last year, they would switch into either French or English in Grade 3. Since September 2005, Grade 3 has become a transition year in the learning of mathematics: 75% of the time allowed for mathematics is spent teaching and learning in Inuktitut; the remaining 25% is in either French or English. But this raises the question of whether or not they learn the same numbers in Inuktitut, the same numerical system as the one they will use in French or English.

Oral numeration

In the Inuit language, Inuktitut, there are the singular (for example, *Inuk* means one person), the dual (*Inuuk* means two persons), and the plural (*Inuit* means many people). Traditionally, it was for three and up that they needed words to express quantities.[1] Their tradition being essentially an oral one, the Inuit have developed a system for expressing numbers orally. They do not have other means of representing numbers; they have borrowed their number symbols from the Europeans. Under European influence (there is even a community in Labrador that counts in German, missionaries from Moravia having introduced numbers in German), Inuit have introduced a word for *one* and another for *two*. The following chart presents some Inuit numbers in Inuktitut and their literal translation (see Figure 1).

Several remarks can be made. First, the numbers 20 and 400 are pivotal numbers, as other numbers are built from these two numbers. The Inuit have a base-20 numeral system. Furthermore, words chosen to designate numbers may have an impact on Inuit students' conception of certain numbers. For example, using the word *Atausik* for one, meaning 'indivisible,' may hinder their understanding of fractions. This is one of the many questions still to investigate with the research team. The reader may have been struck by the length of certain number words in Inuktitut. One can imagine the challenge for a 5- or 6-year-old student learning to count in Inuktitut. But the challenge is also in the fact that each number has different forms according to the context. The Inuit tradition being essentially an oral one, the Inuktitut speaker is always mindful of being understood by others (we will come back to this in discussing the Inuit sense of space). Such precision in language brought the Inuit to develop several forms for each number to mark the context in which it is used. Figure 2 presents the number three in six different contexts—three of them developed under European influence: the playing card (Inuit truly enjoy playing games), digits, and patterns. The reader can also glimpse Inuit writing (symbols given to them by an European missionary in the late 1800s).

1	Atausiq *(Indivisible)*
2	Marruuk
3	Pingasut
4	Sitamat
5	Tallimat *(Arm)*
6	Pingasuujurtut *(They are many threes)*
7	Sitamaujunngigartut *(They are not exactly many fours)*
8	Sitamaujurtut *(They are many fours)*
9	Quliunngigartut *(They are not exactly ten)*
10	Qulit *(The top)*
11	Qulillu atausirlu *(And ten and one)*
12	Qulillu marruulu *(And ten and two)*
13	Qulillu pingasullu *(And ten and three)*
14	Qulillu sitamallu *(And ten and four)*
15	Qulillu tallimallu *(And ten and five)*
16	Qulillu pingasuujurtulu *(And ten and six)*
20	Avatit *(The limbs)*
21	Avatillu atausirlu *(And twenty and one)*
30	Avatillu qulillu *(And twenty and ten)*
40	Avatit maqruuk *(Twenty two (times))*
60	Avatit pingasut *((Twenty three (times))*
80	Avatit sitamat *((Twenty four (times))*
100	Avatit tallimat *((Twenty five (times))*
146	Avatit tallimat avatit maqruuk Pingasuuiuqtulu *((Twenty five (times) ((Twenty two (times)) and many threes)*
400	Avatimmariit *(The real twenty)*

Figure 1: Numbers in Inuktitut.

Sense of space

Imagine that you are an Inuit hunter, in the snow- and ice-covered tundra, at minus 60 degrees. How will you orient yourself? Days afford a few hours of light only, and getting lost far away from your camp or village is

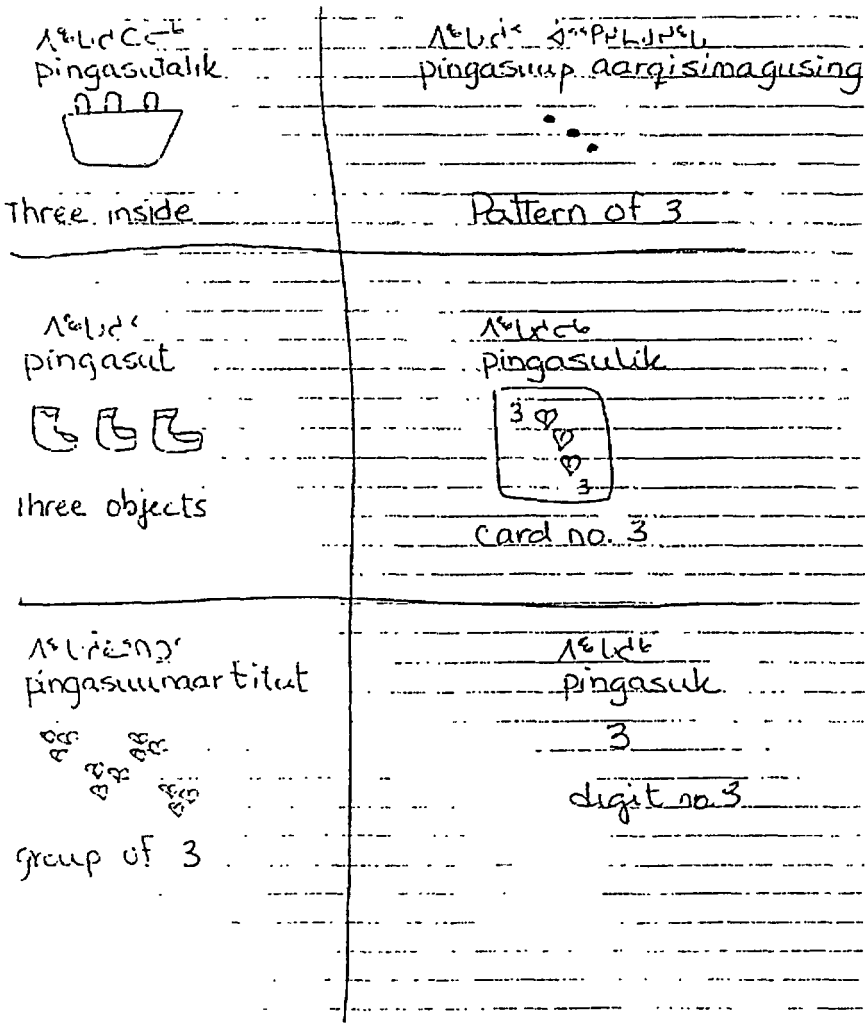

Figure 2: Number 3 under six different contexts.

a death-defying experience. The Inuit have developed an outstanding sense of space to help orient themselves. They have learned to 'read' snow banks and assess the direction of winds. I was told that they can say how far they are from the bay by smelling how salty the air is (each village is built on the banks of a bay). But mostly, for thousands of years, Inuit have built *inuksuit* (singular, *inukshuk*) to help them. An *inukshuk* is a huge human-shaped pile of rocks (*inukshuk* [that looks like a person]). An *inukshuk* helps travellers in the North: because of its great height, it is seen from very far and

it transmits messages: 'Someone was here; it is a good fishing spot.' An *inukshuk* can also shield the hunter from the wind and be a hiding place for surprising caribou.

We have already spoken of Inuktitut speakers' great concern for being understood by others. Such precision of language can also be seen when an Inuk describes the path one must take to reach a spot. Space in the North is an ever-changing space, changing with the season, the time of day, the temperature, and so on. Béatrice Collignon, a geographer, wrote in 1996

> *Il est impossible pour un inuk (sic) de décrire un lieu de façon objective. Il prendra toujours soin de préciser selon quel point de vue il est décrit. La saison est spécifiée... l'endroit où se place le spectateur: est-il plus haut, plus bas, vient-il de la terre ferme, de la mer, d'un lac gelé qu'il traverse à pied, en motoneige ou en traîneau à chiens? Est-il seul ou en groupe? Pourquoi est-il là? Toutes ces données contextuelles doivent être précisées si l'on veut que la description soit comprise.* (p. 72)[2]

Inuit have also developed a very precise vocabulary for speaking about spatial relations, as can be seen in Figure 3.

Measuring

In this section, we present the traditional measures for length and also the traditional calendar used by the Inuit.

Measuring length

As soon as humans needed clothing and shelter, they needed to measure. The first measuring tools were parts of the body (the finger, the foot, etc.). Still today, Inuit women use certain parts of their bodies to measure length—for example, the palm when making *atigi* (parkas). Measuring the base of your neck will help make a perfectly fitting parka. If they need to be more precise—for example, when making *kamiik* (boots)—they will use one phalanx as a smaller measuring unit.

The traditional calendar

One day, I was wondering about the Inuit's traditional calendar: Is it lunar or solar? I asked the Inuit teachers whether their traditional calendar is divided into months. They told me that 'yes,' their calendar is made of months. I asked if these months have the same number of days in each (lunar calendar) or if the number of days change according to the month (solar calendar). They answered that it changes. I then asked, 'What about September? How many days in September?' They answered that the word for *September* in Inuktitut means 'when the caribou's antlers lose their velvet' and that the number of days changes, since it depends on how long it takes for the caribou's antlers to lose their velvet. Their traditional

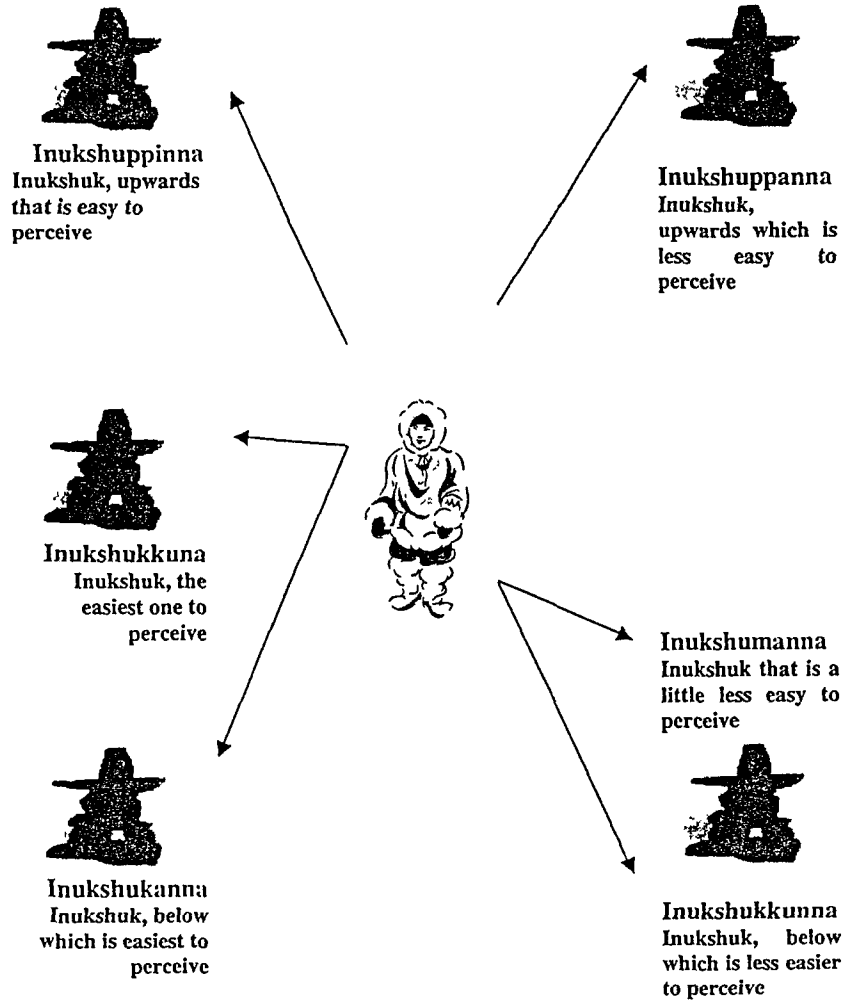

Figure 3: Severall ways of expressing the relative position of an inuksuk.

calendar is neither lunar nor solar, since it is based on natural, independently recurring yearly events.

The name of each month comes from animal activity or from nature:

- coldest of all months
- when baby seals are born but are dead
- when baby seals are born
- when bearded baby seals are born
- when baby caribou are born

- when birds lay their eggs
- when the ice breaks
- when sea elephants rest on land
- when the caribou's antlers lose their velvet
- when male caribou fight for a female
- when the caribou's antlers fall
- when two stars appear in the sky

How long one month is depends on how long it takes for a natural event to take place; associated with each month are everyday activities that men and women repeat each year (picking fruit, hunting, gathering eggs, preparing animal hides for sewing, etc.)

A few elements of Inuit traditional mathematics have been presented here, but we still have a lot to explore and understand. In addition to discovering their mathematics, we have tried to understand the structure of their language—Inuktitut. Being from an oral tradition, the Inuit rely on their language; in fact, not only do they rely on it, they identify themselves with their language. The following are remarks about Inuktitut and its structure; also given are words used to talk about certain mathematical concepts.

Inuktitut and mathematics

Collignon (1996), talking about Inuktitut, wrote that this language '*est marquée par une très forte subjectivité qui interdit pratiquement tout discours abstrait ou hors contexte*' (p. 58).[3] Could such a characteristic intervene in the construction of mathematical concepts? We should do further research on this important question. But first, some characteristics of the language will be briefly presented.[4]

Inuktitut uses 3 vowels and 14 consonants. As for its syntactic construction, Inuktitut is a suffix-driven language. Each sense unit is made from the addition of suffixes to basic words.[5] Words in Inuktitut are like blocks built from a base through the adding of suffixes (up to 16 of them in a certain order). For example, the English phrase, 'I never said that I would go to Paris,' is translated in Inuktitut by the expression: *Pariliarumaniralauqsimanngittunga.*

Here are some examples of words built from the same unit—*putu* (hole):

- *puturlaaq* (with several holes)—strainer
- *putulik* (with only one hole)—pineapple
- *putulapaaq* (hole by excellence)—lace
- *putuurriti* (which makes several holes)—electric drill

One might wonder why the word *pineapple* was built from the unit *hole*. Inuit, of course, do not have fresh pineapples, and the pineapples they are familiar with, the canned variety, sport one large hole in the middle!

Inuktitut	English	Literal translation
Sikkitaq	Square	
Sikkitakuluk	Cube	Many little squares
Sikkitaaluk	Barge	Big square
Kisitsit	Number	
Kisitsiguti	Inch	Which helps to measure, to count
Kisitsivuq	He counts	That does a number
Tirirquq	Angle	
Tirirqulik	Setsquare	Which has an angle
Iqirraq	Internal angle	Open corner of the mouth
Pingasunisinaalik		The three sides (Pingasut : 3)
	Triangle	
Makkaujaq		That is like the top of a hood (makkaq)
Marrnunnik		Two sides that have in front of
ialimuttuunnik quajuaqtuq	Isoceles triangle	Them a long side / (Marruuk : 2)
Tukimuartuq	Line	
Tukimuartukutaaq	Straight line	Adopted line
Ammalunniq	Curve	In the state of a circle (ammalukitaaq : circle, amma : repetition niq : state of)

Figure 4: Examples of mathematical terms in Inuktitut.

We will now look at a few mathematical terms in Inuktitut and at their literal translations in English given in figure 4.

We can observe how some mathematical terms were built. For example, the expression for *cube* comes from *square* and means that a cube is made of several small squares. Some concepts are expressed with more than one expression. There are two terms for triangle—*pingasunisinaalik* and *makkaujaq*, but the expression *pingasunisinaalik*, with its basic unit *pinga* (three) is closer to the English word *triangle* than the expression *makkaujaq*, which means 'that looks like (*-ujaq*) the top of a hood (*makk(q)*)'. Some expressions, however, may cause difficulty. For example, the expression chosen for an *isosceles triangle*—'two sides that have in front of them an elongated side.' One wonders what conception of an isosceles triangle such an expression can develop? The same goes for the expression for *rhombus*—'the square of the playing card.' And what about the expression for a *straight line*—'the adopted line'? My explanation for this last is that, in the Inuit environment, there are very few straight lines but many curves.

As we just saw, a community's choice of expressions, when it has a different culture, language, or even, as in the case of the Inuit, mathematics is a tremendous challenge. As the project develops and the teaching of mathematics in Inuktitut is extended, some new Inuktitut mathematical terms will be needed.

In closing, I would like to speak about the structure of this project. This project aims to reveal Inuit mathematics and build teaching activities adapted to the Inuit context. The importance of having members of the Inuit community take part in the research cannot be overemphasized, for real progress cannot be made by the researcher alone if we want (and we do) development to be adapted to the context.

When a researcher develops teaching activities, there is always the question of their 'validity' (Arsac, Balacheff, & Mante, 1992; Artigue, 1990; Bednarz, Poirier, Desgagné, & Couture, 2001; Desgagné, Bednarz, Couture, Poirier, & Lebuis, 2001). Teachers change the activities in light of their teaching environment, their experiences, and their conceptions. In the result, the researcher may not even recognize her/his work; and the teachers themselves often have difficulty reproducing what researchers suggest because of the nature of their environment. This seems to us particularly true of the Inuit situation. A 'triple entry' into the development of teaching situations, therefore, appears to be essential: a didactical entry, one through the experiential knowledge of the teachers, and one through the cultural knowledge of the Inuit.

The development of teaching activities must take into account teachers' understanding of their teaching and their teaching context. It was of the outmost importance to include members of the Inuit community in the research team. Our team was made of three or four teachers from the Kativik school board, three or four teacher trainers and curriculum developers, all of them Inuit, and myself, with the support of a linguist and research assistants. By working with Inuit teachers and curriculum developers, we were able to develop teaching activities that took into account both traditional ways of teaching and learning and elements of Inuit culture. For example, in Grade 3, to introduce odd and even numbers, we used and adapted an Inuit legend, the legend of *Kajutaijuq, The Evil Spirit*:

> Many, many years ago, a group of nomad campers (migration camp) had to leave some people behind, with the promise that they would come to get them later on with dog teams. The people left behind got tired of waiting to be picked up. They were hungry and as there was no food around, they decided to walk to the new camp. When they saw the camping area, a young boy and girl quickly ran ahead to one of the empty snow houses in the hope of finding left over food. Instead of food, they came upon something quite stunning.
>
> In the snow house was this amazing creature called Kajutaijuq. Kajutaijuq was a female spirit without a body. She had a humongous head resting on two short legs with three toes. She had the reputation of causing thunder when she

walked and of devouring Inuit who were not aware of her presence. When she saw the children, here is what she said:

'I should eat you both because you were not aware that I was here. But you seem way too young to die, so I will give you a chance. Find the answer to my riddle and you will not die. Now, listen carefully: One part of my body is unhappy because it has an uneven number of elements. However, when I pair it up with another identical part of my body, together, these parts of my body have even elements. What part of my body am I thinking of?'

Collaborative research

Collaborative research seemed to us one of the best approaches to use, since it considers as central research data both the teacher's actions and the rationale behind those actions (Desgagné, 1997). It is a matter not only of developing useful teaching activities to help students acquire certain knowledge (something a more traditional didactical research would also do) but also of developing teaching activities viable in the classroom context, with the help of the teachers' experiential knowledge and, in this project, their knowledge of Inuit culture.

The collaboration among researcher, teachers, teachers' trainers, and curriculum developers takes place through reflective activities that require teachers to make explicit and analyse their experiences, analyses that, in turn, lead to the development and trialling of new teaching activities in their classrooms. This approach is closely related to the reflective analysis described by Schön (1987). It took the form of an alternation between developing activities, experimenting with them in the classroom, and reflecting upon that experimentation. '*La dynamique action-réflexion constitue la structure rendant possible la restructuration progressive de séquences à travers un processus dans lequel chercheurs et enseignants jouent un rôle important.... Cette activité réflexive apparaît ainsi le lieu de médiation entre le point de vue des praticiens (le cadre de pratique à partir duquel ils vont aborder les situations d'enseignement) et le point de vue des chercheurs (le cadre didactique qui est le leur, partant duquel ils vont aborder ces situations)*' (Bednarz et al., 2001, p. 45).[6] Such reflective activity takes the following form: meeting the team to develop activities, teachers' experimenting with these activities in their classrooms, meeting the team to discuss and analyse the trials and develop new activities, and experimenting in the classrooms. For the past five years, we have been meeting five or six times each year to discuss teaching activities and experiments with them in the classroom and also to better understand Inuit mathematics, culture, and language.

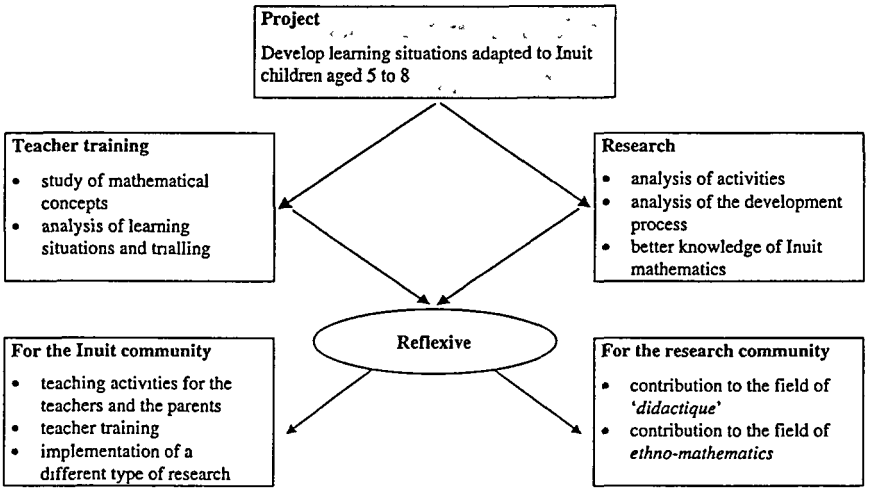

Figure 5: The colaborative structure of the Inuit Mathematics project.

Figure 5 shows how our collaborative model emphasizes two aspects in particular: research and training, on the one hand, and the contributions to both the Inuit and research communities expected from this research, on the other.

Furthermore, this model of collaborative research answers the requirements of the Inuit community for tangible benefits (although often studied, the Inuit have seen very few benefits from all this research). This article has aimed at giving the reader a first look at Inuit mathematics. Much work is still needed to uncover the richness of Inuit traditional knowledge.

Notes

1 I will not distinguish here between traditional and modern Inuktitut, nor between the different dialects spoken in Nunavik. For example, the Ungava Bay Inuit and Hudson Bay Inuit speak different dialects.

2 'It is impossible for an Inuk to describe a place in an objective manner. He will always be sure to specify the point of view, the place where he is positioning the observer: Is he higher or lower? Is he coming from the land, or a frozen lake? Crossing by foot, on a skidoo or a dogsled? Is he alone or with a group? Why is he there? All this contextual data is essential if one wants the description to be understood.' All translations are the author's.

3 'is marked by a strong subjectivity making almost impossible any abstract or out of context discourse.'

4 This work on Inuktitut was done in collaboration with M. Hafezian, post-doctoral graduate.

5 It is for the sake of convenience that we use the term *word* to designate units. As R. Lowe (1981) wrote, this terminology (words, verbs, etc.) is borrowed from Indo-European languages and does not correspond with the Inuktitut reality.

6 'The structure of alternation between action and reflection makes possible the progressive re-structuring of teaching sequences through a process where researchers and teachers play

an important part.... This reflective activity becomes the mediator between the teachers' point of view (the practical framework from which they tackle the teaching activities) and the researchers' point of view (the didactical framework through which they analyse these activities).'

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