The Basotho Origin of Mathematics – A Public Lecture

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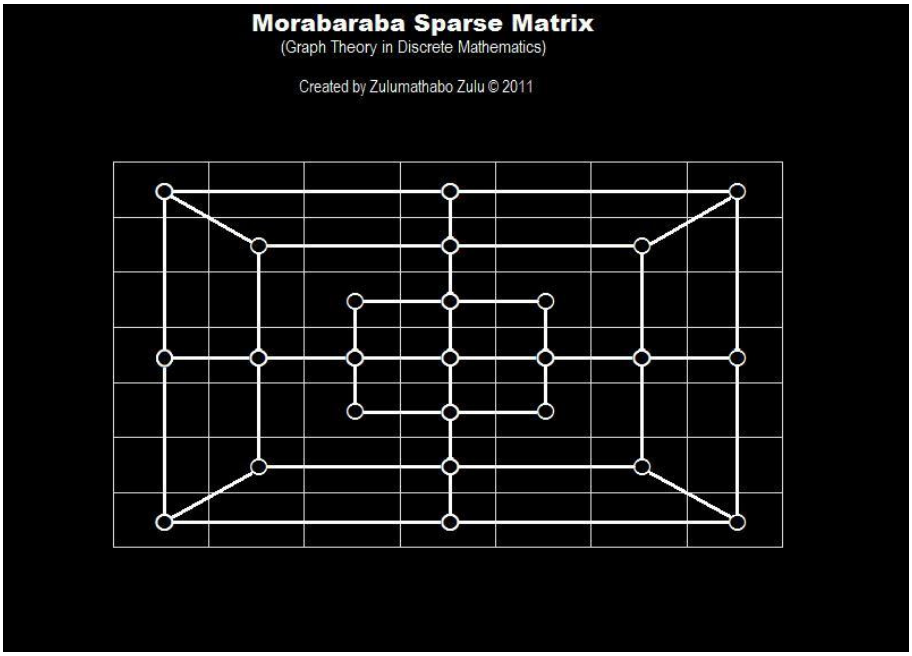

Figure 1 *Morabaraba sparse matrix designed by Zulumathabo Zulu at Carleton University School of Computer Science, Ottawa, Canada.*

Basotho ba kgale bare "*Ngaka haeboyele badimong le ditaola; Etshwanela hodisiya le basetseng*". Ka lehlakoreng le leng bare "*Ngaka eka sesiyi ditaola le bao ba dikgesang. Etla tshwanela hotsamaya letsona. Ditla kgutla ka hokgutla hohong*". When they say *Ditaola* they are referring to cultural knowledge and the knowledge of self. This critical mission is a cultural revolution and requires your support so that researching, preserving and disseminating of original African knowledge can persist for future generations. Please consider supporting this sacred work of the ancestors by pledging or making a donation. See last page for details.

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Abstract

The popular myth in South Africa is that the African natives were devoid of mathematical knowledge until the advent of the Europeans. Nothing could be further from the truth. The Basotho, like other Africans, boasted an incredible mathematical lexicon long before the advent of the Europeans. The Basotho have used mathematics in order to count, estimate, measure, philosophize, solve and model, among others. In this public lecture we show an African origin of mathematics among the Basotho as confirmed by the ambitious book project Sesotho Dictionary of Mathematics.

The Cosmic Knowledge

The Basotho trace their genesis to the cosmos. They believe that their ancestors originate from the heavens. The idea of tracing their genesis to the heavens is not exclusive to the Basotho. The Zulu people also trace their genesis to the heavens. As a matter of fact, the name Zulu means "the people of the heavens". In Northern Botswana where I lived in exile in the ANC camp of Dukwe, the dominant ethnic group the Makhalanga "meaning the people of the sun" also trace their genesis to the cosmos. In my family background on the mother's side, we are the Mlangenis. Mlangeni means "those of the sun".

As a result of their cosmic genesis, the Basotho possess a cosmic knowledge that allows them to be guided by the heavens. They refer to stellar bodies as the stars as opposed to the Europeans who distinguish among planets, stars, meteors and so forth. The stars and the moon guide the sacred calendar of the Basotho. Unlike the colonial calendar which we are currently using in South Africa which begins in January and ends in December, the Basotho calendar begins in Phato (August) and ends in Phupu (July). A very important star system known as Selemela determines their agricultural activities. They look to Selemela to determine the kinds of crops they will be planting. Selemela also ushers the New Year of Phato in the Basotho calendar.

Selemela is a cluster of stars. There are seven stars but from the earth one can see six stars. The number seven is one of the sacred numbers among the Basotho and part of the reason has to do with the Selemela. This star does have an influence on the Basotho architecture as well as their mathematical knowledge. Other important stars include Mphatlalatsane, Sefalabohoho, Tosamasiu, Tosa le madinyana a yona. It is noteworthy, that Tosa (Jupiter) is one of the celebrated star systems. The axiom "Hobona tosa le madinyana a yona" means, "To see Jupiter along with its youngs". The youngs refer to the moons of Jupiter. These moons are not visible to the naked eye and some of the moons are literally baby moons. How do the Basotho know about the baby moons of Jupiter without using a technological instrument of any kind? This is yet another confirmation that they possess cosmic knowledge and do not need telescopes or any technological instrument to know of the cosmos because this knowledge is in their blood. The mystery does not end here. They also pay tribute to another star Makgakga which is not visible to a naked eye. How is that possible without a telescope?

As a result of their cosmic genesis, the Basotho possess a cosmic knowledge which was passed down from their ancient ancestors and this knowledge passes from generation to generation using oral tradition, ditema writing system and the artefacts that possess the ancestral messages of long ago.

Rebotsa Maphelo (Inquiry of the Collective)

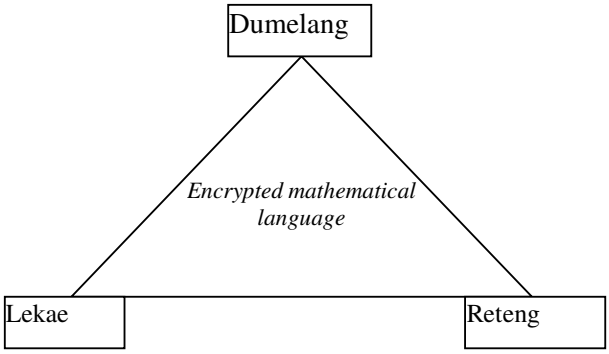
When the Western people do not see numbers like 1,2,3 and so forth, they automatically assume that mathematics does not exist. In order for mathematics to exist, they must see the numbers.

This is a very narrow view of mathematics. Mathematics exists in many forms including language. Mathematics can exist in words.

The Sesotho language is a highly mathematical language but for the most part, the mathematical language is encrypted so that if you have no inside knowledge, you are going to assume that the Basotho have no mathematical knowledge.

In this section, we decode the mathematics from the language. We are going to use greetings of Dumelang to decode the mathematics from the language. Forget everything you know about the English translation of the Basotho greetings because it does not get even close. I will be giving you a decoded description of the greetings.

The Basotho greet one another using a three-step process. The number three among the Basotho is a sacred number. This is also a triangle as shown below:



We decode as follows:

Step One – Dumelang

When the Basotho say Dumelang, they are actually saying, "*We seek the agreement of the collective*".

Dumelang refers to the collective, the elements of the collective, the agreement of the collective and the plurality or cardinality of the collective. This refers to set theory where there is a concept of a collective in a form of a set and the elements of the set as well as the cardinality of the set.

Step Two – Lekae

After exchanging Dumelang, they then say "Lekae" which decodes as "*Where are you located in the space?*" This is interesting because it inquires about the location of the collective in the space. Mathematically, this refers to the location in the space and the collective. In order to locate something in space, you need some serious mathematics like three coordinates of x,y,z. The x refers to the horizontal, the y refers to the height and the z refers to the perspective. Locating anything in space requires some serious mathematics of Linear Algebra or Vector Calculus.

Step Three – Reteng

After exchanging Lekae, they then conclude by saying "Reteng" which means "*We are located in the space*". This means they have solved the space location.

Unless something decoded this for you, you would never know that the Basotho greet one another using a mathematical language. Why is it like that? Why is the language based on mathematical knowledge?

This has to do with the fact that the Basotho trace their genesis to the cosmos. They come from the stars. They are the sons and daughters of the stars. They are governed by the heavens and the stellar bodies. *Bahloka dipalo hohahlaula mafaufau* meaning "they need numerical knowledge to traverse the space".

African Philosophy of Science

As result of their cosmic knowledge, the Basotho like other Africans possess their own philosophy of science. They analyze and describe matter differently from the way we know and understand matter. For example, in the Eurocentric curriculum they teach us that matter is a material that occupies space and has mass. Matter consists of an atom. An atom consists of electrons, protons and neutrons. An atom is a particle. Electrons, protons and neutrons are also particles. This then means that according to a Western philosophy of science, matter is particle based. This has serious implications even in areas of medicine in that when a doctor is diagnosing diseases he will be looking for particles in one way or another. In contrast to Western science, the Basotho believe that matter is fluid based. This means that matter is wave-based and therefore has wave properties. This fact is attested for in the Sesotho language.

For example, when Basotho dish out food they say "Retshela dijo". The word "tshela" is used for fluid and it means "pouring" as if the food is fluid-based. When Basotho throw away waste they say "Retsholla dithole" meaning "We are pouring out the waste" as if waste is fluid-based. If you were to count fluid-based words in the English language, the list would soon hit a lexical limit whereas a fluid-based lexicon in the Sesotho language is almost endless. I counted more than hundred words and still counting in the Sesotho language. This confirms the fluid origin of matter according to the African philosophy of science. This has implications for medicine and other areas of science. A cell is a fluid-based and therefore the cellular laws of fluid dynamics govern the contents of the cell including the particles.

There is a lot of mathematics in fluid. The kind of mathematics used in fluid is non-linear because of the fact that you are dealing with wave-based properties of matter. This agrees with the Basotho dominant use of a circle as the most important geometric shape. We see the circle in the architecture, in the household items, in the use of ditema, in the modeling of phenomena like the use of Diketo.

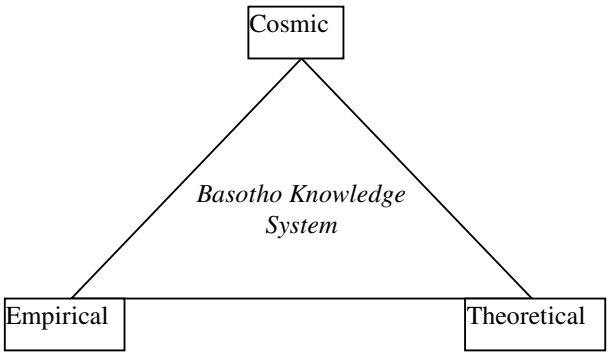
What is actually a fluid? The Sesotho word *Mokedikedi* also known as *Kedikedi* describes a fluid system in a more generic fashion. Phofo or flour is *kedikedi.* The phenomena of *Mokedikedi* include fire, clouds, and any kind of phenomenon that behaves like fluid even if it is not a fluid.

The concept of fluid based matter requires non-linear mathematics. The Basotho use a circle as the most fundamental geometric figure to derive other geometric shapes. If you take the two halves of a wave and flip them together you get a circle. From a circle you also get a triangle. In fact Basotho ba Kgale who needed to construct a house, used a rope on the ground to measure a diameter and then traced a circle around the diameter. This is how they built houses.

The concept of a fluid based matter does not discount a particle but rather treats a particle as a subset of the superset of a wave as opposed to Western science that treats the wave properties of matter as subsets of particles.

Nahanotsebo (Theory of Knowledge)

To appreciate the Basotho origin of mathematics, it is important to understand their knowledge systems *Nahanotsebo*. The Basotho have three kinds of knowledge namely (1) cosmic knowledge, (2) empirical knowledge and (3) theoretical knowledge. This knowledge is best represented as a triangle as follows:



Cosmic Knowledge

This knowledge comes from their genesis of the cosmos. The cosmic knowledge is a transcendental knowledge that transcends the senses and the mind. It is a pure form of knowledge that transcends the space-time domain. As previously mentioned, it is the cosmic knowledge that has shaped their mathematical knowledge as confirmed in their architectural tradition where the use of non-linear geometry like the circle is part of the design goal to construct a built environment that is aligned with the stellar universe.

Empirical Knowledge

Empirical knowledge is the knowledge of the senses. This kind of knowledge comes from experiencing the physical world in its natural setting. The Basotho attain sensory knowledge by means of the senses of *vision, hearing, touch, smell* and *taste*. Through these five senses we can produce a body of knowledge. The Basotho regard empirical knowledge as very important at an experiential domain. This kind of knowledge is also known as *Tsebokato* or *Tsebo ya Mokato* meaning concrete knowledge. Prior to colonization, this empirical knowledge formed part of their traditional medicine.

Theoretical Knowledge

Theoretical knowledge is a knowledge that is not based on experience vis-à-vis the empirical knowledge. This is knowledge is acquired before or outside experience. This system uses logic and relations to produce knowledge as opposed to empirical knowledge that uses senses or instruments to produce knowledge.

This contrasts sharply with Western knowledge systems where there are two types of knowledge namely (1) empirical knowledge and (2) rational knowledge or abstract knowledge. The Western society believes that the ultimate knowledge is the empirical knowledge while the Basotho regard their cosmic knowledge as the superset of all knowledge systems. This means that empirical knowledge and rational knowledge are subsets of the cosmic superset.

The unique perspective of the Basotho can contribute greatly to scientific knowledge. As a matter of fact, we need to move towards integrating traditional knowledge into the formal curriculum so that our educational experience can be enriched.

Pale ya Dipalo (History of Mathematics)

Until more archeological findings came about to confirm the African origin of mathematics, it was always thought, believed and taught in schools that mathematics originated in Europe. We know now that this is no longer the case. In fact the Africans are the first mathematicians. In 1950 Dr. Jean Heinzelin of the Belgium Royal Museum of Natural Science in Brussels discovered mathematical artifacts (Heinzelin, 1964) in the village of Ishango, in the present day country of Congo. This mathematical artifact had a variety of number systems including the prime numbers making the Africans the first people to invent prime numbers. It is also reported by other scholars (Zaslavsky, 1979) and (Taylor, 1991) that the Ishango Bone was also used as a lunar calendar for the periodicity of female menstruation making the woman the first mathematician; the African woman mathematician at that!

Mathematical Concepts of the Basotho

The Basotho mathematical knowledge is integrated into the language. This means the Sesotho language has a native support for mathematical knowledge. The language provides a built-in facility for numerical reasoning. This is in contrast with the English language whereby mathematics and language are separate. Part of the reason for this separation has to do with the fact that about two-thirds of the English language is borrowed from other languages mainly

German. Only about a third of the English language is native to the language. As a result of growing by borrowing the English language is more discrete than continuous.

The Sesotho language is effectively hundred percent native. Moreover, Sesotho has got certain syntactic rules which are not available in the English such as conjugation rules. As a result of this, Sesotho is more of a continuous language as opposed to English which is more of a discrete language. This is one reason that provides a platform for an expansive mathematical knowledge. Let's take an example of two things namely (1) circumference and (2) the number three. If you generate a list of words that describe a circumference in the English language you might say *circumference, perimeter* and then immediately reach a lexical limit. With regards to the number three, you might list *three, thrice, triple* and then reach a lexical limit. On the other hand in Sesotho you can generate a more comprehensive list as shown below:

Table 1 Circumference / Mopotoloho[1]

Word Type	Sesotho	English
Infinitive	Hopotoloha	To traverse the circumference
Noun	Mopotoloho	Circumference
Noun	Potoloho	State of circumference
Verb	Potoloha	Follow the circumference
Plural Verb	Potolohang	Follow the circumference (plural)
Past Tense	Potolohile	Has rounded the circumference
Future Infinitive	Hotlapotoloha	To traverse the circumference in future

Table 2 Three / Tharo

Word Type	Sesotho	English
Noun	Tharo	Three
Noun	Raro	Root of three
Conjugated Noun	Hararo	By three
Conjugated State	Boraro	State of being three
Conjugated Plural	Bararo	To be three
Conjugated Plural	Babararo	They are three (beings)
Conjugated Plural	Ditharo	They are three (objects)
Verb	Thatholla	Unravel the three
Root	Thatho	Root of three
Infinitive	Hothatholla	To unravel the three
Future Infinitive	Hotlathatholla	To unravel the three in future

The Basotho's mathematical knowledge commands depth and breadth. The depth refers to the length of time in which mathematical knowledge was developed. The Basotho have developed and perfected their indigenous knowledge over millennia and they form part of the Nilotics or people of the Nile. I was pleasantly surprised when I was invited to address the **United Nations Economic Commission for Africa** in which I saw the Ethiopians dancing mokgibo wa Basotho. This is what confirmed to me that the Basotho were the descendants of the Nile. This explains the depth of indigenous knowledge of the Basotho. The breadth of knowledge refers to the many mathematical projects that the Basotho have engaged in as a culture. We see these projects in

[1] Sourced from the book Sesotho Dictionary of Mathematics.

their architectural tradition, hunting expeditions, pastoralist tradition, medicine, cartography, storytelling, farming culture, trade routes, symbolic communication using ditema, nteterwane, motwa, drums and others.

In this section we outline some mathematical concepts with a focus on Hosema (quadrature), Hokgetha Dinawa (sorting), Hophutha (collecting), Hothata (forming), Sedikadikwe (the circle) le Kgutlotharo (the triangle).

Hosema (Quadrate)

Basotho have the artifact of moseme. Moseme serves a variety of functions such as being used as a mat or in sacred ceremonies including placing sacred objects on moseme. Besides the sacred use of moseme, moseme also has a mathematical function. It was used as a tool of measuring area. The word *Hosema* means exactly that. You will hear Basotho say "Sebaka sena sebatla selekana meseme e meraro" meaning "this area requires three meseme". The concept of using some kind of geometric shape like a rectangle to measure area is known as quadrature. The Africans have used this technique to carry out a variety of measurements. The Greek mathematician Pythagoras is credited with having introduced the concept of quadrature in his homeland of Greece. Pythagoras may have learnt the concept in North Africa where he was a student of mathematics. According to his biography, Pythagoras spent about 23 years as a student in the Egyptian temples.

Mokgetho Wa Dinawa (Sorting)

The Basotho have this practice of Hokgetha (sorting). They sort a variety of agricultural produce such as dinawa. Dinawa provides plant-based protein. Meat provides animal protein but it is interesting that they don't mix beans with meat. If they eat beans, there will be no meat because they believe that plant protein is adequate according to their nutritional science. So sorting beans is an extremely important skill. Sorting takes place after winnowing the beans.

Sorting is a numerical activity. It requires counting, comparison, pattern recognition, temporary storage, and algorithmic techniques in terms of inserting, selecting, merging and so forth. Another consideration is the efficiency of sorting. The efficiency is determined by the algorithm used. In this case there is a random access to the beans to be sorted and this improves the efficiency of sorting. As a result of the efficiency of the method, it could take as good as a logarithmic time. The interesting thing about a logarithmic time is that it is less sensitive to the input size of the problem being solved.

I recall my grandmother teaching me mokgetho wa dinawa at a young age of 13 and by the time I was studying computer science in Canada and was given a sorting assignment, I recalled vividly how she taught me to sort. I got an A in that assignment thanks to the Mosotho grandmother.

Hophutha (Collect into a Round Mass)

Hophutha is a very interesting mathematical concept among the Basotho. According to Basotho ba kgale, hophutha means "to collect objects into a round mass". This concept was mostly used for traveling. When Mosotho is about to embark on a journey, she will say "Jwale rephuthela tsela" meaning we are now collecting our items into a round mass for the journey. The concept of *Hophutha* entails *gathering, analyzing, grouping, clustering* and *forming* into a round mass.

It so happens that this concept is also a scientific method. It has the same rigour and process as a scientific method. The question then is what is a scientific concept? What constitutes a scientific method? A concept or method is considered scientific if it uses an inductive logic. Induction is about moving from the particulars of the phenomenon to the theory of the phenomenon. In the case of *Hophutha*, the particulars are the items that need to be collected and the theory is the round mass that has now emerged as a result of the formation into *Polokwe* that is a round mass.

In hophutha, Mosotho is collecting the various items and then forming them into a round mass. The round mass becomes the conceptual articulation of the items. This is how inductive logic works in a simple case. Polokwe or round mass is now the theory that articulates and encapsulates the concrete items that existed before.

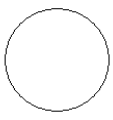
Thus, in the theory of hophutha we learn the mathematical and scientific concepts of geometry as a result of the round mass (spherical shape), set theory as a result of collection and inductive logic as a result of moving from the concrete to the theory.

Hothata (Form into a Round Mass)

Hothata means to form into a round mass. Not to confuse with the previous concept of hophutha which meant to collect into a round mass. The concept of hothata is mostly used by the Basotho women when they take a piece of cloth and tie it around their head to form this round mass. When they do that, we say "Baya thata" meaning they are forming a piece of cloth into a round mass or shape.

It is interesting that a commonly used infinitive like hothata is in fact a linguistic exercise in mathematics without others knowing about it. It is one of those parts of language which are encrypted. You don't need to know the underlying mathematics to appreciate the language. This is very much the case because even today when you ask people in the urban areas about what it means hothata they will simply say it means horwala tuku.

Sedikadikwe (The Circle)



Probably the core of mathematical knowledge among the Basotho is the circle. This is what ties them to the cosmos. This reminds of the cosmos and their genesis. They use the circle in the built environment so that they don't forget where they come from.

Sedikadikwe (the circle) is an amazing geometric shape. From the circle you can get a straight line in a form of a diameter; you can get a wave if you slice the circle in half, vertically flip the bottom half and then slide it so that starting point of it is aligned with the second point of the above half as shown below.

Why is the circle so important? The reason has to do with the cosmic knowledge and the spirituality of the Basotho. As part of the cosmos, the Basotho must only take what they need from nature without wasting the natural resources in accordance with their spiritual principles. This means the concept of surplus does not exist because it would violate the principles of the cosmos. The concept of no surplus ties in with another Sesotho concept of Hoila which means to deny or defer self-gratification.

If you occupy a piece of land and you use a circle to construct a built environment then you will have occupied exactly what you need without waste. This satisfies the rule of no surplus. It also satisfies the ritualistic rules of Hoila. Thus an engineering artisan among the Basotho is a practitioner of technical and spiritual knowledge. This means the artisan is guided by a moral code in discharging his or her duties.

On the other hand if you used a rectangle to occupy a piece of ground then you will be wasting land because you will be using more land than you need.

To understand this concept, let's imagine we want to occupy 19 square units of a piece of ground. We first try to use a rectangle with an area of 19 square units. We draw the rectangle as follows:

The Rectangle Occupancy

6.33 units

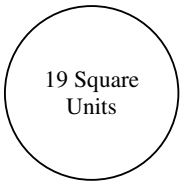
3 units | 19 square units

Analysis of the Rectangle

Area	19 Square units
Perimeter	18.7 units

Now let's try to occupy the same area of 19 square units using a circle:

The Circle Occupancy



The Circle Analysis

Radius	2.5^2
Area	19 Square units
Circumference	15.7 units

Notice the difference in the perimeter of the rectangle with respect to the circumference of the circle. The circle requires only 15.7 units to occupy 19 square units whereas the rectangle requires a whopping 18.7 units to occupy 19 square units. It is obvious that the rectangle is more expensive than the circle. The rectangle is taking more from the land than the circle. The rectangle costs 3 more units to occupy 19 square units whereas the circle costs 3 units less to occupy the same square area.

As a result of having a cosmic knowledge and also living in accordance with the heavens, the Basotho take only what they need from nature without waste.

Dipalo Papading (Mathematics at the Playground)

A child who learns mathematics in the village of Matamong first encounters numbers in a playground in a form of a game such as *Diketo* as opposed to a Western society where a child learns mathematics in a formal classroom setting. The implication of this playground approach towards learning mathematics is that it ignites the interest of the child and excites the child about numbers. The child feels that numbers are the familiar objects she plays with and there is nothing strange about that.

In a Western society, mathematics is taught as an abstract subject. When a teacher standing in front of the class and using the chalkboard to say:

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[2] Radius rounded off. Actual number is 2.456 which would further reduce the circumference by several percentage points.

One plus one is two, the child has to use imagination to remember what the teacher has just said. Even when the teacher gives exercises to solve simple number problems, the child is still operating at an abstract level of learning and as such the child does not get to experience the numbers.

In the traditional society of Matamong, they use rocks, a hemispheric pit to play the game of Diketo. The game requires counting in order to play. So the child is motivated to learn counting. They use the rocks to learn counting. As a result, you find little kids as young as three years of age having mastered the fluency of counting the rocks. Another point is that, the kids are very cruel and if you don't know how to count they kick you out. So no one wants to be kicked out of this absorbing game. The use of a game like Diketo as an effective tool to teach mathematics enables the students to experience numbers. It is that experience of numbers that is the reason for the efficacy of the pedagogical method.

The Basotho's Nahanotsebo (Theory of Knowledge) tells them that the human brain is not comfortable with abstract knowledge as a baseline of knowing. The reason for this is that the brain structure known in Sesotho as PLT (pelathabeng) is not able to resolve an abstract stimulus in terms of the preservation of the survival experience of the organism. The brain would rather have the abstract knowledge grounded in experience or some culturally authentic knowledge. In this way, the brain is able to resolve the ambiguity of abstract knowledge and ensure the maximization of the survival of the organism. This theory of knowledge was attested for by the traditional surgeons who shared their traditional knowledge with the author.

In addition to the playground, the teaching style provides a multi-sensory experience in that the natural senses like *eyesight, hearing, touch, taste* and *smell* are fully utilized and stimulated by the game. The game also requires eye-hand coordination, calculated throwing, calculated fetching, manual dexterity, vertical vector forces, horizontal vector forces, angular motion, among others in order to be proficient in the game.

In this way, the Matamong village provides platform that enables the students of numbers to experience numbers. Leveraging experience as part of learning is a powerful concept. The sensory experience of the child is also enriched by additional things like texture of the rocks, color of the rocks, shape of the rocks and weight of the rocks. The color and texture of the soil add further sensory excitation.

In the evening when the griots of the village render storytelling and poetry about the myths and legends of those who have gone before them, the game of Diketo was also used as a reference point to buttress the storytelling.

Hoetsahatsa Dipalo (Application of Mathematics)

In order for mathematics to become alive and excite the students, it must find application in the real world. The Basotho have always placed an emphasis on application of numbers. They use numbers in their ceremonies as part of the sacred numbers. They use number in their architecture. They use numbers in therapeutics. In this section, I want to use Diketo as a tool of applying mathematics in the real world. A lot of people think of Diketo as merely a game and

nothing more. Nothing could be further from the truth. Diketo is also a powerful tool of modelling and simulation; a teaching tool in learning about other advanced concepts.

Diketo is a game of rocks played by girls and boys alike. It requires a hemispheric pit on the ground. About 11 rocks are placed inside the pit. The player is required to throw Keto into the air while removing all the rocks from the pit. The player then returns all the rocks minus one until there is nothing to return using Lekgutla (recursive function). The recursive function used to model the game is:

$f(x_n) = K(x_n - 1)$

where **x** is the staging of the rocks, **K** is a constant and **n** is the index of the staged rocks.

As reported in the *African Origin of Mathematical Teaching and Learning* (Zulu, 2013):

"Counting ability is a mandatory skill in order to play the game of Diketo. The concepts of *increment, decrement, accumulator, counter, eye-hand coordination, manual dexterity, three dimensional space, estimation, area, volume* and *time* are inherent in the game. Moreover, the rocks provide tactile sensation, texture sensation, three dimensional experience, quadratic modeling, visual stimulus, acoustic stimulus, angular velocity, and angular momentum, among others. This shows a multi-disciplinary and multi-sensory nature of the game."

Besides being a game, Diketo can be used to teach and model counting, causation and flight simulation, as shown below.

Counting

The interesting fact about Basotho numerical algorithms is that they are based on counting. Counting is the basic mechanism through which the algorithms are developed. This algorithmic strategy makes these algorithms more efficient as opposed to the Western algorithms used in schools. Our little grandson was having trouble adding numbers like 10 + 5. I brought the wooden game of Diketo and two bags of different flat marbles. I asked him to remove 10 marbles from one bag. He did that. I asked him to remove 5 marbles from another bag. He correctly did that. I then asked him to push all 10 and 5 marbles into the pit of Diketo. He did that. I then asked him to count all the marbles inside the pit. He counted 15. I then asked him, 10 + 5 and he responded with a smile "15". In this case Diketo provided that visualization and experience of the numbers and the process of counting. Notice in this case that we solved an addition problem using counting. Who said you must only use an addition method in order to solve an addition problem?

Theory of Causation

Causation is about understanding the cause of something; it is about what causes what. Causation has application in many fields of study like medicine, social science, engineering, technology, physics, philosophy, experimental science, team building, negotiation, motivation and more. Usually there is event A followed by event B. If you observe the succession of event A and event B with some degree of regularity, you will eventually conclude that event A causes event B meaning event B is the result of event A. How do we know that to be true? How do we establish

the causal link? This is where Diketo as a modelling can be used to analyse causation in order to separate pseudo processes from the real causation.

Let's make an example:

I use my hand to throw Keto into the air and at the same time I remove the remaining rock from inside the hemispheric pit. Let's call Keto event A and the remaining rock event B. While event A rises into the air, event B is moving horizontally across. The observer, watches this succession of A and B with some regularity and concludes that A is the cause of B. We show the observer that my hand is the one that is responsible for the movement of A and B. We then reason that both A and B have a common cause in a form of a hand. The observer then concludes that the hand is the common cause.

We further dissect the causation and discover that the hand is in fact not carrying A into the air. Instead the hand generates some invisible force that causes A to rise into the air. We call this invisible cause vertical force. We also discover that the hand generates another invisible force that causes the appearance and movement of B and we call that the horizontal force. The discovery of these invisible forces shows that the hand is not a direct cause of A and B. There is a layer of indirection between the hand and the event. So far, through the modelling of Diketo, we have discovered that at face value we attributed the cause to the hand when in fact the hand played an indirect role in the causation. By repeating the simulation of the events A and B, we have isolated the pseudo processes and narrowed the direct causation to the invisible vector forces along the vertical and horizontal direction.

This brief modelling gives us an ontological insight into the real causation. What we learn from this Diketo modelling is that our explanation of causation must be ontological as opposed to epistemological. What I mean by that is that we shouldn't rely on some rational knowledge to explain causation. Rather, it should be based on empirical evidence as to the real causation of event A with respect to event B. If we follow this paradigm analysis using Diketo then we can avoid some of the tragic mistakes that were done by medical science such as was the case with a neurosurgery or psychosurgery known as lobotomy. The inventor of lobotomy was Dr. Antonio Egas Moniz who was awarded a Nobel Prize for Physiology or Medicine in 1949. Lobotomy was used to treat psychiatric illnesses like anxiety, depression, aggression, bipolar and so forth. The real problem with lobotomy is that it was prescribed for patients without an ontological analysis of causation. The people who got the treatment including the sister of the American President John F. Kennedy became like vegetables afterwards.

The correct understanding of causation has great implications for a variety of fields including therapeutics. In the traditional medicine of the Basotho, the Diketo simulation, I have just demonstrated, was used to teach ontological concepts of causality along with other diagnostic instruments known as Ditaola. Numerical reasoning was an important part of the analysis of causation.

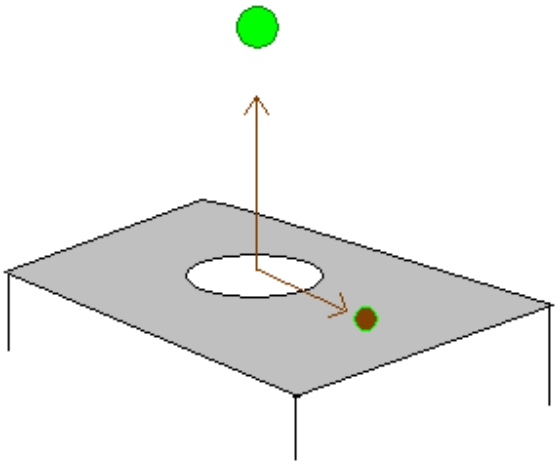
Our concept of causation is not limited to a simple case of event A followed by event B. Diketo allows us to expand the complexity so that we can chain the causations and thus analyse a causal chain. We can even extend our understanding of causation in terms of the types of causation

namely deterministic causation, probabilistic causation or stochastic causation or a causation that is characterized by an interaction of deterministic and probabilistic factors.

Flight Simulation

In the village of Matamong, we have done a lot of observation of flight of the birds. How birds fly; how they take off and various ways in which they achieve that. As a result of the observation, as part of our indigenous knowledge training, we discovered three kinds of take off by a variety of birds namely (1) Sefofatsepa (vertical lift), Sefofarapa (horizontal takeoff) and (3) Sefofarutla (jumping into the air).

Figure 0-1 Diketo Flight Simulation



In the case of Sefofatsepa, the bird lifts itself vertically from the ground into the air; an amazing feat by all accounts. In the case of Sefofarapa, the bird first runs like in a runaway like an airplane before takeoff. In a case of Sefofarutla, the bird jumps into the air and then flies away.

In all their different strategies of takeoff, they must do the same thing which is flap their wings using an upstroke and a downstroke. The upstroke provides a lift while a downstroke propells the bird forward.

Using Diketo modeling, we can assign Keto as upstroke event U and another rock as downstroke event D so that when we throw keto into the air and subsequent to that the other rock will be moving horizontally forward. As we simulate the flight using U and D we then realize that even though these forces seem to be moving in different directions, the sum of these vector forces provides the necessary lift and forward movement that enables the bird to fly.

A numerical system of Diketo makes it possible to model and analyze certain phenomena as mentioned above like causation and flight. Other systems that can also be simulated include algorithm analysis.

Conclusion

We have shown in this public lecture that the Basotho commanded mathematical knowledge long before the advent of Europeans on the South African soil. Their cosmic knowledge produced great wealth of their knowledge system including their African philosophy of science. The traditional knowledge of the Basotho including areas in farming, hunting, astronomy and architectural tradition, among others, confirm their indigenous mathematical concepts. A game like Morabaraba encapsulates powerful mathematical concepts like recursive systems, binary logic, algorithms, heuristics and permutation. While another game like Diketo which requires counting as a prerequisite skill reveals further mathematical concepts which can be used to model natural phenomena like counting, causation and flight as already shown.

The Basotho have developed and perfected their traditional knowledge over millennia and such rich knowledge can be used to enrich our curriculum towards a more holistic and well-rounded teaching and learning experience. Education must speak to the being of the students. The students must find themselves in the official curriculum. It has been unfortunate that the official curriculum has marginalized traditional knowledge as if it had nothing to contribute to the advancement of modern science. Education should not be like a parachute that lands and never incorporates traditional knowledge. The curriculum must reflect a locally grounded knowledge while embracing a global perspective. The question then is are the members of the new generation going to take a page from the rich knowledge that has been passed down over centuries so that they can face the future knowing that they are grounded in terms of where they come from? Are the architects of the education system ready to explore the Basotho traditional knowledge in order to incorporate this into the official curriculum? Other nations in other countries like the United Nations University has already embarked on the path towards incorporating the traditional knowledge of the indigenous peoples and local communities in order to put indigenous knowledge on the same path as other scientific systems of knowledge. Are we ready to embrace traditional knowledge or shall we continue to be affected by a sense of disdain towards traditional knowledge?

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