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EDITORS

Prof C. Kasanda & Mr. J. S. Uugwanga,

EDITORIAL COMMITTEE

External Editor: Prof Chosi Kasanda, *University of Namibia*

Internal Editor: Mr. Jafet S. Uugwanga, *National Institute for Educational Development*

EDITORIAL OFFICE

NIED

Reform Forum

Private Bag 2034

Okahandja

NAMIBIA

E-mail: [juugwanga@nied.edu.na](mailto:juugwanga@nied.edu.na)

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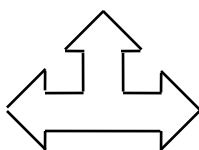
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**REFORM FORUM**

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## Editorial

Welcome to the National Institute for Educational Development's (NIED) 2018 volume 26 of the journal *Reform Forum*. This volume includes 6 most recent articles contributed by our readers which include titles like: *The historical development of number systems in Namibia*; *Exploring the understanding of the number pi: A case of pre-service secondary school mathematics teachers at a selected institution of higher learning in Namibia*; *Scientific reasoning skills: A theoretical background on science education*; *Environmental education practice in natural and social sciences in primary schools in Okahandja, Namibia*; *Why student-teachers fail basic mathematics module in first year of study at Rundu Campus of the University of Namibia*; and lastly, *The nature of science conception: A review of literature*. This latest publication fulfils NIED's mission of dissemination of educational information, experience and the results of studies as essential part of the Institute's mandate, closely linked with its (teacher) training, research activities and curriculum development. We invite you to sit down while you read this edition with great interest and think contributing an article towards the next publication. The reader could visit our website:

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The Editorial Committee

## The historical development of number systems in Namibia

<sup>1</sup>Ilukena, Mbonabi Alex, <sup>2</sup>Haimbodi, N. Frans, and <sup>3</sup>Sirinji, A. Reuben

<sup>1,2,3</sup>University of Namibia, Rundu Campus

### **Abstract**

*This research paper focuses on the historical development of number systems in Namibia. The research uses a qualitative paradigm to explore the number systems used by several ethnic groups in northern, north-eastern and eastern Namibia. The data was collected from a sample of 76 students at the University of Namibia (UNAM), Rundu Campus, who were asked to write the traditional counting numerals from their places of origin. Data revealed that most of the ethnic groups in the studied regions used base 5 (Quinary Numeral System) counting system and a few base their counting on the fingers. The study recommends that research be conducted to look into the effects of the base 5 system used traditionally on the performance of learners in primary schools.*

**Keywords:** numerals, counting, number systems, number, digits

### **Introduction**

The Namibian Government attaches great significance to the teaching of Mathematics in Namibian schools. "Mathematics is indispensable for the development of science, technology and commerce" (National Institute for Education Development [NIED], 2010a, p. 18). The value attached to Mathematics led to the reform policy that Mathematics was to become a compulsory subject for every child in Namibian schools (NIED, 2010b; Ilukena, 2011), at the beginning of 2012.

The teaching of Mathematics in Namibia has been a challenge since independence in 1990 as the learners' performance in Mathematics has been unimpressive (NIED, 2009; Iyambo, 2010). Studies on Mathematics performance in Namibian schools indicated unimpressive learners' performance in Mathematics particularly at Upper Primary Phase (Sichombe, Tjipueja, & Nambira, 2013). Sichombe et al. further add that efforts on promoting the status of Mathematics nationally and improving learners' performance are of great importance. This can happen if a solid foundation is properly laid at lower grades.

### **Background of the research**

#### ***Numbers origins***

A numeral system, or system of numeration, is a writing system for expressing numbers, that is, a mathematical notation for representing

numbers of a given set, using digits or other symbols in a consistent manner. Numeral systems are sometimes called *number systems*, but that name is ambiguous, as it could refer to different systems of numbers, such as the system of real numbers, the system of complex numbers, the system of  $p$ -adic, etc. For this study, such systems are not the topic for discussion.

However for the purpose of this study, a number system should be seen in the context that allows the symbols "11" to be interpreted as the binary symbol for *three*, the decimal symbol for *eleven*, or a symbol for other numbers in different bases. The number, the numeral represents is called its value. Because ideally, a numeral system will:

- *represent a useful set of numbers for example integers, or rational numbers;*
- *give every number represented a unique representation (or at least a standard representation); and*
- *reflect the algebraic and arithmetic structure of the numbers.*

Moreover, the focus is basically on the simplest numeral system, the unary *numeral system*, in which every natural number is represented by a corresponding number of symbols. If the symbol is chosen, for example, then the number *three* would be represented by ///. The tally marks represented on such system

are still commonly used all over the world, Namibia not being an exception. Although the *unary system* is only useful for small numbers, it still plays an important role in theoretical computer science, Elias gamma coding, which is commonly used in data compression, expresses arbitrary-sized numbers by using *unary* to indicate the length of a binary numeral.

Historically, whole numbers began with the ancient Egyptians who built up a powerful structure of numerals with discrete hieroglyphs from *I* up to *IO*, and all the exponents of 10 up to over 1 million. For instance, using the original hieroglyphic script of Egyptian numerals where  $| = 1$  as indicated earlier. A place-value system with foundation fundamentally on the numerals was used by the Babylonians between 2000 BCE. and 1000 BCE and their place value system were based on base 60 rather than base 10. This Babylonian system lacked a symbol for zero, although the Babylonians began thinking about the concept of zero in 2000-1800 BCE, it was not until about 200-300 BCE that the concept of 0 as a placeholder and 0 as a number were associated with one another in India much earlier than in Babylon (Reno, 1999; Erwee, 2007 in Ilukena, 2014). The concept *zero* was developed, to avoid much ambiguity about written numbers, for example if the symbol for 6 was written down, there was no way of distinguishing between 6, 60 and even 60, 000 (Ilukena, 2005; Erwee, 2007 in Ilukena, 2014). Due to these ambiguities, zero was then introduced as a placeholder.

Numbers and counting have become an integral part of our everyday life, especially when we take into account how the computer and other programmable systems make use of numbers. These words you are reading have been recorded on a computer using a code of ones and zeros. It is an interesting story how these digits have come to dominate our world. With the need to count, keep records and solve problems, every nation designed its own numeral system, with unique characters. History has revealed origins of numbers in several nations such as Egyptian, Babylonian, Greek, Chinese, Mayan, Hindu and Roman (Ilukena, Haimbodi, & Sirinji, 2015; Smith, 2012). These nations used various base systems ranging from base 10 (Denary), base 20, and base 60 (Sexagesimal) as alluded to earlier.

Therefore it is not surprisingly that the Namibian numeration system is a consistent base ten system that facilitates mental and written notational forms of number for both whole number and decimal fractions. The numeration system allows us to allocate words for numbers in a pattern that follows a base ten system where the multi-unit conceptual structures used involve the powers of ten.

### **Problem statement**

Research has revealed the historical development of numbers in different nations. This research was triggered by these researches and the fact that only few researches have been carried out on the historical development of number system in Namibia, if any. Furthermore, the current education system in Namibia encourages parental participation in their children's learning. This is coupled with the concern that counting in vernacular languages or dominant languages used in the community collates with one used in schools, especially at lower grades. This paper focuses on exploring numeral systems in the northern, north-eastern and eastern Namibia. It, thus, seeks to address the following research questions:

1. *What are the traditional numeral systems used by Namibian ethnic groups?*
2. *What are the challenges encountered by teachers teaching mathematics using base 10?*
3. *How do traditional numeral ethnic groups incorporate the concept of zero?*

### **Theoretical framework**

The study draws upon the Expectancy-Value Theory of Motivation by Hodges. This is a general notion that learners expect certain outcomes from certain behaviours and the more learners value behaviour, the more they are likely to perform well in it (Hodges, 2004). Learners want to obtain good grades and when motivated tend to study comprehensively and perform well. It is further argued that expectancy-value theory depends on the self-esteem of learners and is assured through valuing the expected results of the activities.

### **Literature review**

Western education comes with the art of writing and symbolic expression, it is evident that before that, different races in Africa had

different systems of counting, that is, they had their own different number system. The development of numeration in any particular society ultimately depends upon the economic development of that society. The much celebrated number system with modern mathematics is as old as life in Africa (David – Osuagwa, Anemelu, & Onyeozili, 2000 in Ilukena, 2014). Northern Africa participated in the flowering of Arabic scholarship from the eighth to the fifteen centuries and many of their manuscripts of that period, written in the Arabic language by scholars of various ethnicities have been analysed and translated contributing to mathematics knowledge. Among those who made such original contributions are the Egyptian Abū Kāmil (circa 850 – 930) with his work on Algebra, and Ibn al – Haytham, who contributed to discoveries in optical geometry (Zaslavsky, 1979).

One of the most interesting numeration systems is that of the Yoruba people, of south – west Nigeria, a nation of urbanized traders and farmers, not only is it based primarily on 20, with 10 as subsidiary base, but it relies on subtraction to a great extent. For example, 45 was expressed as “five from ten from, three twenties” illustrated as  $45 = (20 \times 3) - 10 - 5$  some numbers in symbolic notation in the Yoruba as indicated by Zaslavsky (1979) in David – Osuagwu, Anemelu, & Onyeozili, 2000, p. 57) are:

$$\begin{aligned} 106 &= (20 \times 6) - 10 - 4 \\ 300 &= 20 \times (20 - 5) \\ 525 &= (200 \times 3) - (20 \times 4) + 5 \end{aligned}$$

In addition, the Igbos counted in quinary (base 5) and vigesimal scale (base 20). Moreover in Sierra Leone, the two major ethnic groups, the Temne and the Mende had a “toes – and – finger” counting system; they grouped objects in fives then in twenties. The Mende, defined 20 as “*one man finished*” (Ohuche, 1979 in David – Osuagwu et al., 2000), this is due to the utilization of all toes and fingers on one person.

Southern – African societies have also developed mathematical concepts and practice to serve their needs and one can apply ethno-mathematics principles to analyse them. Gerdes (1988) speaks of ‘hidden’ or ‘frozen’ mathematics, meaning that when an artisan discovered a production technique, she or he was thinking mathematically for example

activities on house building and basket-weaving in Mozambique. The Tschokwe/, Cokwe of South – West Africa draw in the sand to illustrate the folklore of their people and instruct the young and such knowledge is passed down from one generation to the next by word of mouth and by example.

Furthermore, mathematical ideas are evident in games of chances and games of strategy for example the two board games that are common in various parts of the world are two-row and the four-row versions Owela (Oshiwambo) or *Mulavalava* (Subia). Players must outwit their opponents in addition, subtraction, division and multiplication. Other games are *Oodoota* or *Kudota* played in Namibia which involve multiples, counting and addition. It should further be noted that the Hottentots of Southern African were the first people to use the binary scale (David – Osuagwu et Al., 2000). They had only two number words; “a” as one and “oa” as two, most people thought this scale was primitive and only meant for those of low mental development, or those who were incapable of forming any other number scale worthy to be called the name. This was only realized after the invention of computers, arguments changed drastically as computers are based on electrical circuitry. An electrical principle is based on “On” and “Off” which agrees with two digits of the binary system. This is how the binary scale has become so popular worldwide today.

As alluded to in this research paper, the level of a society’s mathematical knowledge depends to a greater extent on the culture and technological level of that society. Although we cannot describe the mathematics they used, there is evidence that the Dogon people of Mali plotted the orbits of the Sirius star – system on the basis of knowledge acquired seven centuries ago (Adams, 1983); for what seems to have been an astronomical observation in north – west Kenya dating back over 200 years (Lynch & Robbins, 1978); for the practice of advanced metallurgy in central Africa at about the same time (Schmidt & Avery, 1978) that Africa reached the New World long before the voyages of Columbus (Van Sertima, 1977) and lastly, eight centuries ago southern Africans constructed the massive complex of stone building called “Great Zimbabwe” (Garlake, 1973).

It is not surprisingly that all people count. Numeration systems may range from a few words to the extensive vocabulary of nations with a history of centuries of commerce. Among the ethnic group of West Africa, numeration systems usually based on grouping of twenties, with five and ten as subsidiary bases, while in southern and Eastern Africa ten is the most common base. Frequently number-words are borrowed from neighbouring peoples or from Arabic and European languages. A characteristic of African counting is a standardized system of gestures to accompany, or even replace, the number-words. Familiar to the whole number digits written in standard form or standard notation is our number system, the denary or decimal scale (base 10) the most familiar number system in the whole world that resulted from counting of human fingers and toes used as a matching device, and accepted by the international community; people now count in groups of 10s. This number system has ten symbols, 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9 which we are very familiar with right from primary school.

Lastly, research has shown that any numeral system can be expressed as:

$$\text{number}_b = [d_N \dots d_2 d_1 d_0]_b = \sum_{n=0}^N d_n b^n = d_0 b^0 + d_1 b^1 + d_2 b^2 + \dots + d_N b^N$$

Where:

$b$  = numeral system base

$d_n$  = the  $n$ th digit

$n$  - can start from negative number if the number has a fraction part.

$N + 1$  = the number of digits

## Research methodology

### *Research design and research instruments*

This study was situated in the qualitative paradigm as it sought to obtain an in-depth understanding of the traditional numeral systems (Gay, Mills and Airasian, 2009). The researchers, being lecturers at the University of Namibia, engaged their students in collecting traditional numeral systems from their ethnic groups. The data was then categorized based on the tribes. The data was recorded in tables and analysed based on emerged themes of tribal counting.

### Populations and sample

The population of this study consisted of 50 year 3, and 26, year 4 B. Ed. student-teachers,

respectively enrolled at UNAM Rundu Campus in 2015.

## Results and discussions

The findings show that the mother tongues used by our students enrolled in the B. Ed. programme doing mathematics at upper primary phase were Nyemba (10), Rumanyo (11), Rukwangali (18), Oshindonga (4), Oshikwanyama (3), Umbundu (3), Thimbukushu (2), Subia (2), Chokwe (1), Setswana (1), Otjiherero (1) and Afrikaans (1). It was further established that Nyemba is divided into three dialects namely; Nkangala Nyemba, Masaka Nyemba and Ngangela Nyemba. Rumanyo has two dialects which are Rusambyu and Rugciriku. The one Oshindonga student spoke Oshimbalantu at home. Due to cultural diversification, these participants were either taught through their mother tongue or a predominant local language of the area as per school language policy of 1993. Table 1 shows mother tongue languages taught at lower grades in Namibian schools.



**Table 1: Languages and mother tongue languages taught at lower grades in Namibia**

Language	School	Mother tongue	Not mother tongue	Other language
Rumanyo	11	8	3	Thimbukushu
Rukwangali	20	19	1	Umbundu
Thimbukushu	4	4	0	-
Silozi	2	0	2	Subia
Oshindonga	8	4	4	Oshimbalantu Rukwangali Oshingandjera
Oshikwanyama	6	3	3	Oshimbandja
Otjiherero	3	3	0	-
Setswana	3	3	0	-
Afrikaans	7	1	6	Rukwangali Chokwe Rumanyo Oshikwanyama

The questions were aimed at finding out if these student-teachers expected to be proficient after completing their studies and teach mathematics proficiently with the changes in the new curriculum, where the mother tongue as medium of instruction was from Grade 0 to 5. What challenges could be encountered after being trained in English at University level, and what needs to be done to

remedy the situation? Will they be able to publish or write teaching and learning materials in those mother tongues – or predominant local languages or not, if they are assigned to handle grade 4 to 5 classes? Table 2 gives the different counting strategies in mother tongue of the students who took part in this study.

**Table 2: Numeration in Indigenous languages included in the school syllabus at primary level**

Numeral	Hindu-Arabic	Rumanyo	Rukwangali	Thimbukushu	Silozi	Oshindonga	Oshikwanyama	Otjiherero	Setswana
0	Zero	-	Euta	-	-	Owala	-	Ouriri	Sepe
1	One	Mwe	Zimwe	Thofotji	Nwi	Yimwe	Imwe	Imwe	Ngwe
2	Two	Mbiri	Mbali	Yiwadi	Peli	Mbali	Mbali	Imbari	Pedi
3	Three	Ntatu	Ntatu	Yihatu	Talu	Ndatu	Nhatu	Indatu	Tharo
4	Four	Ne	Ne	Yine	Ne	Ne	Nhe	Ine	Nne
5	Five	Ntano	Ntano	Yikwoko	Tanu	Ntano	Nhano	Indano	Tlhano
6	Six	Ntano-nayimwe	Ntazimwe	Kwoko noThofotji	Silela	Hamano	Nhano naYimwe	Ihambo-umwe	Thataro
7	Seven	Ntano-nambiri	Ntambali	Kwoko noYiwadi	Supa	Heyali	Nhano naMbali	Ihambo-mbalri	Shupa
8	Eight	Ntano-nantatu	Ntantatu	Kwoko noYihatu	Loba-Peli	Hetatu	Nhano naNhatu	Ihambo-ndatu	Robedi
9	Nine	Ntano-nane	Ntane	Kwoko noYine	Loba-nwi	Omugoyi	Nhano na Nhe	Imuvyu	Robongwe
10	Ten	Murongo	Murongo	Dikumi	Lishumi	Omulongo	Omulongo	Omurongo	Shome
Base	10	5	5	5	10	10	5	5	10

It emerged (see Table 2) that the eight mother tongue languages used different number base systems in counting. Five languages, Rumanyo, Rukwangali, Thimbukushu, Oshikwanyama and Otjiherero, used base five while three namely the Silozi, Oshindonga and Setswana languages used base 10. , This finding concurs with the reviewed literature that a variety of bases are used in counting by different ethnic groups in Namibia. We also found that Silozi and Setswana used advanced subtraction methods, as indicated in the Table 3. Reflecting on numeral 7, the Silozi and Setswana ethnic groups say *Supa* (Silozi) and *Shupa* (Setswana) which is the finger we use for pointing at objects or things.

Mathematically, it means fold three fingers below the pointing finger;  $10 - 3 = 7$ , while at *loba* (means break or fold), *Peli* (means two), therefore *Loba - Peli* (means break two from 10);  $10 - 2 = 8$ ; *Loba - ñwi*;  $10 - 1 = 9$ .

Furthermore, statistically 5 out of the 8 (62.5%) of the languages used base 5 and only 3 of the 8 (37.5%) used base 10 which is used in Namibian schools. This shows that it is viable for Namibian schools to adopt the base five numeration system for the languages that use base five. There are other languages in Namibia which are not used as media of instruction in schools, but used by our students at home. Their use in schools may enhance the learning of mathematics in our schools.

**Table 3: Languages found in Namibia and not used as a media of instruction in schools**

Numeral	Hindu-Arabic	Nyemba (Nkangala)	Nyemba (Ngangela)	Nyemba (Mashaka)	Umbundu	Subia	Oshimbalantu
0	Zero	<i>Livunda</i>	<i>Livunda</i>				
1	One	<i>Yimo</i>	<i>Cimo</i>	<i>Yimo</i>	<i>Mosi</i>	<i>Kamwina</i>	<i>Yimwe</i>
2	Two	<i>Vivali</i>	<i>Yivali</i>	<i>Yivali</i>	<i>Vali</i>	<i>Tobele</i>	<i>Mbali</i>
3	Three	<i>Vitatu</i>	<i>Yitatu</i>	<i>Yitatu</i>	<i>Tatu</i>	<i>Totatwe</i>	<i>Nhatu</i>
4	Four	<i>Viwana</i>	<i>Yiuana</i>	<i>Yiwana</i>	<i>Kuala</i>	<i>Tonee</i>	<i>Ne</i>
5	Five	<i>Vitanu</i>	<i>Yitanu</i>	<i>Yitanu</i>	<i>Tanlo</i>	<i>Iyaza</i>	<i>Nhano</i>
6	Six	<i>VitanunaCimo</i>	<i>Pandu</i>	<i>Hambowomwe</i>	<i>Epandu</i>	<i>Iyaza ni Kamwina</i>	<i>Hamano</i>
7	Seven	<i>VitanunaVivali</i>	<i>Panduvali</i>	<i>Hambombali</i>	<i>Epanduvali</i>	<i>Iyaza ni Tobele</i>	<i>Heyali</i>
8	Eight	<i>VitanunaVitatu</i>	<i>Tjinana</i>	<i>Hambondatu</i>	<i>Epandutatu</i>	<i>Iyaza ni Totatwe</i>	<i>Hetatu</i>
9	Nine	<i>VitanunaYiwana</i>	<i>Tjela</i>	<i>Muvyu</i>	<i>Epanduguala</i>	<i>Iyaza ni Tonee</i>	<i>On'ngoyi</i>
10	Ten	<i>Likumi</i>	<i>Likumi</i>	<i>Likumi</i>	<i>Equi</i>	<i>Ikumi</i>	<i>On'longo</i>
Base	10	5	10	10	5	5	10

The findings from Tables 2 and 3 reveal that eight languages use base 5 while six languages use base 10. The findings further reveal that *analysis of*

*Numerals system* used for counting numbers by different ethnic groups in Namibia in are given in Table 4.

**Table 4: Contrasting the Decimal and the Quinary Base systems**

Decimal Numeral System - Base-10	Quinary Numeral System - Base-5
0	0
1	1
2	2
3	3
4	4
5	10
6	11
7	12
8	13
9	14
10	20
11	21
12	22
13	23
14	24
15	30
16	31
17	32
18	33
19	34
20	40

Table 4 shows the numerals for counting in groups of 5 and 10. It emerged in this study that only the digits less the base number system can be used. For example, in base five only the following digits can be used, that is: 0, 1, 2, 3, and 4 while in base 10, digits such as 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9 can be used. This implies that base five has 5 characters and base 10 has 10 characters. Furthermore, we found that in order to differentiate the number bases

we usually use subscript notation. For example,  $23_5$  read as two, three base 5. Meaning;  $2 \times 5^1 + 3 \times 5^0$  that is 2 fives and 3 ones Equals  $10_{10} + 3_{10} = 13_{10}$ . *Working out the addition and subtraction operations in Base 5 (Quinary System)*. A number system defines how a number can be represented using distinct symbols / characters. An example of addition and subtraction in base 5 would be:

## 1. Addition

1. *Augend*: The first of several addends, or the one to which the others are added.

### *Steps:*

$$\begin{array}{r} 134_5 \\ + 423_5 \\ \hline 1112_5 \end{array}$$

1. Add right to left;  $4 + 3 = 7$  (value bigger than base value). Hence divide 7 by 5 = 1 rem 2. Write remainder down and carry a 1.
2.  $3 + 2 + 1$  (the carried number) = 6,  $6 \div 5 = 1$  remainder 1. Write remainder 1 down
3. and carry the 1.

## 2. Subtraction

1. *Minuend*: The number from which another number is subtracted
2. *Subtrahend*: The number being subtracted

$$\begin{array}{r} 4312_5 \\ - 303_5 \\ \hline 4004_5 \end{array}$$

### *Steps:*

1. Subtract right to left. Since  $2 < 3$ , borrow a 'five' from the next place value. Now value in first column is 7, minus 3 = 4.
2. Second column now has zero in the minuend.  $0 - 0 = 0$ .
3. Third column,  $3 - 3 = 0$ .

It also emerged that it is common practice to count articles like oranges, eggs, vegetable leaves and cassava in groups. Most such articles are often displayed for sale in piles. Counting is usually done in groups of twos, threes, fours or fives. Traders

count in groups because it is faster. It also emerged that the base number should be smaller than the digit in use for that particular base; this is further illustrated below in Table 5.

**Table 5: Base Number and System digits**

Ten	Two	Three	Four	Five	Six	Seven	Eight	Sixteen
0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1
2	10	2	2	2	2	2	2	2
3	11	10	3	3	3	3	3	3
4	100	11	10	4	4	4	4	4
5	101	12	11	10	5	5	5	5
6	110	20	12	11	10	6	6	6
7	111	21	13	12	11	10	7	7
8	1000	22	20	13	12	11	10	8
9	1001	100	21	14	13	12	11	9
10	1010	101	22	20	14	13	12	A
11	1011	102	23	21	15	14	13	B
12	1100	110	30	22	20	15	14	C
13	1101	111	31	23	21	16	15	D
14	1110	112	32	24	22	20	16	E
15	1111	120	33	30	23	21	17	F
16	10000	121	100	31	24	22	20	-
17	10001	122	101	32	25	23	21	-
18	10010	200	102	33	30	24	22	-
19	10011	201	103	34	31	25	23	-
20	10100	202	110	40	32	26	24	-



The Octal Numeral System - Base-8 uses digits from 0 to 7 while Hexadecimal Numeral System - Base-16. Hexadecimal numbers use digits from 0 to

9 and capital letters of alphabets from A to F. The H denotes *hex* prefix as B denotes binary prefix which uses digits 0 and 1 only.

### Conclusions and recommendations

In this research paper, we critically analysed and reviewed various number systems embedded in home languages used in teaching mathematics in lower primary schools. We found that there are more home languages in Namibia than those used in schools. The switching of languages may contribute to difficulties in learning mathematics. The teaching and learning of mathematics is subject to challenges emanating from translations across languages and number systems. While some numerals like *inne* (*four*), and *imwe* (*one*), tend to remain consistent across several dialects, they drastically mutate, as language hieroglyphics continue shifting. We further found that graduates of UNAM may face challenges in teaching mathematics at grass roots level because some of the concepts may be lost in the translation of numeral systems. We therefore recommend that:

1. teachers of mathematics should be sensitive to the transition of number sense across home languages and from English;
2. further research should be conducted to look at the implications of the traditional number systems on classroom settings which use base 10; and
3. research should be carried out in computation in base 5 to establish the difficulties learners encounter when using the four basic operations in mathematics.

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# Exploring the understanding of the number $\pi$ : A case of pre-service secondary school mathematics teachers at a selected institution of higher learning in Namibia

<sup>1</sup>Shiwana T. Naukushu and <sup>2</sup>Choshi D. Kasanda

<sup>1</sup>University of Namibia, Hifikepunye Pohamba Campus and <sup>2</sup>University of Namibia, Main Campus

<sup>1</sup>[snaukushu@unam.na](mailto:snaukushu@unam.na) and <sup>2</sup>[ckasanda@unam.na](mailto:ckasanda@unam.na)

## Introduction

Pi ( $\pi$ ) plays a crucial role in circle geometry as well as other areas of Mathematics and Science. Despite the role it plays, its meaning and significance in Mathematics and Science is often underscored.

Most of the high school leavers use this number but they are not aware of what it means and its significance in Mathematics and Science. Many learners in the Namibian high schools are aware of the existence of  $\pi$ ; however they do not really know what it means. This study was therefore deemed necessary in the light of emphasizing deep learning of Mathematics as opposed to the rote learning that is based on the traditional education among first year secondary school pre-service teachers of Mathematics.

In this paper the researchers assessed the understanding of  $\pi$  among the first year secondary school pre-service teachers of Mathematics on their Mathematical experiences of  $\pi$ . Furthermore, the researchers also sought to relate the understanding of  $\pi$  among pre-service first year secondary school pre-service teachers of Mathematics to their academic performance in circle geometry.

Consequently this study sought answers to the following questions:

What meaning do the first year secondary school pre-service Mathematics teachers attribute to  $\pi$ ? To what extent do the first year secondary school pre-service Mathematics teachers possess understanding of  $\pi$ ?

## Literature review

Currently there is no agreed upon and precise meaning of  $\pi$ . Posamelner and Lekman (2004) define  $\pi$  from a historical point of view that historically,  $\pi$  is the numerical relationship between the diameter and circumference of a circle. Posamelner and Lekman (2004) further allude to  $\pi$  as a geometric constant thereby operationally defining geometry as the study of drawn figures.

$\pi$  has a rich history. Its history can be traced back to at least four thousand years, often with mathematicians attempting to extend their understanding of  $\pi$ , by calculating its value to a high degree of accuracy (Beckman, 1986). Other literature such as Boyer and Merback (1991) indicated that before the 15th century, mathematicians such as Archimedes and Liu Hui used geometrical techniques, based on polygons, to estimate the value of  $\pi$ . Eymard and Lafon (1999) on the other hand state that starting around the 15th century, new algorithms based on infinite series revolutionized the computation of  $\pi$ , and were used by mathematicians including Madhava of Sangamagrama, Isaac Newton, Leonhard Euler, Carl Friedrich Gauss, and Srinivasa Ramanujan in their calculations.

The common idea among the foregoing literature and also by Blamer (1999); Lay-Tong (1986) opines that the number  $\pi$  is a mathematical constant that is the ratio of a circle's circumference to its diameter. The

literature further state that  $\pi$  is a constant and is approximately equal to 3.14159.  $\pi$  is represented by the Greek letter " $\pi$ " since the mid-18th century (Posamelner and Lekman, 2004). Writers such as Blamer (1999); Eymard and Lafon (1999) as well as Posamelner and Lekman (2004) further suggest that the number  $\pi$  is an irrational number, which means that it cannot be expressed exactly as a ratio of two integers (such as  $22/7$  or other fractions that are commonly used to approximate  $\pi$ ); consequently, its decimal representation never ends and never repeats.

The recent developments in the history of  $\pi$  are that it has been utilised in diverse scientific fields of study. For instance, Posamelner and Lekman (2004) noted that the 20th century, mathematicians and computer scientists discovered new approaches that when combined with increasing computational power, extended the decimal representation of  $\pi$  to over 10 trillion ( $10^{13}$ ) digits. However, the recent studies of  $\pi$  are more record driven rather than being scientifically motivated.

While scientific applications generally require no more than 40 digits of  $\pi$ , the primary motivation for these computations is the human desire to break records, but the extensive calculations involved have been used to test supercomputers and high-precision multiplication algorithms (Posamelner and Lekman, 2004, p. 131).

Furthermore several individuals have endeavored to memorize the value of  $\pi$  with increasing precision, leading to records of over 67,000 digits (Posamelner and Lekman, 2004). Because its definition relates to the circle,  $\pi$  is found in many formulae in trigonometry and geometry, especially those concerning circles, ellipses, or spheres. It is also found in formulae from other branches of science, such as cosmology, number theory, statistics, fractals, thermodynamics, mechanics, and electromagnetism (Blamer, 1999). It can therefore be argued that the ubiquitous nature of  $\pi$  makes it one of the most widely known mathematical constants, both inside and outside the scientific community. Also, literature (e.g.

Blamer, 1999; Eymard and Lafon, 1999; Posamelner and Lekman, 2004) devoted time and effort to the study of  $\pi$  leading to a  $\pi$  day which is celebrated on  $\pi$  Day which is every 14<sup>th</sup> March, where findings and approximations of  $\pi$  to several are shown.

Furthermore, the later literature shows that  $\pi$  is used to get the volume or a surface area of a disc, the circumference of a circle, areas and volumes of cylinders, spheres and hemispheres, etc. It is also used to measure how fast and how powerful a computer is. Because it is well known it can be used to check computer accuracy and if it has a problem in its software or hardware.  $\pi$  is also used to get the value of trigonometry functions like sine, cosine, tangent, etc.  $\pi$  also, plays a crucial role in mechanics where it is used to measure circular velocity of rotating objects for instance a truck wheel, motor shafts, engine parts, gears, etc. (Blamer, 1999).  $\pi$  continues to play an important role in the study of electronics where it aids in the measurement of AC voltage across a coil and a capacitor. In the natural world  $\pi$  is utilized in measurement of ocean waves, light waves, sound waves, and river bends among others.

The Namibian school Mathematics curriculum assumes that  $\pi$  is common knowledge and therefore learners are expected to learn it constructively from interacting with their environment. Findings of this study indicated that high school graduates show low facility of  $\pi$ . Mathematics teachers often do not deem it necessary to incorporate the teaching of  $\pi$  as a concept that should be taught but they rather make use of it when teaching circle geometry and other scientific concepts that involve  $\pi$ .

This study therefore deemed it necessary to investigate whether  $\pi$  is integrated in the high school curriculum in order for learners to pay attention to its value and role in the scientific arena.

### **Theoretical framework**

This study is informed by the constructivist theory. Constructivism is mainly concerned with cognition, the progression of development of thinking and reasoning as a human action by individuals. Jooste (2011) noted that the constructivist theorists such as Piaget and Vygotsky both advocate and exemplify

“transactional, relational and contextualized” approaches for considering human development through interaction with the environment. Constructivism further holds the view that learners construct their own understanding of the knowledge (Jooste, 2011).

This study assumed that during the learners’ secondary school years the learners are exposed to instruction regarding the use of  $\pi$ . Therefore the first year secondary school pre-service Mathematics teachers were subjected to a rich environment that enabled them to gain a better understanding of  $\pi$ .

The researchers therefore, opined that the learners construct their Mathematical concepts through their own experiences and prior understanding. This prior understanding should have been acquired from their previous Mathematical background; hence, there was no need for University lecturers to re-teach the concept of  $\pi$  to them. This study therefore sought to gauge the first year pre-service mathematics teachers’ understanding of the number  $\pi$ .

### Methodology

The study sought to assess the first year secondary school pre-service Mathematics teachers’ comprehension of  $\pi$  as a number and its influence in their understanding of circle geometry. To do this the study adopted a sequential mixed methods (qualitative and quantitative) research design. Cresswell (2003) indicates that the use of the dual research i.e. qualitative and quantitative approaches has become a common practice in research and yield comprehensive results in the sense that results obtained through the quantitative method are described thoroughly by the qualitative data obtained from the research participants (Loraine, 1998).

Twenty first year secondary school pre-service Mathematics teachers at Hifikepunye Pohamba Campus of the University of Namibia were randomly elected in order to assess their understanding of  $\pi$ .

The random sampling procedure was used in this study because of the large number of first year secondary school pre-service Mathematics teachers because the group was too large to be studied.

### Presentation and discussion of the results

Students were asked to indicate their grades in Mathematics at Grade 12. Table 1 shows their responses.

**Table 1: Grades of the first year secondary school Mathematics pre-service teachers in the Mathematics Grade 12 examinations (N=20)**

Grade	No. of students
A	5
B	9
C	3
D	1
E	2
<b>Total</b>	<b>20</b>

From Table 1, 17 of the first year secondary school pre-service Mathematics teachers had quite a good mathematical background. Therefore, one expects them to possess a better understanding of  $\pi$ .

Students were asked to indicate at what grade they first encountered  $\pi$ , Table 2 shows their responses.

**Table 2: The grade level when the first year secondary school pre-service Mathematics teachers encountered  $\pi$  (N = 20)**

Grade level	No. of students
Grade 7	6
Grade 8	8
Grade 9	2
Grade 10	4
<b>Total</b>	<b>20</b>

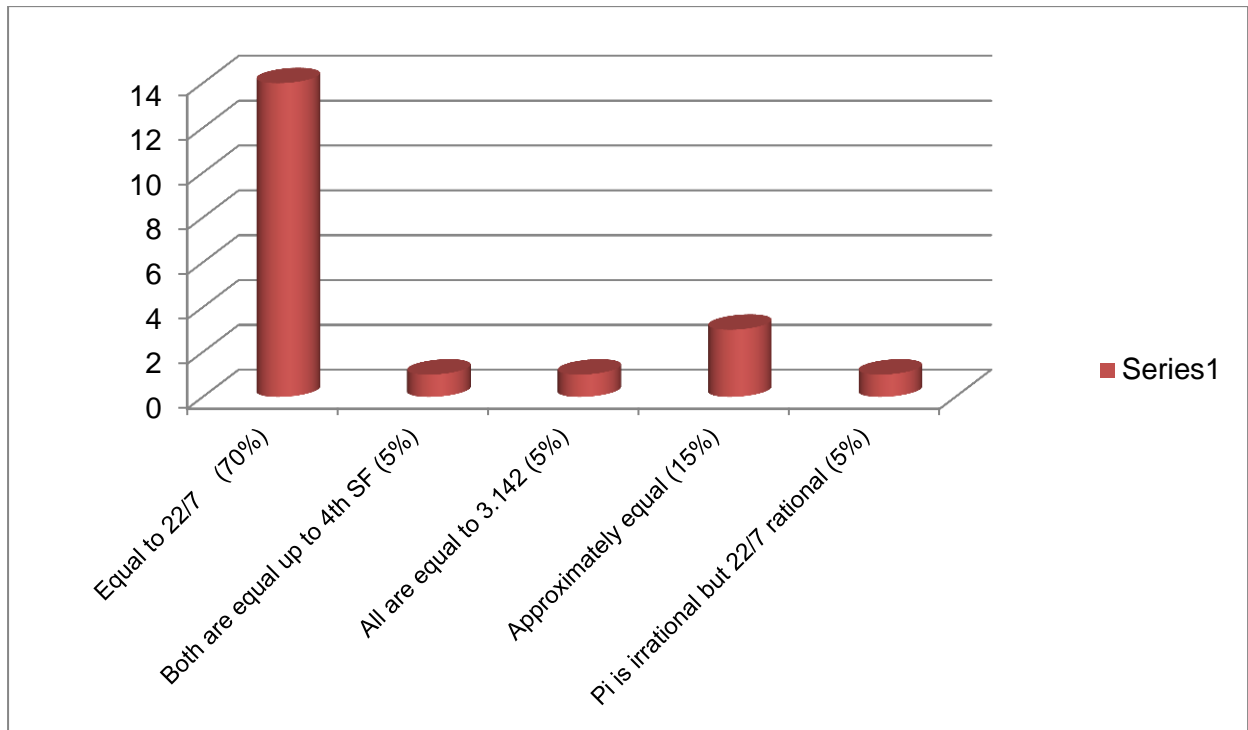
Table 2 indicates that the concept of  $\pi$  is developed as early as Grade 6 in Namibian schools. This finding seems to indicate that the participants in this study had interacted and used the concept  $\pi$  for over 5 years.

First year secondary school pre-service Mathematics teachers were further asked to indicate the sources of their information about  $\pi$ . Five (5) participants indicated their Mathematics teacher; 10 indicated from the Mathematics textbooks<sup>2</sup> indicated from dictionary, the remaining 3 participants indicated that they did not remember how they acquired the concept of  $\pi$ .

Furthermore, the student teachers were asked to explain what they understood by the concept  $\pi$ . Two indicated that  $\pi$  meant  $\frac{22}{7}$ , 1 said  $\pi$  meant 3.141592654, 3 said that  $\pi$  meant nothing to them, 2 students indicated that  $\pi$  meant 3.142, 3 students said  $\pi$  meant 3.14. Five student Mathematics teachers indicated that  $\pi$  was a ratio of the circle's circumference to its diameter. Another three student Mathematics pre-service teachers indicated that they had no idea what  $\pi$  meant. From the results only 5

Mathematics preservice teachers had an accurate meaning of  $\pi$ . This result points to either poor instruction at secondary school level or that the students had not grasped the meaning of  $\pi$  prior to their admission to university to be trained as Mathematics teachers.

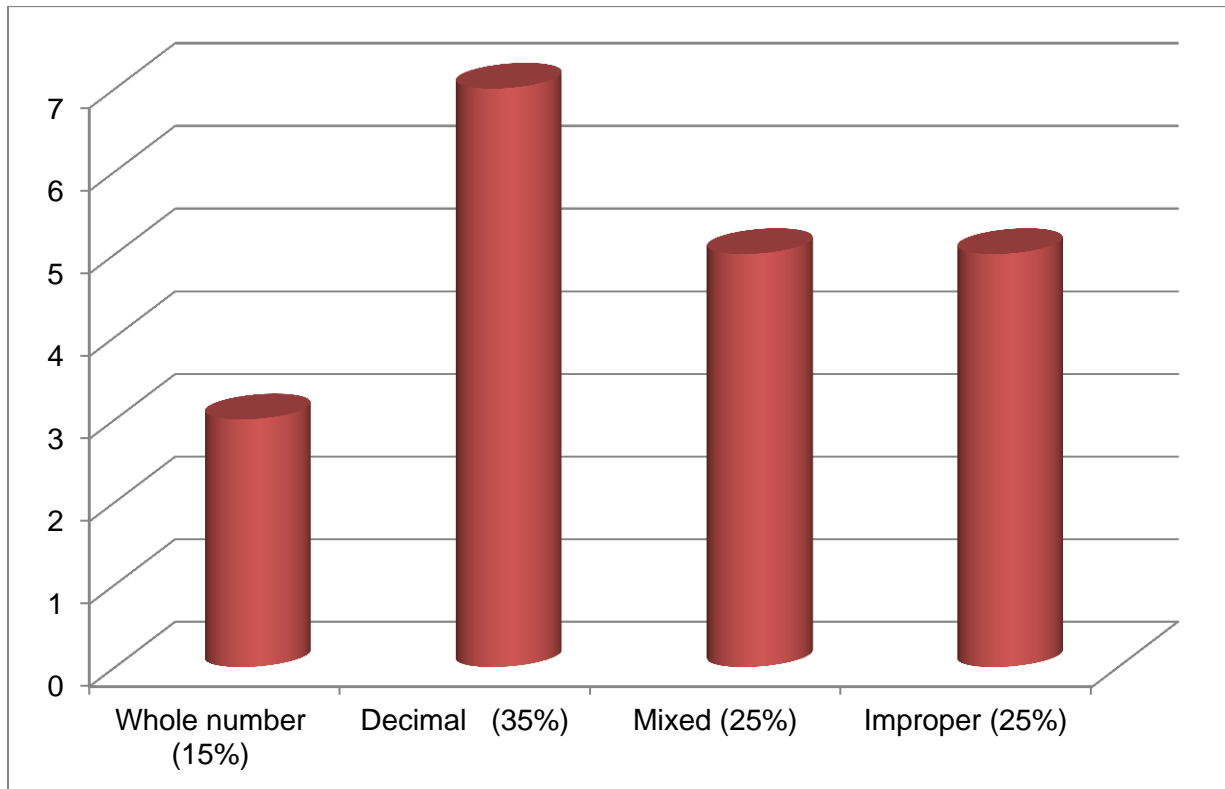
Students were also asked to indicate the relationship between  $\pi$  and  $\frac{22}{7}$ ; their responses are given in Fig 1.



**Fig.1: Students' responses on the relationship between  $\pi$  and  $\frac{22}{7}$ .**

Fig 1 indicates that 14 of the Mathematics pre-service teachers indicated that there was no difference between  $\pi$  and  $\frac{22}{7}$ . This is a common misconception in Mathematics, and supports Posamelner and Lekman's (2004) findings that research has proven that approximately 75% of high school leavers possess misconceptions about  $\pi$  and  $\frac{22}{7}$ . Moreover 3 of the pre-service teachers indicated

that  $\pi$  was approximately equal to  $\frac{22}{7}$ , while one indicated that  $\pi$  and  $\frac{22}{7}$  were equal up to 4 significant figures. The pre-service Mathematics teachers were also asked to indicate what type of a number  $\pi$  is. The pre-service Mathematics teachers responded according to the supplied options which included: *improper fraction, proper fraction, whole number, decimal; and mixed number*. Their responses are presented in Figure 2.

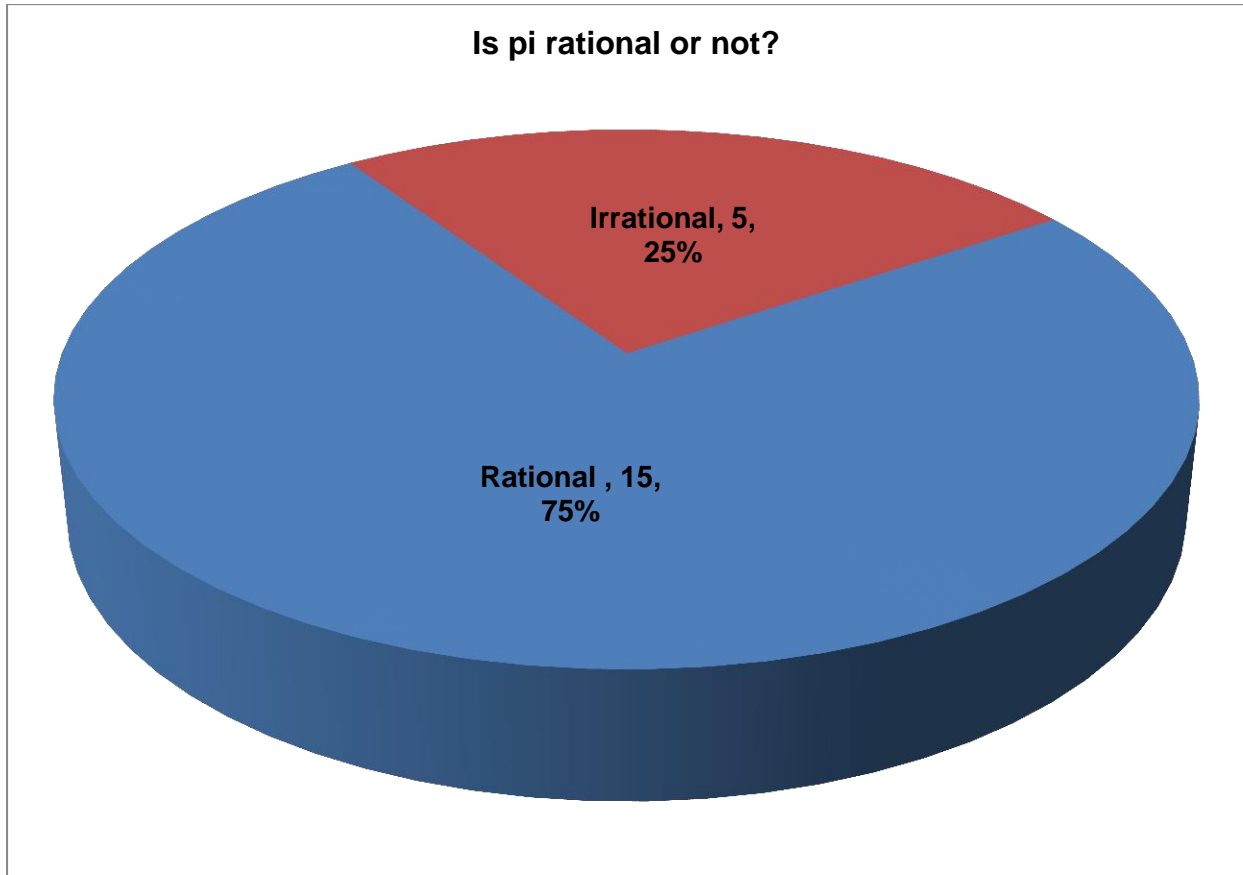


**Figure 2. Pre-service Mathematics teachers' responses regarding what type of number  $\pi$  is.**

Figure 2 shows that the pre-service Mathematics teachers lacked basic understanding of number theory. Thirteen of the participants did not know that  $\pi$  is a none terminating or repeating decimal. It is interesting to note that these participants were expected to join the teaching profession in four years' time and if their

misconceptions regarding the concept  $\pi$  are not. The other issue that was addressed by this study was whether  $\pi$  is a rational or an irrational number. Figure 3 shows the responses of student teachers regarding the question of rationality of  $\pi$ .



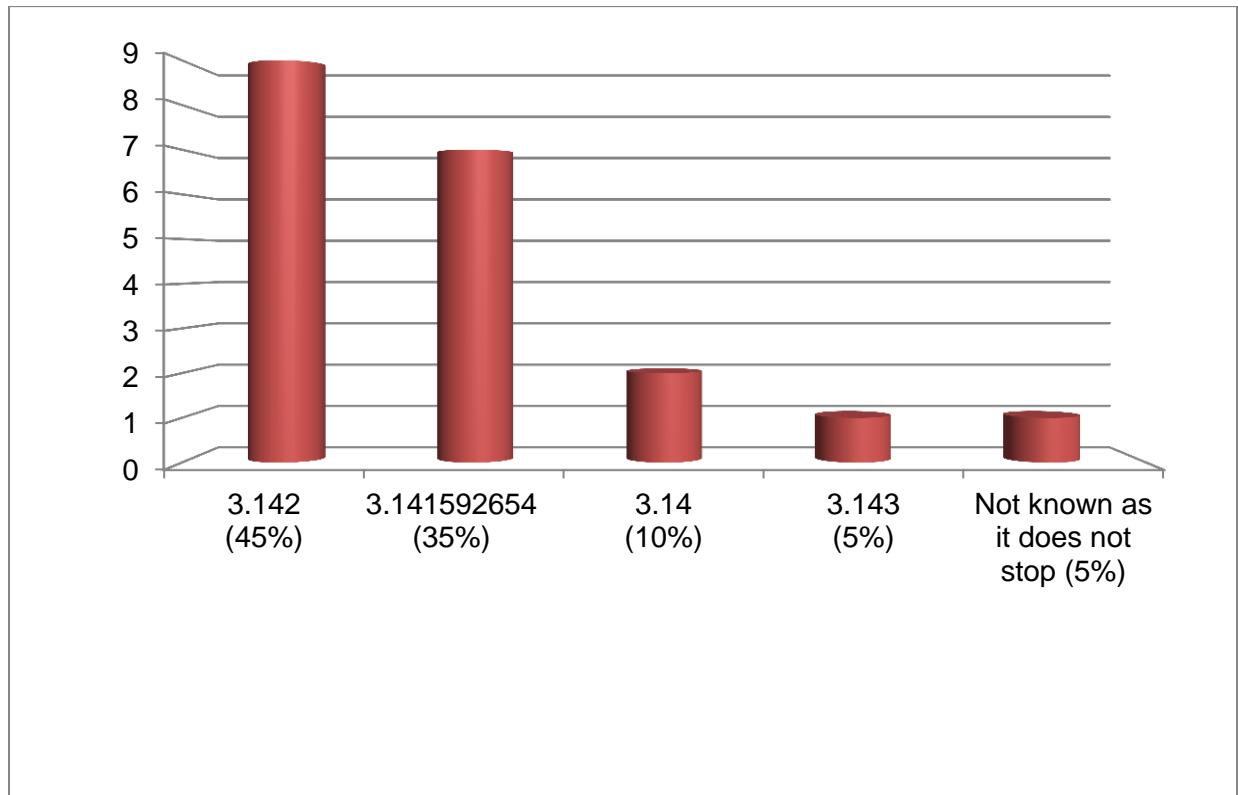


**Fig. 3. Students' responses on the rationality of  $\pi$ .**

Fifteen of the pre-service teachers of Mathematics did not possess a better understanding of rational and irrational numbers and therefore could not respond accurately to the rationality of  $\pi$ . It is important that the pre-service Mathematics teachers be remedied on the concepts "rational" and "irrational". Moreover, there is need to include the teaching of number theory to learners in Grades 11 & 12 at secondary school phase so as to remedy the

misconceptions they possess on the rationality of numbers.

The other issue that was addressed in this study was the perceptions of pre-service teachers on what the exact value of  $\pi$  is. To date mathematicians and scientists have not managed to give conclusively the value of  $\pi$  to a finite number of decimal places (Posamelner and Lekman, 2004). The Mathematics student teachers were asked to give the value of  $\pi$ . Their responses are shown in Figure 4.



**Fig. 4. Pre-service Mathematics teachers' perceptions of the exact value of  $\pi$ .**

Nineteen pre-service Mathematics teachers did not possess an accurate understanding of the value of  $\pi$  (Figure 4). This could be attributed to the fact that they did not know what is meant when a number is irrational. Most of the pre-service Mathematics teachers in this study who indicated that  $\pi$  is rational also had failed to give the "exact" value of  $\pi$ .

### Conclusion and recommendations

The following conclusions are made on the basis of the data presented in this study.

Most (17) of the pre-service Mathematics teachers possessed good grades in Mathematics (A to C) in their Grade 12 school leaving examinations giving the impression that they had grasped the content given at this level prior to their admission to UNAM. Fourteen of the pre-service Mathematics teachers had learned and met the number  $\pi$  during their Junior Secondary phase (i.e. Grades 8-10) while 6 had met the concept of  $\pi$  as early as Grade 7. There is need to start teaching Mathematics content at the same grade levels in Namibian schools, so that all learners enter secondary school and tertiary institutions with almost the same content. It is

hoped that the implementation of compulsory may address this problem.

Fifteen of the pre-service Mathematics teachers held the idea that  $\pi$  was an irrational number but could not explain why. Moreover, the pre-service Mathematics teachers did not seem to understand the characteristic features of irrational numbers. This needs to be emphasised in the teaching of school Mathematics.

Nearly all of the pre-service Mathematics teachers (19) in this study lacked an understanding that scientists and mathematicians have not really to date found the exact value of  $\pi$ . The pre-service Mathematics teachers therefore used the approximated values of  $\pi$  and took them to be the exact value. This could be due to the fact that their primary and/or secondary school Mathematics teachers did not probably adequately explain that all values of  $\pi$  used in their mathematical content did not really represent the exact value but were mere approximations.

Most of the students adequately summarised the use of  $\pi$  in Mathematics as to find the area and circumference of circles. However most of the students could not really

account for the use of  $\pi$  beyond the mathematical arena. Teachers need to extend the use of numbers beyond the Mathematics classroom. The overall conclusion is that pre-service Mathematics teachers in this study did not possess a better grasp of the concept of  $\pi$ , therefore, Mathematics teacher educators should ensure that pre-service teachers are proficient in basic Mathematics content for their learners to benefit from classroom instruction.

In summary the findings of this study were that first year secondary school pre-service Mathematics teachers did not possess strong understanding of the concept of “ $\pi$ ”. About 90% of first year secondary school pre-service Mathematics teachers who demonstrated low level understanding of  $\pi$  also scored low marks on the circle geometry test. Analysis of the high school curriculum indicated that the concept of  $\pi$  was not specifically taught in high school Mathematics curriculum and this deficiency could have compromised the first year pre-service mathematics teachers’ understanding of  $\pi$ .

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## Scientific reasoning skills: A theoretical background on science education

<sup>1</sup>Kambeyo, Linus and <sup>2</sup>Csapo, Beno

<sup>1</sup> & <sup>2</sup> Doctoral School of Educational Sciences, Institute of Education, University of Szeged, Hungary,

<sup>1</sup>[kambeyo@gmail.com](mailto:kambeyo@gmail.com) and <sup>2</sup>[csapo@edpsy.u-szeged.hu](mailto:csapo@edpsy.u-szeged.hu)

### **Abstract**

*To enhance scientific content and investigative skills that help students to acquire problem solving and lifelong learning skills, the assessment of scientific reasoning in science education has gained momentum of late. The purpose of this paper was to review and synthesize empirical studies on scientific reasoning skills and science education with the view to help improve science education in Namibia. Different methods were used to select and identify studies for this review.*

*First, the multi-dimensional reviews of studies were based on publications between the late 90s to March 2016. Second, the publications were searched from different academic databases, such as but not limited to, EBSCO, Science Direct, Web of Science, ERIC, and the search engine Google Scholar. Third, a wide range of search terms were employed in searching for diversified studies. Amongst others, the findings from the literature reveal that, science education is vital as it; i) promotes a culture of scientific thinking and inspires citizens to use evidence-based reasoning for decision making, ii) ensures that citizens have the confidence, knowledge and skills to participate actively in an increasingly complex scientific and technological world. The literature also reveal that inquiry based lessons promote scientific reasoning skills in students and that scientific reasoning skills have a long term impact on students' achievement.*

*Furthermore, it was found that in the K-12 education in the United States of America (USA), China and in most Organization for Economic Cooperation Development (OECD) countries, the development of scientific reasoning skills has been shown to have a long-term impact on students' academic achievement.*

**Keywords:** *scientific reasoning, science education, students' assessment, and science inquiry*

### **Introduction**

Science education is the field concerned with sharing science contents and processes with individuals, and the world community at large (Adey & Csapo, 2012). The field of science education includes work in scientific contents, the scientific methods and reasoning skills, scientific literacy and teaching pedagogies (Bao et al., 2009; Osborne, 2013; Adey & Csapo, 2012). Engaging and maintaining children's interest in science is of national and international concern. As in many other countries, the need for reform has been recognized in Namibia (National Institute for Educational Development,

NIED, 2010). International educational standards claim the importance of mastery of the scientific reasoning skills, scientific methods and understanding of the nature of science from the beginning in elementary (primary) up to secondary school (Mayer, Sodian, Koerber, & Schwipert, 2014). This then begs the question: What is scientific reasoning? International studies on scientific reasoning have defined scientific reasoning as a 'formal reasoning' (Piaget, 1965) or 'critical thinking', represents the ability to systematically explore a problem, formulate and test hypotheses, control and

manipulate variables, and evaluate experimental outcomes (Zimmerman, 2007; Bao, Cai, Koenig, & Fang, 2009; Kuhn, 2011). Basically, it represents a set of domain general skills involved in inquiry science supporting the experimentation, evidence evaluation, inference and argumentation that lead to formation and modification of concepts and theories about the natural and social world.

Furthermore, expectations of the outcomes of education in the 21<sup>st</sup> century increasingly focus on higher order thinking of synthesis, analysis and evaluation (Osborne, 2013), yet school science education is still dominated by lower level cognitive demands - in particular recall. Failure to transform science education for the needs of the 21<sup>st</sup> century is a consequence of a lack of a good model of scientific reasoning, scientific literacy and a body of expertise about how to assess such higher order cognitive competencies (Osborne, 2013). The main purpose of this paper is to review literature on scientific reasoning skills with the view to understand the theoretical backgrounds on science education. At the end of this paper, suggestions for future research are identified.

Research findings are synthesized to address the following review question; what does literature say about scientific reasoning skills of learners? In addition, this review contributes to finding out what specific effects does the assessment of scientific reasoning has on learners' learning and growth.

### **Methodology**

In this section, we briefly introduce the indexes of selecting literature and its outcomes, to give an overview of related studies on scientific reasoning skills and its impact on learning of science education. Different methods were used to select and identify studies for this review. First, the multi-dimensional reviews of studies were based on publications from the late 1990s to March 2016. Second, the publications were searched from different academic databases, such as, but not limited to; EBSCO, Science Direct, Web of Science, ERIC, ProQuest, and the search engine Google Scholar. Third, a wide range of search terms were employed in searching for diversified studies. During the

screening and searching of literature, studies were included based on the following:

- *they were about the assessment of scientific reasoning and thinking skills in science lessons;*
- *they involved students from elementary (Primary) school;*
- *their outcomes reported on students' scientific reasoning skills and impacts on science education;*
- *they were empirical studies: descriptions, explorations of relationships or assessment;*
- *they were carried out during the period 1990-2016; and*
- *they were published in the English language.*

We also had to hand-search target journals, such as Studies in Science Education from Southern Africa, and from Namibia in particular. Finally, these terms match flexibly but thematically. For example, we mixed “scientific reasoning skills of primary school children” “assessment” “thinking skills” whether from the title, abstract, or both, in order to identify the information strongly related to the review topic as available.

### **Results**

#### ***Synthesis of the findings of the studies in the review***

##### *Importance of science education*

Current thinking about the desired outcomes of science education is rooted strongly in a belief that an understanding of science is so important that it should be a feature of every young person's education (OECD, 2013). Indeed, in many countries science is a foregrounded element of the school curriculum from kindergarten until the completion of compulsory education. The emphasis on the curricula and its frameworks should not rely on producing individuals who will be producers of scientific knowledge, but rather it should be on educating young people to become informed critical consumers of scientific knowledge, a competency that all individuals are expected to need during their lifetimes (OECD, 2013).

Amongst others, literature reveals that science education is vital as it i) promotes a culture of scientific thinking and inspires citizens

to use evidence-based reasoning for decision making, ii) ensures that citizens have the confidence, knowledge and skills to participate actively in an increasingly complex scientific and technological world (Zhou et al., 2016). Further, Turiman, Omar, Daud, and Osman (2012) recommend that, to overcome the challenges of the 21<sup>st</sup> century in science and technology education, students need to be equipped with the 21<sup>st</sup> century skills to ensure their competitiveness in the globalization era. Tytler echoed the same sentiment whether debate about the role of school science education hinges on the question of whether the aim is to (i) prepare students for tertiary science studies and careers in science, or (ii) raise the scientific literacy of the community as a whole (Tytler, 2007).

The 21<sup>st</sup> century skills in science education that are expected to be mastered by students comprise four main domains, digital age literacy, inventive thinking (reasoning), effective communication and high productivity (Turiman et al., 2012). In their report, (OECD, 2013) affirms that many of the challenges of the 21<sup>st</sup> century will require innovative solutions that have a basis in scientific thinking and scientific discovery.

Elsewhere, developers of Australia's national science curriculum identify three possible pathways for students' need to be prepared for; to make personal decisions on the basis of a scientific view of the world; to become the future research scientists and engineers; and to become analysts and entrepreneurs in the diverse fields of business, technology and economics (National Curriculum Board, 2009).

Although in Namibia, secondary school teachers historically tend to enact a view that they are preparing students for university as Kapenda, Kandjeo-Marenga, Kasanda, and Lubben (2002, p. 60) argued, "teachers rarely used practical work in science education to develop skills in planning an investigation, in processing experimental data, or in communicating results of experimental work". International educational plans, like the Australian School Science Education plan 2008-2012, (Goodrum & Rennie, 2007) identify the fundamental purpose of school science education as among others, promoting scientific reasoning

and scientific literacy. They further extend these views by stating that science not only prepares students for citizenship but "provides firm basis for more specialized, discipline-based subjects in upper secondary school that lead to science courses at university, and prepares students for technical education courses that lead to science-related careers" (Goodrum & Rennie, 2007, p. 70), thus bringing together both sides of the debate. This focus is in line with NIED's (2014) views that scientific and technological literacy are the key purposes for science education for all students, not just those destined for careers in science and engineering, while the National Core Curriculum (2012) for Hungary, proposed that scientific literacy should enable individuals to navigate their way through life, rather than focusing on tertiary studies only.

Furthermore, science education has always been considered one of the best tools for cultivating students' minds. Scientific activities such as conducting empirical research, designing and executing experiments, gaining results from observations and building theories are seen as those in need of the most systematic forms of reasoning (Adey & Csapo, 2012). Elementary science education introduces young children to the basic facts about objects, materials, and organisms as well as the activities involved in designing and conducting a scientific investigation (Lazonder & Kamp, 2012). By engaging in these activities, children can start to develop proficiency in the scientific reasoning skills as well as scientific literacy.

#### *Importance of scientific reasoning skills*

Science and mathematics education is emphasized worldwide. Reports from large-scale international studies such as Trends in International Mathematics and Science Study (TIMSS) and Programme for International Students' Assessment (PISA), PIRLS (the Progress in International Reading Literacy Study) and National Assessment of Educational Progress (NAEP) continually make use of science, mathematics and reading contents within their question items. As a result, many countries in the world are advocating for the increase and implementation of a more extensive basic education curriculum in science, technology, engineering, and mathematics

(STEM) education. Educational reforms worldwide stress the need for a prepared 21<sup>st</sup> century workforce, which translates into students learning not only science contents, but also acquiring advanced transferable reasoning skills (Kuhn, 2011). The development of these skills will better enable students to handle open-ended novel situations and design their own investigations to solve scientific, engineering, and social problems in the real world (Bao et al., 2009).

As science education continues to become fundamental to modern society, there is a growing need to pass on the essential aspects of scientific inquiry and with it the need to better impart such knowledge. The current style of the content rich STEM education, even when carried out at a rigorous level, has little impact on the development of students' scientific reasoning abilities (Bao et al., 2009). The findings from their comparative study (Bao, et al., 2009) between American and Chinese students indicate that it is not *what we teach*, but rather *how we teach it*, that makes a difference in student learning of higher-order abilities in science reasoning. They further indicate that students ideally need to develop both content knowledge and transferable reasoning skills (Bao et al., 2009). The onus is upon researchers and educators to invest more time in the development of a balanced method of education, such as incorporating more inquiry based learning that targets both goals. Previous studies have indicated that scientific reasoning is critical in enabling the successful management of real-world situations in professions beyond the classroom (Han, 2013). For example, in the K-12 education in the United States of America (USA), the development of scientific reasoning skills has been shown to have a long-term impact on students' academic achievement (Adey & Shayer, 1994). Positive correlations between students' scientific reasoning abilities and measures of students' gains in learning science content have been reported (Coletta & Phillips, 2005), and reasoning ability has been shown to be a better predictor of success in Biology courses (Lawson, 2000).

The above findings support the consensus of the science education community on the need for the basic education (Grade1-12) students to

develop an adequate level of scientific reasoning skills along with a solid foundation of content knowledge. Zimmerman (2007) claims that investigation skills and content knowledge bootstrap one another, creating a relationship that underlies the development of scientific thinking. Research has been conducted to determine how these scientific thinking skills can best be fostered and which teaching strategies contribute most to learning, retention, and transfer of these skills (Osborne, 2013). For instance, Zimmerman (2007) in her research conducted in Illinois, United States of America (USA), found that, children are more capable in scientific thinking than was originally thought, and that adults are less so. She also states that scientific thinking requires a complex set of cognitive skills, the development of which require much more practice and patience. It is therefore important for educators to understand that scientific reasoning ability is best developed through science inquiry based education.

#### *Scientific reasoning in school-children*

Traditionally, developmental psychologists have considered the thinking and reasoning of elementary school children as deficient and have argued that scientific reasoning skills emerge only during adolescence (Inhelder & Piaget, 1958). However, in the last 20 years, developmental research has brought forth evidence for early competencies (Mayer et al., 2014). In his research, conducted in Southern Africa, Libienberg (2013) found that San people use scientific reasoning skills when they are tracking down animals in the veld. He further posits, "An example of inductive-deductive reasoning in tracking would be the way tracks are identified as that of an animal belonging to a particular species, such as the porcupine. Footprints may vary according to the softness or hardness of the ground" (p. 9) and this will guide the San people on the direction of where the animals are. It is also further argued that if the required foundations are not constructed, serious difficulties may rise at later stages of learning, as failures suffered during the first years of schooling will delimit children's attitudes towards education for the rest of their lives (Csapo & Szabo, 2012). The development of concepts related to science begins before the

start of formal education and the first years of schooling, and play a decisive role in steering conceptual development in the right direction. Early science education shapes children's thinking, their approach to the world and their attitudes toward empirical discovery (Csapo & Szabo, 2012).

Moreover, research has also found that, even pre-school children understand the relationship between covariation data and causal belief, when only potential causal factor (e.g., red or green food) covaried partially or perfectly with outcomes (good or bad teeth) (Osborne, 2013). When the effects of more than two variables must be taken into account, young children often fail to interpret patterns of empirical evidence (Kuhn, 2011). Unlike adolescents or adults, children tend to neglect or distort data, when covariation evidence does not agree with their prior beliefs or knowledge (Molnar, Greiff, & Csapo, 2013). Therefore, research findings indicate that basic experimentation and evidence evaluation skills in pre-school and primary school children do exist (Mayer et al., 2014). The onus is upon teachers and researchers to develop and assess the scientific reasoning in children while at an early stage in their schooling with the view to enhance learning. When children's scientific reasoning and thinking skills are assessed, it would inform the teachers and parents on the best possible ways on how to help the children in their education.

#### *Assessment of scientific reasoning*

In a review of the relevant research conducted for the US department of Education, Hannaway and Hamilton (2008) in Osborne (2013), found that standards and accountability policies lead teachers to focus on particular subject areas and types of instructional practices. In addition, they found that teachers focused on competencies specific to assessment and testing procedures (Osborne, 2013). Thus, a shift in the nature of assessment is important if science education is to transform itself from an emphasis on knowledge and the lower order cognitive demands of recall and comprehension to the higher order cognitive demands of evaluation and synthesis. One of the aims of diagnostic assessment of reasoning within science amongst others, is to monitor

students' cognitive development, to make sure they possess the reasoning skills necessary for them to understand and master the science learning material in a meaningful way on the one hand, and to check if science education stimulates students' cognitive development as much as it can be expected, on the other hand (Csapo, 2012). This idea is echoed by Adey and Csapo (2012), Adey and Shayer (1994) and Csapo and Szabo (2012), who assert that the content-based methods of enhancing cognition by applying science material for stimulating development provide rich resources for identifying reasoning processes which can be relevant in learning science and which can be developed through science education.

Furthermore, tests in scientific reasoning can provide valuable information at various levels as alluded to earlier. Teachers will be able to evaluate and reflect on their teaching styles should the results of the test bring no satisfaction. Both teachers and children may be motivated if the results of the test are good. Adey and Csapo (2012) argue that once teachers overcome the urge to teach the reasoning skills directly, they (teachers) will find the results of reasoning test useful to inform them of where children are now so that they can; (a) map out the long road of cognitive stimulation ahead, (b) better judge what type of activities are likely to cause useful cognitive conflict - both for a class as a whole and for individual children. Moreover, a diagnostic assessment programme should support the renewal of primary education. This programme has a dual purpose (Nagy, 2009), it assists individual development by providing learner-level feedback and its aggregated results can be used to establish various reference norms. It is further explained that, diagnostic assessment as a direct tool of criterion-referenced education is a method of learner-level evaluation by definition (Nagy, 2009), as such, it is reliant on the longitudinal documentation of individual progress.

#### *Assessment tools of scientific reasoning skills*

What are the possible mechanisms of assessing and testing scientific reasoning? Adey and Csapo (2012) suggest a way of assessing scientific reasoning. They argue that computerized testing could be much closer to the ideal individual



interview than a paper-and-pencil assessment. Furthermore, administering the same test to every subject improves the objectivity of the assessment (Adey & Csapo, 2012). Mayer et al. (2014) suggest that a variety of task formats that can be used to explore scientific reasoning competencies in young children. Apart from self-directed experimentation tasks in which participants may be involved in hands-on physical activities, tasks using story problems are common measures of scientific reasoning. Additionally, contextual support (abstract vs. concrete), task complexity (single - vs. multi-variable), plausibility of factors, response format (choice vs. production), strength of prior belief or prior content knowledge in scientific domains (e.g., Physics, Chemistry and Biology) have been shown to influence performance on scientific reasoning tasks (Lazonder & Kamp, 2012; Adey & Csapo, 2012). Predict-Observe-Explain (POE) items ask children to make informed predictions about a presented situation (Fu, Raizen, & Shavelson, 2009), and following an observation or summary of what happens, and asking students to provide explanations. For example, students might be asked to predict whether a given object sinks or floats in water. Once they find out that the object sinks or floats, they must explain why this occurred. This provides opportunities to reliably capture how students reason through and justify their predictions and explanations (Fu et al., 2009).

From a more operational perspective, scientific reasoning is assessed and operationally explained in terms of a set of basic reasoning skills that are researched thoroughly and found to be needed for students to successfully carry out scientific inquiry. This includes problem exploration, formulating and testing hypotheses, manipulating and isolation of variables as well as observing and evaluating of consequences. To that end, the Lawson's Test of Scientific Reasoning (LTSR, 1978) and Lawson's Classroom Test of Scientific Reasoning (LCTSR, 2000), provide a solid starting point for assessing scientific reasoning skills (Lawson, 1978, 2000). The tests are designed to examine skills such as; conservation of matter and volume, proportional reasoning, control of variables, probabilistic reasoning, correlation reasoning and hypothetical-deductive reasoning.

These skills are deemed important concrete components of the broadly defined scientific reasoning ability.

The popular version of Lawson's Classroom Test of Scientific Reasoning (LCTSR, 2000) has been used and it is still being used to assess scientific reasoning among students. Many science education researchers have been using the Lawson test to study the relationships between students' scientific reasoning abilities and science subjects (e.g. Physics, Biology or Chemistry). It is a 24 item two tier, multiple-choice test. Osborne (2013) describes a two-tier item as a question with some possible answers followed by a second question giving possible reasons to the first question. The reasoning options are based on students' misconceptions and that are discovered through free response tests, interviews and the literature. Furthermore, guided by Piagetian tasks, a number of researchers have developed measurement tools and instruments to assess scientific reasoning skills. These are the Group Assessment of Logical Thinking Test (GALT) by (Roadranga, Yeany, & Padilla, 1982) and the Test of Logical Thinking (TOLT) by (Tobin & Capie, 1981).

#### *Development of scientific reasoning*

What mechanisms can be used to stimulate and enhance students' scientific reasoning and by extension all of their reasoning skills? The development of scientific reasoning, as with the development of any reasoning, must necessarily be slow and organic process in which the students construct the reasoning for themselves (Adey & Csapo, 2012). Morris et al. (2015) concurred with them that effective scientific reasoning requires both deductive and inductive skills. Individuals must understand how to assess what is currently known or believed, develop testable questions, test hypotheses, and draw appropriate conclusions by coordinating empirical evidence and theory.

Furthermore, lessons which promote scientific reasoning provide plenty of opportunities for social construction (Adey & Csapo, 2012), that is to say, students are encouraged to talk meaningfully to one another, to propose ideas, to justify them and to challenge others in reasonable manners. Research (Harlen,

2013) has shown that the adoption and the use of inquiry based science learning has the potential to inculcate scientific reasoning and thinking skills required in the 21<sup>st</sup> century. Harlen (2013) further posits that embracing inquiry based science education recognises its potential to enable students to develop the understandings, competencies, attitudes and interests needed by everyone for life in societies increasingly dependent on application of science.

Notwithstanding that inquiry leads to knowledge of the particular objects or phenomena investigated, but more importantly, it helps build broad concepts that have wide explanatory power, enabling new objects or events to be understood (Harlen, 2013). A stimulating classroom environment is characterized by high quality dialogue, modelled and organised by the teacher, meaning that students will be working within the Zone of Proximal Development (ZPD) as proposed by Vygotsky (1978). The more knowledgeable students will be able to help their peers without the peer feeling less important (Vygotsky, 1978). However, despite the over-whelming evidence that asking higher-level, open ended questions has the potential to promote students' higher level reasoning and problem-solving abilities, teachers still struggle to use these types of questions when interacting with their students (Gillies, Nichols, Burg, & Haynes, 2014). Therefore, the development of general scientific abilities is crucial to enable science students to successfully handle open-ended real world tasks in future careers (Bao et al., 2009). Bao et al. (2009), further state that teaching goals in science education include fostering content knowledge and developing general scientific abilities. One such ability, scientific reasoning is related to cognitive abilities such as critical thinking and reasoning. Moreover, scientific reasoning can then be developed through training and can be transferred (Adey & Csapo, 2012; Bao et al., 2009). Training in scientific reasoning may also have a long term impact on students' academic achievement.

### **Conclusion**

Although there exists a number of understandings on what constitutes scientific reasoning, the literature seem to generally agree

that scientific reasoning represents an important component of science inquiry. Therefore, a better understanding of the nature of scientific reasoning requires extended knowledge of science inquiry. Scientific inquiry is embedded in the early research on constructivism and reasoning (Vygotsky, 1978; Inhelder & Piaget, 1958). Vygotsky (1978) posits that children learn constructively when new tasks fall within their Zone of Proximal Development (ZPD). That is, if a task is one that a child can do with a more knowledgeable knower's help, then the children will eventually learn to perform this task on their own by modelling the more knowledgeable person. The idea that children build on existing knowledge is also reflected in Inhelder and Piaget's (1958) work with formal reasoning development. Their model articulates clearly the levels through which children develop from birth (sensorimotor stage) to adulthood (formal operational stage).

On developing scientific reasoning, research has shown that inquiry based science instruction can promote scientific reasoning abilities (Adey & Csapo, 2012; Lawson, 2001). Controlled studies have shown that students had higher gains on scientific reasoning abilities in inquiry classrooms over non-inquiry classrooms (Bao et al., 2009). On the other hand, students and teachers' levels of reasoning skills can significantly influence the effectiveness of using inquiry methods in teaching and learning science courses (Lawson, 2001). Therefore, in order to effectively implement inquiry based curricula, improving scientific reasoning abilities need to be highly emphasized in basic education curriculum for both students and teachers. We are of the opinion that if children are to be diagnostically assessed before any progression to the next level in their schooling, it will enhance their performance in subject areas, especially in Science, Technology, Engineering and Mathematics (STEM). Teaching goals in STEM education include fostering content knowledge and developing general scientific abilities such as scientific reasoning skills.

With these findings from the reviewed literature, Namibia could learn a thing or two to improve the reasoning skills and learning content of the students. In China, it is traditionally often expected that rigorous content learning in

science and mathematics will help develop students' scientific reasoning abilities. This is proven by Chinese students' performance in PISA and TIMSS regularly. According to the results of PISA in 2012 and 2015, Chinese students had high-level science literacy (OECD, 2014; OECD, 2016). In PISA 2012, Shanghai-China ranked as number 1 in the science and mathematics assessment, and number 6 in the problem solving assessment (OECD, 2014); and in PISA 2015, China (Beijing, Shanghai, Jiangsu, Guangdong) ranked as number 10 in science and number 6 in mathematics. This performance is still much higher than the average level of OECD (OECD, 2016). However, studies have shown that the traditional style of STEM education has little impact on the development of students' scientific reasoning abilities (Bao et al., 2009). It is not what we teach but rather how we teach it that makes a difference in student learning of higher order abilities such as scientific reasoning.

Therefore, a synthesis of the findings from literature reveals that, OECD countries have been carrying out research on the effectiveness of their educational system on a regular basis (PISA, TIMSS and NAEP). Results from these studies provide valuable feedback as to whether their education systems were sufficient in preparing students to thrive in future (OECD, 2013). Amongst other components, scientific literacy has always been part and parcel of these studies and to a lesser extent scientific reasoning. Equally, there have been also many researches on scientific reasoning (Bao et al., 2009; Kuhn, 2011; Adey & Csapo, 2012; Osborne, 2013; Zhou et al., 2016). However, all the above research were conducted mostly in developed countries. Research of these kinds are hardly carried out in Namibia, and currently we do not have empirical data on Namibian students' scientific reasoning abilities as well as on scientific literacy. This presents an opportunity for research in this field of scientific reasoning skills for both upcoming and established researchers.

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## Environmental education practice in natural and social sciences in primary schools in Okahandja, Namibia

Simalumba, Patrick

National Institute for Educational Development

[psimalumba@nied.edu.na](mailto:psimalumba@nied.edu.na)

### **Abstract**

*In the twenty-first century, learning and teaching at school must prepare young people to engage in a complex and dynamic world influenced by human activities and natural phenomenon. This research is based on a study carried out in selected senior primary, Grades 4-7 schools in Okahandja, Namibia. The research sought to explore the extent to which schools implement environmental education (EE) by focusing on teachers' and learners' knowledge of environmental issues, teaching and learning strategies, skills and attitudes needed to contribute to health of the environment; learning support materials/resources, extra-mural activities and the role of stakeholders. Wickenburg (2000) affirms that for substantial learning to take place, stakeholders should be actively engaged and establish local supportive structures for EE in schools.*

*The research design was qualitative in approach. The methodology involved data collection methods such as interviews with teachers, focus group discussions with learners and interviews with local Environmental Health Practitioner (EHP). The research, among others, concluded that teachers and learners had knowledge of factual information about environmental learning topics such as ecosystem, pollution, deforestation, etc. in Natural Science and Health Education (NSHE), and Social Studies, Grades 4-7. However, teachers had sufficient knowledge of skills and attitudes needed to contribute to the health of the environment. Teachers indicated that they used class discussion and experiential teaching methodologies to teach EE. The research also disclosed a good parental and stakeholder involvement in school activities. Teachers were confident that environmental learning in natural and social sciences contributed to change in learners' lifestyles. The role of the local Municipal Town Council in school environmental learning was also, found to be inadequate.*

**Keywords:** *environmental education, social and natural sciences, transformative learning, learning approaches, whole school approach to learning*

### **Introduction**

Since independence in 1990, the Namibian government has given high priority to environmental concerns. Article 95 of the National Constitution (Government of the Republic of Namibia, 1990) refers to the promotion of the welfare of the people through sustainable use of resources. Namibia has ratified a number of international agreements concerning the environment, such as the Convention on Climate Change (1992), the Biological Diversity Convention (1992), Combating Desertification (1994) and the Basel

Convention (1999) (Ministry of Environment and Tourism, 2008).

Namibia's Vision 2030 (GRN, 2004) identified sustainable development as an important national development strategy. The ESD Strategy for Namibia, 2009-2014 (Ministry of Education, 2008) aims to empower citizens to generate and take positive actions to improve the environment and society. The plan of implementation of the World Summit on Sustainable Development (WSSD) at Johannesburg (South Africa) in 2002 points out that education is essential to support sustainable

development (Jickling, 2005). In 2015, Namibia also signed the Sustainable Development Goals (SDGs): The Post 2015 Agenda (2015-2030), and goal 4 focuses on quality education for all.

According to Ministry of Education (2010), basic education for the future society should focus on atmospheric, land and water pollution, and reducing pollution from urban and industrial areas, ensure that farms and natural ecosystems are productive and sustainable socially, economically and ecologically. The social and natural science curriculum content, skills and values can contribute significantly towards achieving these objectives.

### **National research**

At national level, many research studies on environmental education issues in Namibian schools have been undertaken since 2000. For example, in his study on Namibian schools, Kanyimba (2002) concluded in general that environmental learning revolves around the integration of knowledge dimensions with lack of integration of values and attitudes including action and skill dimension of the environment. This was echoed by Haindongo (2014) who found that the teaching of Biology in Namibia concentrated on cognitive information about the ecology. She further found that educators lacked professional development support to integrate sustainability issues.

In research, investigating how geography educators were implementing enquiry-based learning through fieldwork, Simasiku (2010), found that although educators engaged learners with enquiry-based fieldwork learning activities, the findings indicated that educators faced severe limitations in terms of integrating environmental learning into the Geography curriculum.

### **Regional research**

On a regional level, Mukoni (2013) sought to establish whether environmental education has any transformative impact on the behaviour of secondary school educators and learners towards the environment through an assessment of their actions on the immediate school and the outer surroundings in Zimbabwe. The significant finding of Mukoni's study was that what was going on in schools was merely the 'greening' of the curriculum with a factual stance at the

expense of action competencies. The study carried out in six primary schools in the Empangeni district in Kwazulu-Natal by Makhoba (2009) found that educators applied selective teaching of EE topics, preferring narrative teaching methods.

### **Conceptual framework**

According to Pillbeam, Winter, Oelofse, and Zukulu (2000), the purpose of studying natural and social sciences in schools is to enable learners to explain processes, spatial patterns, make well informed judgements about changing environments and think critically and creatively about what it means to live sustainably. The broad curriculum policy advocates that upon completion of senior primary, learners should be able to relate the implication of scientific understanding to personal and social health, and the sustainable use of resources for future generations (Ministry of Education, 2010).

In southern Africa, there has been a shift in conceptualisation of 'environment' from ecology to include aspects of social, economic, political and biophysical (Ministry of Education, 2005). Ballantyne and Oelofse (1998) define EE as an education process dealing with the interrelationships among the natural world and its man-made surroundings; is experience based; is interdisciplinary in its approach; and is a continuous, lifelong process that provides the citizenry with basic knowledge and skills necessary to individually and collectively encourage positive actions for achieving and maintaining a sustainable balance between man and the environment.

One way to become environmentally literate was first suggested by an Australian educator, John Fien. He noted that this would involve: Learning ABOUT, IN/THROUGH or FOR environment. What are implications for this to a school life or learning in general?

- Learning ABOUT the environment involves developing a sound base of knowledge with understanding so that learners can make sense of environmental issues. Knowledge with understanding about the environment enables learners to critically evaluate issues and situations in light of the informed

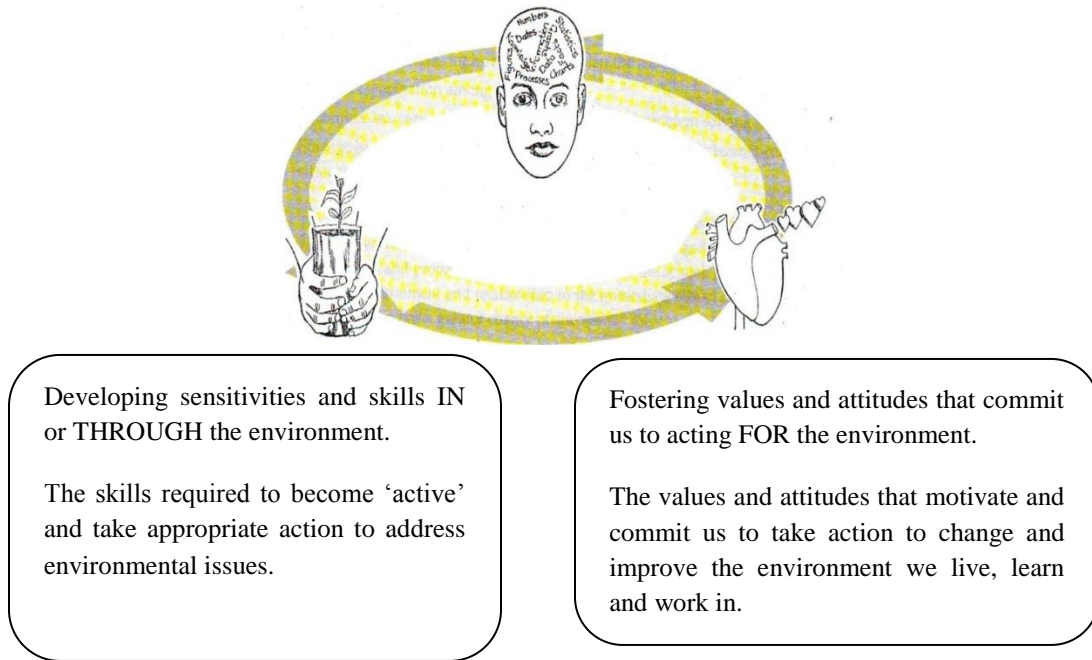
understanding (Palmer, 2003; Schnack & Jensen, 1997).

- Learning IN or THROUGH the environment provides experiences that play an essential part in learning, whether on school ground, in a city street, a beach, a park, farm or forest (Schnack & Jensen, 1997). Learners identify and explore environmental challenges. This approach provides opportunities to learn out – doors and enable learners to develop skills for data gathering such as observation, sketching, measuring, interpreting, photography, interviewing, including social

skills such as cooperation and appreciation (Palmer, 2003; Schnack & Jensen, 1997).

- Learning FOR the environment involves developing informed concerns about and encouraging a sensitive use of the environment now, and in the future. The aim is to promote willingness to adopt life styles that are compatible with the wise use of natural resources (Schnack & Jensen, 1997). Education for environment may be located within the socially-critical traditions in education because of its concern for social critique and reconstruction.

The diagram below summarises three main areas of environmental learning.



**Fig. 1. Adapted from Ministry of Education (2005, p. 11)**



Wickenburg (2000) suggests that environmental behaviour is associated with components such as personality factors (attitudes, locus of control, efficacy perception, personal responsibility); knowledge of issues, knowledge of action strategies and action skills; intention to act; and situational factors (constraints and opportunities).

Bornman (1997) argues that traditional philosophies (perennialism and existentialist) of education were replaced by contemporary philosophies such as progressivism and reconstruction. The emphasis is a shift from knowledge and information to problem solving and functioning in one's social environment. Wickenburg (2000) affirms that for substantial learning to take place, stakeholders should work actively and establish local supportive structures for EE in schools. Meanwhile, Duhn (2011) and Elliot (2010) believe that engagement of young children in environmental learning has been recognised as a key element in cultivating a potentially life-long disposition of care for the environment. It is argued that environmental issues are best learnt if they are relevant to the needs of the community; involve learner participation through encounter – dialogue and reflection framework of action (Elliot, 2010). Meanwhile, UNESCO (2012) reminds us that education should increase capabilities to transform learners' vision into reality through motivation, justification and social support.

### **Research problem**

Little is known about the extent to which Grades 4-7 Natural and Social Sciences (NSHE and Social Studies in particular) are contributing to environmental learning in senior primary schools in the Namibian curriculum. Despite the integration of EE in the Namibian basic education curriculum in 2005, questions remain regarding the extent to which environmental learning is organized and practiced at a school level. This means there is a lack of insight into learners' and teachers' knowledge of EE, learning processes, strategies and the extent to which the local environment and stakeholders are serving as resources. Teachers are expected to deal with practical issues and create an opportunity for learners to develop sustained

environmentally responsive knowledge, skills and attitudes.

The successful implementation of environmental learning requires a re-orientation in the approaches to teaching and learning if teachers were to spearhead the process of change. Guidelines for teaching strategies and methods which emphasise learner empowerment in the process of learning and continuous assessment tasks are explained in the curriculum documents. Although learning support materials on environmental learning were produced and distributed to schools, it was important to understand how these materials had impacted on teachers and learners' perception of their environment, teaching and the learning process.

### **The research purpose**

Based on the research problem, the purpose of the research was to determine how the social and natural science curriculum empower learners to become strongly engaged in their learning and to think critically about issues; and develop sustainable living practices. The paper assessed:

- the level of knowledge for environmental learning among senior primary school teachers and learners;
- the skills and values senior primary learners need in order to address environmental issues and concerns;
- various environmental related teaching and learning strategies applied in schools;
- the level of stakeholder support for environmental learning; and
- ways to strengthen environmental learning in schools.

### **Methodology**

#### ***Research design and method***

The research design is a qualitative approach. This study involved a number of detailed interviews and focus group discussions (qualitative) to obtain deeper explanation of information. The qualitative researchers do not narrowly focus on a specific question, but ponder the theoretical-philosophical paradigm in an inquisitive, open-ended process as they adopt a perspective (Neuman, 2006). This suggests that the research is in an interactive process in which steps blend into each other and a later step may

stimulate reconsideration of a previous one. Qualitative research conforms to the constructivist view which holds that there are multiple versions of reality. The meaning is socially constructed during the process and it is conceived that there are multiple versions of truth and reality.

According to Merriam and Tisdell (2015) and Bogdan and Biklen (2007), the qualitative research methods look for patterns in the lives, actions and words of the people in the context of the study. Each participant in the study has brought a set of ideas, circumstances and perspectives to the study providing a variety of versions of the experiences from the schools. Bless, Higson-Smith, and Kagee (2006) and Miles, Huberman, and Saldana (2014) profess that the qualitative work and linguistic symbols are relied upon to provide meaning to the data. The researcher in this study wanted to understand the meaning people attach to their everyday lives and practices. The researcher found meaning as he analysed the data. The researcher must provide evidence of rich, detailed and textured descriptions to allow readers of the research to make connections between the ideas and their own experiences. This research, which is based on phenomenological study, draws from the experiences of teachers, learners and an Environmental Health Practitioner (EHP) for a town under study.

### ***Data collection***

In order to gather data, multiple data collection instruments for teachers, learners and an EHP were used. Bogdan & Biklen (2007) claim, that qualitative data collection is more spontaneous and is in its natural environment or context. The instruments for this study were qualitative. The findings and analysis of the data were the result of triangulating the data from all instruments. According to Neuman (2006), triangulating data from the various instruments could be used to 'confirm' the findings and thus enhance their validity. In this study triangulation consists of data which comes from three perspectives: teachers, learners and an EHP. Neuman (2006) and Gay, Mills, and Airisian (2006) indicate that a pilot study makes it possible to do preliminary checks on the validity and reliability of

questions. Instruments in this study were trial tested at a local school to determine if participants understood questions and amendments were made accordingly.

### ***Sampling***

The research population in this study were teachers for Social Studies and Natural Science and Health Education Grades 4-7, learners and local EE officials. In support, Neuman (2006) and Ruane (2005) highlight that the primary purpose of sampling is to collect specific cases that can clarify and deepen understanding so that the researcher learns about the processes of social life.

The study was conducted in Okahandja town. Three (3) primary schools participated in the interviews and focus group discussions. Schools were chosen using the following criteria according to predominant social economic class of the local community in which they were located: lower income (informal settlement), middle income (former 'lokasi' [township]), and the upper class.

Purposeful sampling method was used to target all teachers for Natural Science and Health Education, and Social Studies Grades 4-7 in all three participating primary schools. Teachers assisted in the identification of six learners at each school who participated in the focus group discussions while the EHP official who participated in the interview was the only participant with rich work-related practical experience on environmental education in the Town Council.

### ***Data analysis***

Analysis of data involves organising, breaking down, synthesising, searching for patterns and discovering new information (Bogdan & Biklen, 2007; Neuman, 2006). Qualitative researchers analyse data inductively by categorizing and organizing the data into patterns that produce a descriptive and narrative synthesis. In this study, transcripts of interviews were typed out and thoughts and ideas of each participant separately numbered. The statements of each participant were categorized. Statements were under headings specifying the ideas expressed and coded with respect to the themes. All data, once coded for each participant, were placed in a

category depending on key words and phrases reflecting the content of the statement.

Checks for triangulation of content among participants were performed along with an in-depth review of the researcher's decision, points and observations. Neuman (2006) defines triangulation as a strategy of looking at something from multiple points of view to improve accuracy. Finally, the data was analysed comprehensively by viewing the conclusions reached in a critical manner that openly confronted alternative interpretations.

### **Ethical considerations**

The researcher had a duty not to put participants in a situation where they might be at risk of harm as a result of participation. Neuman (2006) and Bogdan and Beklin (2007) note that the researchers should protect the privacy and identity of participants. To that end, the researcher took the following specific steps to ensure that participants' privacy and rights were protected:

- informed consent was assured by allowing respondents sufficient knowledge and comprehension of the purpose and intentions of the study;
- protection of respondents was guaranteed through anonymity of participants in the study; and
- adherence to the actual audio recordings by either paraphrasing or using actual excerpts from these recordings supported the credibility.

### **Results and discussion**

#### ***Knowledge and understanding of environmental learning***

Ministry of Education (2010) and Palmer (2003) indicate that learners should develop knowledge with understanding in relation to the bio-physical and ecological processes in the environment; the impact of human activities; the environmental interdependence of living and non-living systems; how humans live and livelihoods are dependent on the environment particularly in context of limited resources and the danger of over-exploitation

The results from the teachers interviewed revealed that in NSHE they taught learners about

ecosystems – the living and non-living things and how they interact. Environmental issues related to water dominated the teaching in senior primary phase. In addition, teachers had knowledge and taught about other environmental issues such as air and soil pollution, global warming, biodiversity in general and endangered plant and animal species in particular. In Social Studies Grade 7, they also taught about deforestation, natural disasters such as floods, drought, earthquakes, and primary health care issues including HIV and AIDS. One Grade 7 teacher from school B indicated how she/he taught HIV and AIDS which is a social aspect of the environment as follows:

*I taught learners about HIV/AIDS in which we discussed about HIV transmission, how we could protect ourselves and, things we could do without infecting one another with HIV (e.g. hugging, swimming, eating together); and things which could lead to infections (sharing the use of needle/blade, unsafe sex, mother to baby) - myth and facts about HIV/AIDS. I also taught learners about other opportunistic infectious diseases such as Tuberculosis. Learners were also taught about nutrition e.g. balanced diets and food groups.*

All teachers indicated to have acquired knowledge of environmental issues from schools and colleges of education they attended. They however, indicated that their knowledge for cross-curricular integration was inadequate.

On the other hand, learners understood the environment as their surrounding which included air, water, land and the community in general. They revealed that their environment is damaged by pollution e.g. littering of plastic, papers, bottles and iron scraps which may harm animals and make the environment look unattractive. Learners persistently claimed that cutting down of trees was a serious problem irrespective of where schools were located. Reference was made to veld-fires, sewage water flowing from drains and human defecating in the open (bush) due to lack of latrines or flush toilets. Learners successfully illustrated the negative impacts of human activities on the natural environment. Asked on ways learners thought people were

destroying the environment, one learner from school C explained as follows:

*People were destroying our environment by cutting down of trees for firewood and building materials. People made the environment untidy with plastics, empty bottles and papers. People burned hips of rubbish causing air pollution which could lead people to get sick. Killing of wild animals was another problem.*

Interestingly, learners from participating schools revealed the environmental problems prevalent near their schools by predominantly making references to pollution created by the mushrooming of shebeens (alcohol selling outlets) and burning of waste. A learner from school A illustrated the point as follows:

*The most environmental problem was shebeens/bars which made noise pollution and learners could not study or prepare properly for their school work.*

Another learner from the school added that: *Sewage water from drainage pipes were flowing all over the place causing smelling stagnant water which may cause diseases.*

### ***Skills and attitudes***

It is argued by the Ministry of Education (2005), that NSHE and Social Studies should nurture skills for observation, investigation, experimentation and innovation. It goes on to elaborate that learners should achieve environmental literacy and show an appreciation for and knowledge of a range of environmental issues, perspectives and positions; and be taught how to think through an issue using critical-thinking skills.

Generally, the results from data analysis of interviews indicated that teachers understood the skills and attitudes which learners required in order to contribute to the health of the environment.

Four (4) out of ten (10) teachers indicated that learners needed to have the foundational knowledge of environmental issues. Secondly, learners should have practical ability of how to keep the environment clean. One teacher from school A explained what skills and attitudes

learners needed to have in order to contribute to the health of the environment as follows:

*Learners should be able to have listening skills so that they could understand the impact of human on the environment from teachers, elders and the media. They should practice and implement what they learned and be able to appreciate the importance of all living and non-living things in the ecosystem.*

A teacher from school B echoed as follows: *Learners should have practical ability of how to keep the environment clean, practice what they were taught e.g. planting of trees, using water sustainably (not to waste) and taking care of other resources.*

The last teacher from school C summarized change in learners' attitudes after classroom instructions as follows:

*When I taught learners on health issues related to body hygiene, I noticed that some of them learnt something and reflected a change in the ways they cleaned themselves including their clothes. There was a change in mind sets.*

### ***Teaching and learning***

The extent to which teachers use adapted teaching strategies determines the successful implementation of environmental learning in schools. Learners should engage in educational processes based on democratic principles, promoting higher level of thinking and leading to actions. Various learning approaches suggesting learners' autonomy, innovation and active participation can be utilised in the context of a school or learning environment and goals to be achieved. These include teaching methods such as experiential learning, co-operative learning, problem solving, and value clarification methods (Olusegun, 2006).

The result of the interviews with a sample of teachers indicated that they used class discussion and experiential learning in which learners were involved in practical activities. One teacher described how he/she taught environmental issues using models as teaching aids as follows:

*I used models and practical demonstrations e.g. on water purification by using sand soil filters and cleaning of water by boiling. When learners were learning soil erosion, I dug a hole around the school ground to indicate for learners to observe basic layers of the soil and we visited one of the local ephemeral rivers so that learners could see gullies for themselves.*

Five (5) out of ten (10) teachers interviewed indicated to use information communications technology such as DVDs in classes and one teacher explained as follows:

*I taught environmental related topics such as water pollution by making learners to observe on DVDs or analysed the posters with learners involved in group discussions based on an environmental topic and sources.*

Large class size was cited as a challenge to implement learner-centred teaching approaches. Sitting arrangements (limited space) did not facilitate the use of group work. Only a limited number of teachers (3 out of 10) described teaching methods related to value clarification methods and problem solving.

### ***The use of outdoor activities***

The NSHE and Social Studies curriculum requires learners to do outdoor activities in order to observe, investigate and experiment. Outdoor activities provide learners with valuable experience in getting closer to nature and sensitising them on environmental issues in a systematic manner (Olusegun, 2006). Learning can be enhanced by concepts such as ‘whole school approach’ to learning where learners, teachers, local government and community members are brought together (UNESCO, 2014). This is in line with the framework for Agenda 21 which advocates partnership and where learners are encouraged to be involved in sustainable development at local level.

The results of the empirical study revealed that 6 out of 10 teachers used outdoor learning activities in which environmental experts from stakeholders on conservation, for example were used to guide learners and facilitate learning in the field. When asked on outdoor activities

which learners carried out, one learner from school B explained as follows:

*We used to participate in the Local Authority (Town Council) organised clean up campaigns. As learners we were taught and reminded of using the water resource and papers at school in a careful way.*

The third school did not indicate exposing learners to outdoor activities except learner participation in cleaning campaigns which were ‘not organised’ learning opportunities.

### ***Learning support materials and resources***

The result of interviews with teachers indicated that they had fewer learning support materials to teach environmental issues. The school libraries and the internet service were sources for more environmental information for teachers. Two (2) teachers from one school reported to involve learners in construction of models used as teaching aids. One of the teachers explained as follows:

*We requested learners to bring certain objects or models from home, for example, learners brought charcoal stoves to school for exhibition to enable other learners to observe what they learned from the textbook. Learners were once involved in construction of solar stoves using recommended material and demonstrated how it could be used for cooking or heating of water.*

### ***Extra-curricular activities and community support***

Extra-curricular activities are aimed at supporting learning in a relaxed and informal atmosphere through out-of-school programmes. The concept for ‘whole school approach’ to learning provides opportunity to integrate environmental issues into daily aspects of school life (UNESCO, 2014; Ministry of Education, 2005).

The results of the interview with teachers from two participating schools indicated involvement in cultural activities using cultural groups and the learners were involved in the ‘Window of Hope’ and ‘Girls and Goals’ programmes for learners on life skills and HIV and AIDS education.

One teacher explained their extra-curricular activities as follows:

*Learners competed in Science Fairs where they presented their innovative ideas on environmental topics. The Cheetah Conservation project from the Regional capital (Otjiwarongo) also used to take learners to the centre and taught them how human should live with predators like cheetah. The Ministry of Environment through forestry involved learners in tree planting activities during special days such as Arbor Day.*

This suggests that schools were involved in extra-curricular activities of social dimension in nature. Collaboration between stakeholders (parents, Non-Governmental Organisations [NGOs] and the school) is paramount in expanding the delivery of environmental learning and it is conceived that cross-curricular programmes are better conducted with the local community. Overall, the results of interviews with teachers indicated better parental involvement across participating schools. This is supported by results of learners' focus group discussion referring to cleaning campaigns.

#### ***Changes in learners' lifestyles, attitudes and behaviours***

Environmental learning is rooted in the understanding that learning should lead to sustained change in learners' mind-sets and meaning perspectives (Elliot, 2010). However the results from teachers' interviews indicated a conflicting picture. Two schools (located among the lower and middle income communities) observed moderate change in learners' lifestyles or attitudes as a result of environmental learning related lessons but teachers from the school located among the higher income communities reported major changes in learners' life styles and attitudes. One teacher from school B explained his/her observed change in learners' lifestyles as follows:

*We have noticed how learners changed their lifestyles in ways they take care of the plants and flowers at school. It means they understood the importance of plants. Learners also used cups we provided rather than drinking directly from*

*the tap and the papers flying around the school were reduced because we emphasised on the use of dustbins.*

During focus group discussion, learners indicated basic actions such as cleaning of yards, hand washing, etc. as ways they help improve the health of the environment at home.

#### ***The role of the local Environmental Health Officer (EHP) from the Town Council***

The concept for 'whole school approach' to learning provides opportunities for stakeholders and local experts on environmental issues to participate in education of young people (Wickenburg, 2000).

The results of the empirical study with learners and teachers confirmed that the Town Council used to organise clean-up campaigns. Based on evidence from teachers, learners and the EHP, one can conclusively suggest that the role of the Town Council in local schools seemed to be limited to cleaning of the township. When asked how the office of the EHP in the town council promoted environmental education, the EHP officer explained as follows:

*The schools fall under the Government Ministries. We were only responsible for solid waste management in town. The health inspectors were the ones responsible to inspect schools. The Town Council however, used to organise clean-up campaigns where schools participate.*

#### **Conclusion and recommendations**

This research has contributed to a better understanding of teachers' and learners' knowledge and understanding of environmental concepts such as ecosystems, natural resources, pollution, erosion, deforestation, overgrazing, water cycle, community and sexual health, and how they teach to facilitate the development of skills and attitudes. Although the educators are overall confident that they know enough about environmental education issues and how to teach it, the study showed that there were some limitations in their actual knowledge and teaching skills. The majority of teachers (6 out of 10 teachers) indicated the use of local context and outdoor learning activities. Seven (7) out of

ten (10) teachers considered their teaching as contributing to changes in learners' behaviours and actions. Stakeholder support through EHP can play a role to improve teachers' ability to let EE take place in a conducive way in the Social and Natural Sciences curriculum in Namibia.

From this research, educators should:

- teach learners to view the environment in a holistic way focusing on all dimensions of environmental learning such as the biophysical, social, political and economic aspects. Learners should have basic understanding of the availability and use of resources at local level such as electricity, water, plants, etc.:
- encourage learners to be involved willingly in activities with actions which benefit their own health, others and the environment and show appreciation of nature, biodiversity and multi-cultural nature of our society;
- strengthen the use of investigation and modelling on school ground to expose learners to basic scientific methods in which they collect, analyse, interpret and present data on topics related to water use or litter;
- use the school site and local community to engage learners in authentic sustainability learning. These activities should be action-oriented, with learners exploring and designing responses to sustainability challenges of school and community significance (e.g. energy and water). Furthermore, an enthusiastic key person or group of persons is needed;
- utilise World and National Special Days related to the environment e.g. the Day of Biodiversity, World Heritage Day, World Environment Day, etc. These could be integrated in the school calendars;
- establish the learning environment promoting transformation. This involves activities in which learners have equal opportunities to assume various roles, can become critically reflective, empathetic,

good listeners and synthesise from different points of views; and

- strengthen the role of the local Environmental and Health Officer from the Town Council. The role should be diversified to include education and awareness programmes for communities including schools. A signal from the highest political level in the municipalities is needed.

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## Why student–teachers fail the basic mathematics module in first year of study at Rundu Campus of the University of Namibia?

<sup>1</sup>Ilukena, Mbonabi Alex, <sup>2</sup>Luwango, Luya and <sup>3</sup>Ausiku, M. Charity  
<sup>1,2,3</sup> University of Namibia, Rundu Campus  
<sup>1</sup>[milukena@unam.na](mailto:milukena@unam.na), <sup>2</sup>[lluwago@unam.na](mailto:lluwago@unam.na) & <sup>3</sup>[causiku@unam.na](mailto:causiku@unam.na)

### Introduction

The research paper reports on a study that examined the cause of failure among first year mathematics student - teachers registered for the Basic Mathematics module at the University of Namibia, Rundu Campus since the inception of the four year Bachelor of Education Honours (B. Ed. Hons) programme in 2011. Questionnaires were administered to 92 student teachers, but only 39 returned their questionnaires. The questionnaires sought the participants' perceptions and experiences with various aspects of the Basic Mathematics module. The grade 12 mathematics syllabi and the Basic Mathematics course outline were used to cross check the level of the content covered at secondary school and university.

The purpose of B. Ed (Hons) course was to address the perceived minimal mathematics content knowledge in the previous Basic Education Teachers Diploma (BETD) programme. The study further attempted to explore and identify areas that needed improvement in terms of the gap between high school mathematics and the mathematics offered by the University of Namibia in the first year, and how the situation could be addressed.

### The context of the study

In recent years, there has been a noticeable increase in the diversity of background, talents and aspiration of students entering first year Basic Mathematics in the Department of Mathematics, Science and Sport Education (DMSSE) at Rundu Campus. This is probably due to the implementation of the new University of Namibia (UNAM) curriculum in mathematics since the merging of the UNAM and the four

former Colleges of Education in 2010 that has been embraced with more subject content that was minimal in the BETD programme.

This research was triggered by the large number of B. Ed (Hons) students performing below 50 percent in the module, despite the introduction of two modes of study, a faster –and slow - streamed curricula of mathematics in 2011. The faster (normal) streamed are allowed to do the work in one – semester mode of study (first semester) while the slow – streamed covers the work in two semesters (the whole year). Second, the research investigated whether there was a gap between school mathematics and mathematics offered by the University of Namibia. And lastly it also explored the relevance of this course in terms of preparing teachers to teach mathematics at the Upper Primary School phase in Namibia. The basic mathematics modules cover a total of 6 topics, which are; sets, algebraic expressions, equations and inequalities, functions, trigonometry and sequence (see Table 5). Students often struggle with the following topics: sets, algebraic expressions (advanced factorisation, partial fractions, binomial theorem and expansion), trigonometry (trigonometric identities) and sequences (recursively defined sequences).

### Significance of the study

Although the B. Ed (Hons) programme in Namibia with its emphasis on more subject content was rolled out in 2011, very little research has been conducted specifically on mathematics content knowledge at any of the four satellite campuses.

This research could thus benefit the four campuses, Hifikepunye Pohamba, Katima Mulilo, Khomasdal and Rundu. Furthermore it will be of benefit to the current B. Ed (Hons) mathematics student- teachers, learners, policy makers at National Institute for Educational Development (NIED), the Namibian public at large and other institutions of higher learning in education in the country. Moreover, it will add value to the successful outcomes in mathematics teaching in Namibian schools as a result of the new UNAM curriculum that focuses on equipping mathematics student – teachers with the mastery of more mathematics content knowledge.

### Questions of the study

The study focused specifically on the prospective students at Rundu Campus and asked the specific questions on the strength and weakness of the module.

4. How is the current upper primary B. Ed (Hons) student – teachers' high school mathematics performance like?
5. What is the current upper primary B. Ed, (Hons) mathematics student – teachers' pass rate in Basic Mathematics module?
6. How does the B. Ed (Hons) mathematics student – teachers' performance at UNAM relate to their high school performance in mathematics?

### Literature review

Recent research has shown that many universities have altered their entry requirements in a bid to attract students, by dropping some pre-requisites for enrolment and allowing students to study equivalent subjects once they enter university (Michael, 2013, p. 1). This is attributed to fewer students entering universities and studying higher level mathematics in secondary school.

Universities are now offering bridging courses in mathematics to provide students with the necessary mathematics background to succeed in their tertiary studies. A good example is Mc Master University in Ontario, Canada, whereby mathematics lecturers review and prepare manuals that prospective students study during summer before beginning their first year

of university mathematics (Kajander & Lovric, 2005). The majority of the students are not well prepared for the fast pace of university mathematics (Selden, 2005).

However, Wilson and MacGillivray (2007) found it of benefit to revisit secondary school content in tertiary courses to assist students for the study of tertiary mathematics. This concurs with the findings of Steyn and Du Plessis (2007) at the University of Pretoria in South Africa who noted that extended study programme at universities offer opportunities for students who are at risk academically or do not meet the entry requirements for a certain course of study. Furthermore, Wood and Solomonides (2008 in Michael, 2013) suggested that it is better not to spend time on what mathematics students had difficulty with at secondary school but focus on how they are developing their mathematics at tertiary institutions. It is important to know what level of mathematics understanding they bring with them, as Michael (2013) puts it. The secondary school mathematics focuses more on problem solving whereas tertiary mathematics involves more abstract thinking and formal proofs, which makes it difficult for students to cope with tertiary mathematics.

Research conducted by (Brainer, Cruickshank & Metcalf, 1995; Kasanda, 2005, Driscoll, 2007; Skemp, 1989; Kilpatrick, Swafford, & Findell 2001, as cited in Ilukena, 2008) has shown that teachers with inadequate mathematical content knowledge will struggle to teach mathematics to their learners. It is only teachers with higher mathematics content knowledge who can set higher-level mathematics tasks that engage learners in understanding mathematics concepts and for Namibian Mathematics teachers to be successful, they need adequate subject matter knowledge, which is referred to as the knowledge of the subject that the teacher needs to teach for understanding (Shulman, 1986; Ball et al., 2005; Davis & Krajcik, 2005; Namibia. Ministry of Education [MoE], 2005b in Ilukena & Schäfer, 2013). They also need to develop pedagogical content knowledge (PCK) and curricular knowledge (CK). The PCK includes knowledge of mathematics – specific strategies and various ways to represent content, and learners' thinking

about mathematics, while CK is an array of instructional materials, reinforcement devices and teaching media.

As Mathematics teachers change in their horizons of understanding rather than through sudden leaps of insight, they need to access 80% of the teacher preparation time on subject content as revealed by international research and the remaining 20% representing pedagogy (Shulman, 1986 as cited in Ilukena, 2008).

**Research methodology**

This qualitative study employed document analysis and questionnaires to collect data from the sample. A total of 92 questionnaires were given to students but only 39 (42%) questionnaires were returned. Furthermore, school and UNAM curricula documents were analysed and included the UNAM B. Ed (Hons) degree Basic Mathematics course outline , student – lecturer evaluation reports as well as both syllabi for school mathematics (Ordinary and Higher) level Grade 11 – 12.

A case study design was adopted to gain an in-depth understanding of the challenges encountered by first year students registered for Basic Mathematics at the University of Namibia, Rundu Campus.

**Results**

This section presents findings from the questionnaires, feedback from student – lecturer evaluations reports and the school and UNAM curricula.

**Questionnaires**

*Profile of participants*

It emerged that out of a total of 39 mathematics student teachers who returned the questionnaires, 25 were male and 14 were females. Among them, 2 did high level mathematics, 14 did extended while 23 did core mathematics.

**Table 1: Mathematics student – teacher statistics**

Symbols	A	B	C	D	Level 2	Level 3	Total
Frequencies	1	6	27	3	1	1	39

**Table 2: Pass and fail numbers in mathematics at Rundu campus**

Year of enrolment:	Enrolled:	Passed:	Failed:
2010	1	0	1
2011	32	6	26
2012	7	4	3

From Table 2, 32 students who enrolled in 2011, included one student who had failed in 2010. Among the 26 that failed mathematics in 2011, 15 managed to pass in 2012 while the other 11 who failed registered in 2013 in their 3<sup>rd</sup> year as the module is not a pre – requisite to the subsequent modules namely, Introduction to Mathematics (EMMU 3512), Mathematics Education 1A (EMMU 3611), Mathematics Education 1B (EMMU 3612 ), Mathematics Education 2 (EMMU 3780) and Mathematics Education 3 (EMMD 3890) offered in the department of Mathematics, Science and Sport Education (MSSE), Faculty of Education (FoE), (Faculty of Education [FoE], 2013, p. 175).

*The strengths and weaknesses of the basic mathematics module*

Out of 39 participants, 38 participants indicated that the module was very difficult, hard and complicated to understand, while participant numbered 15 declined to comment. “*Only students with grade 12 high level mathematics pass*” claimed participant 17 The assertion was supported by participants 4, 6, 18, 25, 27, 29, 32 and 39 who claimed that “*high level mathematics should be made compulsory for students who did high level mathematics because core mathematics learners are disadvantaged*” They further suggested that it was better to get rid of core mathematics component at secondary school level. In order to enhance and prepare students for the mathematics subject content topics such as sets, advanced topics from pre – calculus module, analytic geometry and some from basic mathematics module should be included at Grade 12 level.

In addition, some participants (6, 10, 11, 19 and 37) alluded to the issue that the module was supposed to be offered to students doing secondary education and sciences only, due to high level content offered. Therefore to remedy

the situation of high content offered in the module, participants 6, 11, 12, 13, 18, 20, 26, 27, 30, 33, 34, 35, 36, and 37 suggested an intervention: The University should introduce a foundation course before registering for basic mathematics, introduce one mode of study that's a year module. If the intake was high, "*subdivide mathematics student – teachers' into smaller groups of 40 per class during tutorials and extra classes*".

***Feedback from student – lecturer evaluation as per Teaching and Learning Improvement Unit reports (TLIU) UNAM from 2011 to 2013.***

The researchers perused through the evaluation report for SMAT 3580 for 2011 and 2013 as well as SMAT 3511 in 2012 with focus on the following areas:

7. the mathematics content offered at grade 12;
8. the complicity and challenges in terms of the difficulties encountered by mathematics student – teachers in Basic mathematics at UNAM; and
9. the way forward on the offered content in Basic mathematics at UNAM.

It emerged from the analysis that the module is tough, hard, very difficult and complicated particularly for students who did not do extended or higher level mathematics at school in grade 12. "*It's really hard and tough to those who did core mathematics at grade 12*".

*"The module is hard and difficult some of us didn't do the extended or high level mathematics at school"* (Respondent 10). Moreover, one of them complained "*the module was difficult for me*" (Respondent 12).

The mathematics student teachers further complained that the module was not supposed to be done by "*people majoring in education because it's too tough; it was supposed to be given to people studying engineering, science and secondary education*", "*the content of the module is too much for primary teachers as it only suits the Faculty of Science*".

Some students even queried the legitimacy of the module "*I don't know what it has to do in the education faculty*" (One respondent said) while other students stated that they were fine with the content in the module "*No problem associated with module, it is interesting and allows the students to be creative*".

Some respondents further claimed that "*only seniors (repeaters) who understand and proceed with the lessons*".

***Proposed improvements to the module***

1. Equip the library with pure mathematics reference textbooks, as only one prescribed book is available.
2. Students registered for this module were expected to work hard and put in more effort in order to pass the module. Students also asserted that they needed assistance and support from the lecturers. As the module is challenging it needs all your attention and assistance from the lecturer "*The lecturer is helpful and supportive both during lecturing, extra classes and tutorials*".
3. The module is too broad, however; the timeframe given was too short to master the content. *The indicated that; "The module is overloaded as topics couldn't be covered in a period of 4 months which is 1 semester, better to make it a year module, or else people have to just rush through the module instead of exploring the deeper content"*.
4. Students proposed that topics in the Basic Mathematics module should be sequenced in the following order: Difficult topics such as trigonometry, sequences, sets, partial fractions and binomials should be covered first and the easier topics can be taught towards the end of the semester. "*Lecturing should start at least with difficult topics at the beginning of the year especially last two topics trigonometry (identities) and sequences*".

With adequate support and assistance, the students learned to appreciate the content they

had learnt. *“I have learnt a lot of new concepts that I didn’t know in grade 12. “I have learnt more especially about sets which is new topic”.* Despite the challenges experienced by a number of students regarding the complexity of the following topic: sets, partial fraction, trigonometry, algebraic expression; sequence, polynomials some felt that they had mastered these concepts.

5. Some students further suggested that *“...the content can be reduced by considering the relevance of these topics at the upper primary phase in schools”* while others suggested the inclusion of more content.

#### ***School and UNAM curricula***

The findings from the comparisons of the Ordinary and High level Grade 12 school

mathematics syllabi with the B. Ed Basic Mathematics course outline as evident in Tables 3 to 5 showed that, the Higher Mathematics syllabus had more content which was not covered in the Ordinary Mathematics syllabus while the Basic Mathematics course covered substantially more mathematics content than the two school syllabi. Furthermore, the document analysis also revealed that there was a large discrepancy in mathematical content covered in higher and ordinary level school mathematics.

A comparison of Mathematics topics covered by 1st year Basic Mathematics at University of Namibia and School Mathematics for both Higher and Ordinary Levels at Grade 11 & 12 Level is illustrated in the tables below:

**Table 3: Ordinary level (Grade 11 & 12) school mathematics curriculum**

<b>Course Name</b>	<b>Description</b>
Ordinary level (Grade 11 & 12)	<ul style="list-style-type: none"> <li>• Numbers and Operations</li> <li>• Measure</li> <li>• Mensuration</li> <li>• Geometry</li> <li>• Algebra</li> <li>• Graphs and Functions Coordinated Geometry</li> <li>Trigonometry</li> <li>• Vectors in two dimension and Transformation</li> <li>• Statistics and Probability</li> </ul>

**Table 4: Higher level (Grade 11 & 12) school mathematics curriculum**

<b>Course Name</b>	<b>Description</b>
Higher level (Grade 11 & 12)	<p><i>Mathematics Part I</i></p> <ul style="list-style-type: none"> <li>• Numbers and Operations Measure</li> <li>• Mensuration</li> <li>• Geometry</li> <li>• Algebra</li> <li>• Graphs and Functions</li> <li>• Coordinated Geometry</li> <li>• Trigonometry</li> <li>• Vectors in two dimension and Transformation</li> <li>• Statistics and Probability</li> </ul> <p><i>Mathematics Part II</i></p> <ul style="list-style-type: none"> <li>• Polynomials,</li> <li>• Identities, equations and inequalities,</li> <li>• Vectors,</li> <li>• Functions,</li> <li>• Logarithmic and Exponential</li> <li>• Functions,</li> <li>• Absolute value (Modulus),</li> <li>• Trigonometry</li> <li>• Sequences</li> <li>• Differentiation</li> <li>• Integration</li> </ul>

**Table 5: B. Ed degree (UNAM) Basic Mathematics Year 1 Curriculum**

<b>Course Name</b>	<b>Description</b>
B. Ed degree (UNAM) Basic Mathematics Year 1	<ul style="list-style-type: none"> <li>• <b>Algebraic expressions.</b> Definition and examples, Simplification, expansion, factorization, polynomials, remainder and factor theorem, quadratic expressions. Binomial expansions, Pascal's triangle and the Binomial Theorem. Rational expressions, partial fractions.</li> <li>• <b>Sets.</b> What is a set? Set notation, equality of sets, subsets, characterization of equality via the subset relation, empty set, Venn diagrams, intersection, union, complement, de Morgan's laws, set difference, symmetric difference, proofs of simple results on set equality. Standard examples of sets: natural numbers, integers, rationals, real numbers. Absolute value and intervals in <math>\mathbb{R}</math>. A bit about cardinality of sets (examples of finite, infinite, countable, uncountable sets).</li> </ul>

- **Equations and inequalities.** Linear equations in one-variable, simultaneous linear equations, quadratic equations, simultaneous non-linear equations. Linear inequalities, non-linear inequalities.
- **Functions.** Domain, co – domain, image, preimage, even function, odd function.
- **Trigonometry.** Trigonometric ratios, angle orientation in the xy-plane, graphs of trigonometric functions, trigonometric identities, justifying (proving) equality of relatively simple trigonometric expressions. Sum/ difference, double angle, half angle and sum to product formulas.
- **Sequences.** Definition, notation, obtaining the general term in certain sequences, recursively defined sequences, arithmetic sequences, geometric sequences.

It also emerged from the participants in the research that the ordinary school syllabus was of low standard and inadequate to prepare students for the task ahead. This finding concurs with the student – lecturer evaluation feedback of the mathematics student – teachers from 2011 to 2013 which revealed that the module was challenging, tough, confusing, advanced, and difficult for slow students to catch up especially those who were taught at core and extended levels at Grade 12. They further claimed that the Basic Mathematics module should not be compulsory for mathematics student – teachers enrolled for primary education. It was too complicated and had a lot of topics to be covered in one semester. They suggested that it was better if the content would be spread over two semesters.

The first semester could, for example, revisit content covered in Grade 12 integrating the new topics such as inequalities, factorizations, trigonometry (trigonometric functions and identities), binomial theorem, partial fractions, set theory (mathematical reasoning) and functions (range and domain). This will serve as a bridging course to accommodate students who were taught mathematics at ordinary and extended levels at Grade 12, to pave way into tertiary mathematics. It should be noted that, as teacher educators at the university know what types of knowledge and what levels of knowledge acquisition is necessary for our mathematics student – teachers to become effective primary mathematics teachers and what contexts are most conducive to learning how to teach. They need all seven

domains of teachers’ professional knowledge; knowledge of subject matter, pedagogical content knowledge, knowledge of other contents, knowledge of the curriculum, knowledge of learners, knowledge of educational aims and general pedagogical knowledge as alluded to earlier.

We also found that the majority of our mathematics student – teachers appreciated extra tutorials and remedial classes offered during the week, but they were of the opinion that much needed to be done to effect the perception on how mathematics is taught and handled at school and tertiary institution. The inadequacy in the subject content knowledge at ordinary level and partially at higher level hinders students to comprehend mathematics at university level, because of the terminologies, the mathematics concepts, use of mathematical techniques, mathematical reasoning, proof and theorem are more advanced at university and mathematics student – teachers’ can’t make connections with what was taught at secondary school at university. Unless their foundation is secured, it will be extremely difficult to build mathematical and scientific success in comprehending advanced mathematics concepts to cope with tertiary mathematics.

***Enrolment and pass rates in the basic mathematics module at Rundu campus 2011 – 2013***

Tables 6 and 7 show the enrolment and pass rates since the inception of the Basic Mathematics Modules at Rundu campus in 2011.



**Table 6: Students pass rates in Basic Mathematics in 2011 – 2013**

Subject Code	New/repeater	2011			2012			2013			Total
		Fail	Pass	Total	Fail	Pass	Total	Fail	Pass	No result	
MAT3511	New	-	-	-	17	15	32	25	10	1	36
	Repeater	-	-	-	12	14	26	29	5	-	34
MAT3511		-	-	-	29	29	58	54	15	1	70
MAT3580	New	50	17	67	3	3	6	6	6	-	12
	Repeater	-	-	-	5	4	9	3	1	-	4
MAT3580		50	17	67	8	7	15	9	7	-	16
<b>Grand Total</b>		50	17	67	37	36	73	63	22	1	86

**Table 7: Pass rates in Basic Mathematics from 2011 – 2013**

Subject Code	New/repeater	Academic year		
		2011	2012	2013
MAT3511	New		46.90%	27.80%
	Repeater		53.80%	14.70%
MAT3511			50.40%	21.30%
MAT3580	New	25.4%	50.00%	50.00%
	Repeater		44.40%	25.00%
MAT3580		25.4%	47.20%	37.50%
<b>Grand Total</b>		25.4%	48.80%	29.40%

The Table 6 reveals that no mathematics student – teacher sat for Basic Mathematics (SMAT 3511) in June examination 2011, but, they all sat for SMAT 3580 in November examination, 2011. The content in both SMAT 3511 and SMAT 3580 is the same, but SMAT 3511 is offered in Semester 1 while SMAT 3580 is a year module. No mathematics student – teacher sat for SMAT 3511 due to the fact that the Department of Mathematics in the Faculty of Science, the custodian of the module was not informed by the Faculty of Education that the four merged satellite campuses had started offering SMAT 3511. This is how students from the four satellite campus missed the placement test after four weeks of lectures. However provisions were made to support the satellite campuses in terms of tutorials, seminars, workshops, tests and materials required.

Despite all the efforts made in 2011, only 17 (25.4%) of the 67 mathematics student – teachers managed to pass the final examination in November at Rundu campus. However, there was an improvement in terms of the pass rate in 2012 whereby the new intake of students managed to score 46.9% and 50.0% while repeaters managed to score 53.8% and 44.4% respectively in both modules. In 2013, there was an improvement in the pass rate of the new intake, while repeaters dropped drastically in comparison to 2012 academic year. This was attributed to the backlog (additional modules) as opposed to the new intake; they missed most of the lectures in Basic Mathematics at the beginning of the first semester due to School Based Studies (SBS).

Moreover, this module does not have any pre - requisites and it is not aligned to any of the mathematics education modules in MSSE Department. This implies that the student can carry this module until his/her fourth year of the B. Ed programme, although the academic advancement rules stipulate that by the end of each academic year the student is supposed to pass the remaining modules plus at least 75% of the previous academic year modules to proceed to the following academic year. Unless Basic Mathematics module is made a pre - requisite for any of the mathematics education modules in the MSSE Department, students will continue to perceive it as an irrelevant module introduced to

torture them academically. It is imperative that a mechanism is found to remedy the situation.

### **Discussions**

An analysis of the mathematics syllabi and the course outline (See Tables 3 to 5) of the Namibia Senior Secondary Certificate (NSSC) for Grades 11 & 12 programme (Ministry of Education [MoE], 2010a, 2010b) and the UNAM B. Ed (Hons) (Faculty of Science [FoS], 2013, p. 3), confirms that there is a reasonably large gap in both level and area of work covered between the ordinary level and the UNAM syllabus, and to a lesser extent the higher level. This research also reveals that, higher level syllabus has some advanced topics not covered in the ordinary level but covered at University level. The comparison in Tables 3 to 5 seems also to support the claim by the students' evaluation reports from 2011 to 2013 that the ordinary level mathematics syllabus, does not cover much of what is covered in the UNAM B. Ed (Hons) Mathematics syllabus, or it covers it at a lower level and thus students find it difficult to cope or pass this module.

Thus, examinations of the syllabi of these three programmes revealed the following: Firstly, the higher level mathematics course has more content not covered by the ordinary level and some is covered at a higher level. Secondly, the UNAM B. Ed (Hons) degree Basic Mathematics covers substantially more mathematics content than the higher and ordinary levels. The Basic Mathematics further includes a wider scope and greater coverage of more content aspects of mathematics one would expect from a degree course. For example, Tables 3 to 5 indicate that the topics on sets are not part of both Higher and Ordinary school syllabi while polynomials, sequences, functions, trigonometric identities, absolute value (modulus) equations and inequalities are not covered at ordinary level. Algebra and trigonometry are taught in all three courses. Moreover, at higher level UNAM, trigonometry constitutes standard trigonometric functions, graphs and identities unlike at ordinary level where it involves only the three trigonometrical ratios (sine, cosine and tangent). While measure, mensuration, geometry, vectors in two dimension and transformation, statistics and

probability are covered at both higher and ordinary level, but not at first year university level. The shortfalls in the ordinary level content when compared to the UNAM Mathematics degree appear (Tables 3 to 5) in the topics such as logarithmic and exponential functions, differentiation and integration covered only at higher level. This shows deficiencies in the ordinary level mathematics content and should be addressed to enable learners to cope with university Basic Mathematics. It is evident from Tables 3 to 5 and student – lecturer evaluation comments that the level of mathematics at higher level would equip students to cope with Basic Mathematics.

This research further revealed that the aim of the Basic Mathematics course was to introduce students to university mathematics, and required them to work hard, and participate in lectures and tutorials. In order to assist students with a weaker background in mathematics, we found that the Department of Mathematics (FoS) runs two – modes of teaching its first year course. The decision as to which mode a student would take is reached upon after sitting for the compulsory first class test in Basic Mathematics (SMAT 3511), after four weeks of classes. Any student who scores a mark of 40% or higher, in the said test, proceeds with the current mode of study, which enables such a student to complete the first semester mathematics courses in the first academic semester year of registration. The student who scores a mark below 40% proceeds to the slow mode (SMAT 3580), in which the content of first year Basic Mathematics is taught over two semesters.

### Conclusion and recommendations

The Faculty of Education at the University of Namibia should devise a mechanism to introduce a bridging course in mathematics content. This is to bring about necessary fundamental changes in the learning of mathematics content in classrooms at university. The purposes of a bridging course include the following:

- *to increase the possibility of prospective student – teachers to acquire and be equipped with advanced content*

*mathematics to perform when enrolled in basic mathematics module;*

- *to encourage the mathematics student–teachers to read around mathematics content; and*
- *to fill the subject content gap among school learners entering the university.*

It is also evident that there is agreement amongst the participants in this study that there is a need to raise the levels of mathematics content knowledge at school level. Therefore we recommend that the following topics are included at school level; set theory, trigonometric identities, and sequences at ordinary level.

The Ministry of Education through NIED should pitch school mathematics to the first year University Basic Mathematics content. This will address the lack of mathematics content knowledge among the Grade 12 learners. We therefore recommend that the Faculty of Education at UNAM should send its first year students in Basic Mathematics a course outline to help them prepare over summer holiday (December – January) before the beginning of the following academic year with detailed content to be covered in the course.

We also recommend that the faster – stream be phased out to have only one stream of Basic Mathematics in the Faculty of Education, for students to acquire more content.

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## The nature of science conception: A review of literature

Shaakumeni, Simson Ndadaleka

Doctoral School of Educational Sciences, Institute of Education,

University of Szeged, Hungary,

[sshaakumeni@gmail.com](mailto:sshaakumeni@gmail.com) or [shaakumeni@edu.u-szeged.hu](mailto:shaakumeni@edu.u-szeged.hu)

### **Abstract**

*The most important goal of all reform efforts in science education is to achieve a scientific literate citizenry. At the core of that goal, is the strive to enhance students' understanding of the nature of science. The aim of this paper is to present a review of studies on students' and science teachers' conception of the nature of science. The analysis of such studies revealed that both students and science teachers do not possess appropriate understanding of the nature of science that is in line with contemporary science education standards. An accurate understanding of the nature of science is believed to help students identify the strengths and limitations of the scientific knowledge, develop accurate views of how science can and cannot answer some questions. Research suggests that teaching students about the nature of science can facilitate the learning of science subject content and increase student achievement. Studies related to students and science teachers' conceptions of nature of science are hardly found to have been done in Namibia. This paper is part of a study that is currently being undertaken to assess students' and science teachers' conception of the nature of science in Namibia.*

**Keywords:** *scientific literacy, nature of science (NOS), nature of science conception*

### **Introduction**

The most important goal of all reform efforts in science education around the world is to achieve a scientific literate citizenry (Khishfe & Lederman, 2007). At the core of that goal is the strive to enhance students' understanding of the nature of science. Reform efforts have given more attention to the nature of science, particularly in developed countries (Quigley, Pongsanon, & Akerson, 2011; Smith & Scharmann, 1999; Abd-El-Khalick et al., 2017). An appropriate understanding of the nature of science is attributed to developing scientific literacy (Peters-Burton, 2016; Allchin, Andersen, & Nielsen, 2014; Akerson, Hanson, & Cullen, 2007). Several reforms have taken place in the Namibian education system since independence in 1990, particularly in curriculum and assessment areas (Iiping & Likando, 2012). However, none of the reforms provided explicit guidelines on how to teach the nature of science, particularly in science subjects' specific curricula.

The nature of science is viewed by some science educators as an affective learning outcome and not as a cognitive or instructional outcome of equal status with traditional subject matter outcomes (Schwartz, Lederman, & Crawford, 2004; Lederman, 2006). Subsequently, it is not taught explicitly and reflectively in basic education science curricula, despite such curricula advocating that understanding of the nature of science is a prerequisite for scientific literacy development. It is assumed that students would acquire the understanding of the nature of science just by doing science and inquiry activities (Khishfe, 2008). This approach was found to be ineffective (Abd-El-Khalick & Lederman, 2000a; Khishfe & Abd-El-Khalick, 2002). For this reason, Khishfe and Abd-El-Khalick (2002) suggested that understanding of NOS should be considered as a cognitive learning outcome and should be taught explicitly rather than expected to be acquired through some kind of "osmotic

process” while engaging in regular science activities (p. 554).

Research in many parts of the world reveals that students and teachers do not possess appropriate conception of the nature of science (Lederman, 1992; Meichtry, 1992; Moss, Brams, & Robb, 2001; Khishfe & Abd-El-Khalick, 2002; Bell, Blair, Crawford, & Lederman, 2003). There is no shortage of instruments for assessing students’ views of the nature of science (Lederman, Wade, & Bell, 1998). However, no such instruments appear to exist in Namibia. Similarly, research on the nature of science is hardly done in Namibia. The development of a valid instrument for assessing students’ view of nature of science in Namibia is one of the goals of the present study. This paper presents a review of literature on nature of science in science education coupled with a critical appraisal of the nature of science representation in the Namibian basic education science curriculum.

### **The Nature of science (NOS)**

One of the important goals of science education is to foster students’ scientific literacy (Nowak, Tiemann, & Upmeier zu Belzen, 2013; Peters-Burton, 2016). Scientific literacy consists of different components, namely, content knowledge, scientific inquiry and nature of science (NOS). The concept NOS has been commonly used to refer to “the epistemology of science, science as a way of knowing or the values and beliefs inherent to the development of scientific knowledge” (Lederman, 1992, p. 331; 2007). This definition of the nature of science is rather general as to date there is still disagreement among philosophers of science, historians of science, scientists and science educators on the specific definition of the concept (Abd-El-Khalick, 1998). The lack of consensus on the specific definition of NOS is attributed to the complex, multifaceted and tentative nature of the scientific enterprise (Wenning, 2006; Abd-El-Khalick, Waters, & Le, 2008). Similarly, NOS is said to be tentative and dynamic as the conceptions of NOS have changed throughout decades of scientific development (Abd-El-Khalick, 1998; Deng, Chen, Tsai, & Chai, 2011).

However, the various disagreements about NOS are not important to science students in the basic education phase (Grades 1-12) due to the abstract nature of the NOS debates (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). However, a general and simplistic view of some important aspects of NOS can be taken to be accessible and appropriate to basic education science students and it is at this level of simplification that little disagreement exists among historians, philosophers and science educators (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Lederman & Abd-El-Khalick, 1998).

In recent decades, there has been a notable consensus among science educators pertaining to the level of simplicity of the aspects of the nature of science that is suggestively accessible and appropriate to basic education science students. This concurrence is based upon the understanding that scientific knowledge is tentative (subject to change); empirically-based (based on and/or derived from observations of the natural world); myth of “The Scientific Method”; subjective (theory-laden); partially based on human inference, imagination and creativity; socially and culturally embedded; observation and inference are different; and theories and laws are distinct kinds of knowledge (Abd-El-Khalick & Lederman, 2000b; Lederman, 2007; McComas, 2008; Osborne, Collins, Ratcliffe, & Duschl; 2003; Niaz, 2009; Abd-El-Khalick, et al., 2017). The eight aspects of NOS that frame this study are symbiotic of one another and are elaborated on in the following sub-sections.

### **Tentative NOS**

Scientific knowledge is reliable and durable, but never absolute or certain (Abd-El-Khalick et al., 2017; Lederman, 2007). All categories of knowledge including facts, theories and laws are subject to change. Scientific claims change as new evidence, made possible through advances in thinking and technological advances, is found. Similarly, existing evidence may be reinterpreted considering new or revised theoretical ideas or due to changes in the cultural and social spheres or shifts in the directions of established research programmes (Lederman, Abd-El-Khalick, Bell,

& Schwartz, 2002; Abd-El-Khalick, Waters, & Le, 2008).

### **Empirical NOS**

Experiments are useful tools in science but are not the only means to generate scientific knowledge (McComas, 1996). Moreover, scientific knowledge is also derived from observations of the natural world (Lederman, 2007; Lederman, Lederman, & Antink, 2013). However, scientists do not always have “direct” access to most natural phenomena, they rely on the use of human senses augmented by assumptions inherent to the workings of scientific instruments, to make conclusions about the natural world (Abd-El-Khalick, et al., 2017, p. 89).

### **Myth of “The Scientific Method”**

There is a commonly held misconception about science that there exists a single procedure which all scientists follow (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). “This myth is often manifested in the belief that there is a recipe-like stepwise procedure that epitomizes all scientific practice. This notion is erroneous: There is no single scientific method that would guarantee the development of infallible knowledge” (Abd-El-Khalick, Waters, & Le, 2008, p. 838). Scientists do observe, compare, measure, test, speculate, hypothesize, debate, create ideas and conceptual tools, and construct theories and explanations. However, there is no single sequence of (practical, conceptual, or logical) activities that will indisputably lead them to valid claims, let alone “certain” knowledge (Abd-El-Khalick, et al., 2017, p. 89).

### **Subjective/theory-laden nature of scientific knowledge**

Scientific knowledge is theory-laden (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). The work of scientists is influenced by their theoretical and disciplinary commitments, beliefs, prior knowledge, training, and expectations (Abd-El-Khalick, et al., 2017). These background factors affect scientists’ choice of problems to investigate and methods of investigations, observations (both in terms of what is and is not observed), and interpretation of these observations. This self-identity is

attributable to the role of theory in scientific knowledge production (Lederman, 2007; McComas, 2008; Niaz, 2009). Contrary to common belief, science never starts with neutral observations. Like investigations, observations are always motivated and guided by, and acquire meaning considering questions and problems derived from certain theoretical perspectives (Abd-El-Khalick, Waters, & Le, 2008). Further, the impact of individualism on scientific knowledge is mitigated through applying mechanisms such as peer review and data triangulation in order to enhance objectivity (Chen, 2006).

### **Imaginative and creative nature of scientific knowledge**

The empirical nature of science requires the making of observations of the natural world (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). For this reason, science is not necessarily an orderly enterprise. Scientific knowledge production involves human creativity in terms of scientists inventing explanations and theoretical models and this requires a great deal of creativity by scientists (Abd-El-Khalick, Waters, & Le, 2008). Creativity and imagination are vital at all stages of a scientific endeavour; from planning and designing through data collection to data interpretation, though with variable extent between stages (Wong & Hodson, 2008). The creative NOS, coupled with its inferential nature, entail that scientific entities such as atoms, force fields, species, etc. are functional theoretical models rather than faithful copies of “reality” (Abd-El-Khalick, et al., 2017, p. 89). Chen (2006) claimed that “imagination is a source of innovation” (p. 806). She further asserted that scientists use imagination coupled with logic and prior knowledge to generate new scientific knowledge.

### **Social and cultural embeddedness of science**

Science educators claim that science is a human invention that is entrenched and practiced in the context of a larger cultural setting. Different cultures have different perceptual experiences. For this reason, scientific knowledge affects and is affected by various cultural elements and spheres, including social fabric, trends, prestige, power structures, philosophy, religion, and

political and economic factors (Abd-El-Khalick, et al., 2017; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; McComas, 2008). Such effects are manifested, among other things, through control of scientific research by economic interests e.g. research on carbon emission or on apparent dangers of cellular phone usage can be influenced by oil companies or cellular phone manufacturers respectively. As history would discern, many people believed in the geocentric model of the solar system because of religious authority (McComas, 2008). The space race, though it results in increases in science and technology development; it is more political than scientific between the so-called world super powers (Leden, Hansson, Redfors, & Ideland, 2015; McComas, 2008).

#### **Difference between observations and inferences**

The scientific enterprise involves both observations and inferences (Schwartz, Lederman, & Crawford, 2004). There is a crucial distinction between these two scientific processes skills. Observations are descriptions of the natural world that are accessible to the human senses whereby several observers could easily reach an agreement whilst inferences are interpretations or explanations of observations gathered (Lederman, Antink, & Bartos, 2014; Schwartz, Lederman, & Crawford, 2004). Alternatively, inferences are accounts of phenomena that are not directly accessible to the senses such as the notion of falling objects due to gravity or the structure of an atom as a central nucleus composed of positively charged particles (protons) and neutral particles (neutrons) with negatively charged particles (electrons) orbiting the nucleus (Vesterinen, Aksela, & Lavonen, 2013; Abd-El-Khalick, Bell, & Lederman, 1998).

#### **Difference and relationship between theories and laws of science**

There are common misconceptions among students that there is a simplistic and hierarchical relationship between observations, hypotheses, theories and laws of science; and belief that laws have a higher status than theories within a scientific endeavour (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). The notion

that hypotheses are initially developed from observations and then become theories and theories become laws depending on the availability of supporting evidence is inappropriate (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Theories and laws are related but are distinct kinds of scientific knowledge and for this reason they serve different roles in the scientific enterprise and hence, theories do not in any way become laws, even with additional evidence (Niaz, 2009; McComas, 2008; Lederman, 2007).

Generally, laws describe relationships, observed or perceived, of the natural phenomena. Boyle's law, which relates the pressure of a gas to its volume at a constant temperature, is one example of a scientific law. Theories are inferred explanations of the natural phenomena and mechanisms for relationships among natural phenomena (Schwartz, Lederman, & Crawford, 2004). The kinetic molecular theory provides an explanation of what is observed and described by Boyle's law (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Hypotheses in science may lead to either theories or laws with the accumulation of substantial supporting evidence and acceptance in the scientific community. Hence, "theories are as legitimate a product of science as laws" (Abd-El-Khalick, et al., 2017, p. 90). The next section highlights some criticisms levelled against general NOS conceptualisation.

#### **Criticisms of the general aspects of NOS**

Ogunniyi (1982) asserted that "nature of science is a complex concept. It involves the processes, the products, the ethics, the regulative principles, and the logico-mathematical systems, all defining and controlling the methodological inquiries of science" (p. 25). Because of such complexities, understanding NOS becomes a far-fetched goal in basic education. In response to this challenge, science educators have reached a compromise about what NOS understanding for basic education students should entail (Tala & Vesterinen, 2015). This resulted in a list of general characteristics of NOS that are deemed accessible to basic education students (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Lederman & Abd-El-Khalick, 1998; McComas, Almazroa, & Clough, 1998).



Subsequently, this general characterisation has drawn criticisms from some science educators, who felt that such characterisations are not comprehensive and hence cannot describe all kinds of science (Tala & Vesterinen, 2015). Duschl and Grandy (2011) bemoaned this consensus view of NOS that it does not adequately cover all philosophical underpinnings that characterise the generation of scientific knowledge. Echoing the same sentiments was Allchin (2011) who called for whole science approach to NOS characterisation. He argued that the “selective lists of tenets” omitted numerous aspects that shape reliability in the scientific enterprise (p. 518). Moreover, Irzik and Nola (2011) castigated general aspect NOS framework, arguing that:

While we have no objection to this list, provided the items in it are properly understood, we believe that the consensus view has certain shortcomings and weaknesses. First of all, it portrays a too narrow image of science. ...Second, the consensus view portrays a too monolithic picture of science and is blind to the differences among scientific disciplines (p. 593).

They therefore suggested a family resemblance approach in which the differences between scientific disciplines are considered although there would be overlap of common characteristics among sciences.

The eight general aspects of NOS explicated above, though criticised by some science educators as being too general, over-simplified, prescriptive and narrow (Irizik & Nola, 2011; Mathews, 2012; Dagher & Erduran, 2016; Grandy & Duschl, 2008) are considered as a guiding framework for this study as they serve as lenses through which to assess science students’ and teachers’ conceptions of NOS. The decision to adopt this framework is based on the clarification provided by its proponents, who in response to such criticisms stated that the list of the characteristics of NOS is by no means “a definitive or universal definition of the construct” (Lederman, Antink, & Bartos, 2014, p. 286). They further argued that they have never

advocated an absolutist stance on those general statements about nature of science.

Moreover, their focus is on understandings that they want basic education students to have given a plethora of hardly productive debates about the definitive description of NOS.

In support, Kampourakis (2016, p. 674) expressed:

It should be noted that although the “general NOS aspects” conceptualization and the instruments developed by Lederman and his colleagues have been used widely, to the best of my knowledge, there is no empirical evidence that they lead to distorted views of science. In contrast, there is empirical evidence suggesting that this conceptualization is quite effective in teaching and learning about NOS.

He asserted that using the concept of general ideas about nature of science is an effective approach to introduce students to the nature of science, given available empirical data. “Once students start reflecting about general NOS aspects and teachers start addressing their preconceptions, it could be possible to move forward and study NOS in all its complexity” (Kampourakis, 2016, p. 676). The next section discusses the justification of NOS in science education.

### **Rationales for teaching the NOS**

A variety of rationales for teaching nature of science has been suggested by science educators and researchers (Virginia Mathematics and Science Coalition (VMSC), 2013). Bell (2008) argues that an accurate understanding of the nature of science helps students identify the strengths and limitations of the scientific knowledge, develop accurate views of how science can and cannot answer. Moreover, research suggests that teaching students the nature of science can facilitate the learning of science subject content and increase student achievement (Cleminson, 1990; Songer & Linn, 1991; Driver, Leach, Millar, & Scott, 1996; Peters, 2012).

Mathews (1997) posited that an appropriate understanding of nature of science is essential to understanding the relationship between science and religion, the controversy over creation science and science as a distinctive intellectual enterprise with its special values and the essential differences between scientific and non-scientific disciplines. In addition, teaching the nature of science helps increase awareness of the influence of scientific knowledge on society (Driver, Leach, Millar, & Scott, 1996; Meyling, 1997; Lederman, 1999).

Driver et al. (1996) argued that NOS influence society in terms of utilitarian (making sense of science and managing technological objects and processes in everyday life); democratic (informed decision-making on socio-scientific issues); cultural (appreciating the value of science as part of contemporary culture); moral (developing understanding of the norms of the scientific community that embody moral commitments that are of general value to society) and science learning (enhancing the learning of science subject matter). Ultimately, developing appropriate conceptions of NOS has been advocated as critical to acquiring scientific literacy by various science education reform documents worldwide, particularly in United States, United Kingdom, Australia, Canada and South Africa (Lederman, 2006). What follows is the analysis of NOS representation in the Namibian science curriculum.

### **NOS in the Namibian Science curriculum: A critical appraisal**

Science education in Namibia's basic education phase predominantly focuses on teaching the subject-matter content in preparation for high-stakes examinations. Other aspects of scientific literacy such as inquiry skills and the understanding of the nature of scientific knowledge ought to develop in students implicitly. Implicit approach assumes that "students' participation in authentic scientific investigations in itself would help students develop more accurate understandings of the nature of scientific inquiry and knowledge" (Bell, Matkins, & Gansneder, 2011, p. 415). However, the literature shows that this approach has not been effective in facilitating students' and teachers' understanding of NOS (Gess-

Newsome, 2002; McDonald, 2010; Lederman, Lederman, & Antink, 2013).

The National Curriculum for Basic Education (NCBE) which is the broad curriculum, states that Natural Sciences are part of the main drivers of the transformation of society and the world. Hence, there is a need to develop students into scientific literate citizens (Ministry of Education, 2010a). According to the NCBE, scientific literacy which is "the understanding of scientific processes, the nature of scientific knowledge, and the ability to apply scientific thinking and skills, is indispensable today" (Ministry of Education, 2010a, p. 12). Therefore, Natural Sciences area of learning should contribute to the foundation of a knowledge-based society by empowering students with the scientific knowledge, skills and attitudes to formulate hypotheses, to investigate, observe, make deductions and understand the physical world in a rational scientific and sustainable way (Ministry of Education, 2010a).

The aims of the broad curriculum (NCBE) are manifested in the specific Natural Sciences curricula (syllabi). One of the syllabi states that providing basic scientific background for students with the hope of producing the much-needed scientists for the country is the main aim of science education in Namibia. It further states that the Namibian society needs to be scientifically literate if it is to cope with the challenges of appropriate global technology requirements (Ministry of Education, 2010b). At the heart of this study is an attempt to ascertain the extent to which science education is developing students' scientific literacy in terms of acquiring informed understanding of the nature of science, given that this aspect of scientific literacy is not taught explicitly in Namibian schools. The study also seeks to gauge science teachers' views about NOS, as they play a vital role in students' learning of science.

Throughout primary and junior secondary phases of the Namibian education system, the specific science curricula state that scientific processes skills topic should not be taught in isolation as such skills form an integral part of the other topics (Ministry of Education, 2010b, 2010c, 2016). This directive to the science teachers suggests that scientific inquiry skills and simultaneously the nature of scientific

knowledge should not be taught as a “pull-out” content (Leden, Hansson, Redfors, & Ideland, 2015, p. 1144) but should be integrated in the subject-matter content. What such instruction does not clearly spell out is whether the integration should be implicit or explicit. This analysis is triggered by the claim that explicit teaching of NOS has been effective in enhancing students and teachers understanding of NOS (Lederman, 2007; Bell, Matkins, & Gansneder, 2011; Leden, Hansson, Redfors, & Ideland, 2015). Explicit approach entails using NOS and scientific inquiry (process skills as referred to in the Namibian science curriculum) as context for generation and learning of scientific knowledge (Gess-Newsome, 2002). This can be achieved by purposefully planning and integrating NOS in the science content. Lederman (2007) asserts that the best way to enhance students’ conception of NOS is through “explicit, reflective instructions” (p. 869). Moreover, explicit teaching should not be confused with direct instruction however, whether explicit instruction of NOS should be entrenched into the subject content or taught separately is still debatable (Leden, Hansson, Redfors, & Ideland, 2015). Nevertheless, for students to become scientists in the near future as envisioned by the Namibian science curriculum, learning about NOS is a prerequisite (Tala & Vesterinen, 2015).

In the context of this literature review, science refers to Natural Sciences (Physical Science and Biology). There is evident representation of some aspects of NOS within the aims of the Namibian science curriculum. A comparison of the aggregated aims of the Namibian science (Physical Science and Biology) curriculum with the unanimous view of nature of science objectives extracted from eight international science education standards documents (McComas, Almazroa, & Clough, 1998) suggests that the aims of the Namibian curriculum to some extent conforms to international science standards objectives and hence, it is expected that Namibian teachers do teach such aspects of NOS to science students.

However, attention is drawn to one of the aims of the Namibian science curriculum that says students should develop an understanding of *the scientific method* (italics added) and its application (Ministry of Education, 2010d,

2010e). This appears to suggest that there is one single scientific method that all scientists follow. Science educators and scholars argue that there is no single scientific method that would guarantee the development of infallible knowledge. Scientists do observe, compare, measure, test, speculate, hypothesize, debate, create ideas and conceptual tools, and construct theories and explanations. However, there is no single sequence of (practical, conceptual, or logical) activities that will indisputably lead them to valid claims, let alone absolute knowledge (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Abd-El-Khalick, Waters, & Le, 2008; Abd-El-Khalick et al., 2017).

Lederman et al. (2014) argued that basic education students and even the public possess an inaccurate view of the scientific enterprise called the scientific method that has been acquired through schooling, from the media and from the way scientific reports are designed. They further posited that “there is no fixed single set or sequence of steps that all scientific investigations follow. The contemporary view of scientific inquiry is that, the questions guide the approach, and the approaches vary widely within and across scientific disciplines and fields” (p. 290). The next section presents a synthesis of research that has been done on the conception of NOS.

### **Research on NOS conception**

Research on NOS can be traced to over half a century ago (Lederman, 2006). Lederman pointed out that studies on NOS focused on students’ and teachers’ conceptions; curriculum; attempts to improve teachers’ conceptions and effectiveness of various instructional practices. Such studies were underpinned by the premise that scientific knowledge is tentative, empirically based, subjective, partially based on human inference, imagination and creativity, socially and culturally embedded, the myth about the scientific methods, the distinction between observation and inference and finally the relationship between scientific theories and laws (Liu & Lederman, 2002). This review focuses on studies conducted in the most recent decades, focusing on students’ and teachers’ views of NOS.

**Students' conceptions of NOS**

Students' views of NOS have been studied extensively by various researchers and science educators mostly in developed countries (Deng, Chen, Tsai, & Chai, 2011). Results consistently show that students throughout basic education (Grades 1-12) possess inadequate (naïve) and often inappropriate views of NOS (Lederman, 1992; Meichtry, 1992; Moss, Brams, & Robb, 2001; Khishfe & Abd-El-Khalick, 2002; Bell, Blair, Crawford, & Lederman, 2003). The study of which this literature review is part of attempts to assess the state of NOS conceptions amongst Namibian science students and teachers in the highest phase of basic education (Grades 11 & 12). Students in this phase of basic education in Namibia have been studying science for almost twelve years.

Vhurumuku (2010) labelled views about the NOS as either naïve or sophisticated. Students can be designated as possessing naïve views when they reveal understandings such as: scientific knowledge is certain and fixed, proven true, exclusively empirically based (relies entirely, on observation, experimental evidence) and objective; theoretical models (atom structure) are copies of reality; there is one single method of science which all scientists follow; science can answer all questions in nature and scientific observations are free from human prejudices. From Schwartz, Lederman and Crawford (2004) such naïve understandings are such as observations and inferences are one and the same; and that theories become laws.

In extension to Vhurumuku's assertions, students possess sophisticated views of NOS when they exhibit understandings such as: scientific knowledge is dynamic, tentative, scientific claims are subject to change as new evidence is found or existent evidence is reinterpreted; there exists multiple truths and realities which are neither fixed nor absolute; there are several appropriate methods in science; scientific observations are theory-laden and dependent on the prior experience and preconceptions of the observer; while scientific knowledge is empirically based (based on evidence), imagination and creativity of scientists (atom structures) also play roles in knowledge creation; and that although scientists try to be open-minded and objective, there is

always an element of subjectivity, which has to do with the fact that scientists are human beings. Furthermore, students should be able to distinguish between observation and inference and between scientific laws and theories. They should moreover, be able to explain that observations are products of the use of human senses and that inferences are the conclusions made after making such observations; and that laws are descriptive statements of what happens based on what is observed, whereas theories are explanations of what happens (the how and the why) (Lederman et al., 2002; Lederman, 2007). Other science educators use other variations to describe students' views about NOS but still similar to naïve and sophisticated categorisation such as inconsistent versus consistent; adequate versus inadequate and naïve versus informed (Vhurumuku, 2010).

Moss et al. (2001) conducted a qualitative participant observation study to investigate five purposefully sampled high school (Grades 11-12) science students' understandings of the nature of science for a period of one year in the United States. Moss et al. developed a model of NOS (for their study only) to examine students' conceptions of NOS through semi-structured, formal and one-to-one interviews. They captured the narrative of students' descriptions of NOS verbatim and interpreted them according to the NOS model developed for the study. The model consisted of eight characteristics pertaining to both the nature of the scientific enterprise and the nature of scientific knowledge.

The study found that students held informed views that scientific knowledge is subject to change, however, they were not familiar with the idea that scientific knowledge was robust and is a product of many kinds of methods. Further, it was reported that students' preconceptions that scientific knowledge emanates from a specific method such as the scientific method, were largely not impacted by their participation in the year-long project-based, hands-on science course.

Similarly, Bell et al. (2003) employed a pre-post training assessment of ten "high-ability" (p. 489) secondary school (Grades 10-11) students' understandings of the nature of science and scientific inquiry. They used an open-ended questionnaire and semi-structured interviews and

their study used NOS framework as advocated by science education reform documents in the United States such as the National Science Education Standards. The study attempted to explain the effect of an 8-week science training (originally apprenticeship) programme on ten high-ability secondary school students' understandings of the nature of science and scientific inquiry with a view to illustrate any variations in participating students' understandings of the nature of science and scientific inquiry; and to evaluate any direct or indirect effects of participating in the training programme on their understandings of the nature of science and scientific inquiry.

Findings from this study were not any different from the previous study reviewed above. It was found that students' views of the nature of science and scientific inquiry were mostly not commensurate with the objectives of the current reforms. Students' views were characterised by inconsistent or incomplete interpretations. Worth pointing out are for instance the view expressed by all students that data is the only prerequisite for change to scientific claims, missing the notion that theories might also change as a result of reinterpreting existing evidence (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). The belief that scientific laws represent absolute knowledge and failure to delineate the difference between theories and laws are all conforming to a plethora of research findings that basic education students barely possess views of NOS that are in line with science education reform objectives (Lederman, 1992; Meichtry, 1992; Deng, Chen, Tsai, & Chai, 2011). The study found that despite apparent minimal gain in the students' knowledge about the processes of scientific inquiry, their preconceived views about key characteristics of NOS remained nearly the same (Bell, Blair, Crawford, & Lederman, 2003).

The two studies above were all underpinned by an implicit approach to enhancing students' NOS views. Implicit approach assumes that students would acquire NOS understanding "automatically" just by doing science and engaging in hands-on-activities (Khishfe, 2008, p. 471). Using a different approach in comparison with the two studies above, Khishfe and Abd-El-Khalick

(2002) conducted a quasi-experimental study following a "pre-test-post-test non-equivalent group design" (Cohen, Manion, & Morrison, 2007, p. 282) to assess the influence of an explicit and reflective inquiry-oriented instruction compared with implicit inquiry-oriented instructional approach on students' understanding of NOS.

The study involved sixty-two sixth graders allocated to two intact groups. The explicit (intervention) group was exposed to inquiry activities supplemented by reflective discussions of the target NOS aspects. The implicit (comparison) group was exposed to the same inquiry activities but no discussion of any NOS aspect was applied. Due to the abstract nature of NOS, even at the simplified level deemed appropriate for basic education students and with the age of participating students in hindsight, the study was limited to four aspects of NOS namely, tentativeness; empirical; creative and imaginative NOS as well as the difference between observation and inference.

The study found that at the beginning of the intervention, most students in both groups possessed incomplete views of the four target NOS characteristics. However, at the end of the study, most students in the explicit group exhibited a more informed view of one or more of the target NOS characteristics while there was no change in views of students in the implicit group. These results point to the same conclusion as other studies conducted on this component of scientific literacy (Moss, Brams, & Robb, 2001; Bell, Blair, Crawford, & Lederman, 2003). However, this study suggests that involving students in discussions related to NOS during inquiry activities effectively facilitates a shift in their conception of NOS (Khishfe & Abd-El-Khalick, 2002).

Closer to home, Ibrahim, Buffler, and Lubben (2009), conducted a study involving 179 undergraduate students in a South African university. The study was aimed at capturing and describing physics students' views of the NOS using what they referred to as NOS "profiles" (p. 250). These profiles are conceived to be brief descriptions of different views of individual students which can be used to investigate their views of NOS and other associated observable aspects of the scientific endeavour. They found

that only 44% of the sample exhibited desirable views of NOS. Such findings are not surprising as similar results are reported the world over.

Another African perspective on students' views of NOS can be found in Vhurumuku, Holtman, Mikalsen, and Kolsto (2006). They investigated Zimbabwean high school chemistry students' images of NOS during a laboratory session. They found that a substantial percentage of students view scientific knowledge produced by chemistry experiments and observations as "true" (p. 139). Moreover, those who viewed experimental results as not always true justified their reasoning with a blame on "failure to follow procedures, contamination of reagents, faulty apparatus, or unfavourable laboratory conditions" (p. 139). These findings about students' images of NOS point to the prevalent inappropriate view about the validity of scientific knowledge (Vhurumuku et al., (2006). McComas (1996) claimed that the availability of empirical evidence regardless of how much such evidence is does not ensure the generation of valid scientific knowledge due to the problem of the method of induction. He explains that:

It is both impossible to make all observations pertaining to a given situation and illogical to secure all relevant facts for all time, past, present and future. However, only by making all relevant observations throughout all time, could one say that a final valid conclusion had been made (p. 12).

Despite that students and teachers views about NOS have been studied extensively in the last two decades, it has not been possible to locate such studies done in Namibia. Deng et al. (2011) conducted a thorough and critical review of research within the last two decades (from 1992 to 2010) and found 105 empirical studies that examined students' views of NOS. The search was conducted on some major online academic databases. They could locate such similar studies done in South Africa and Zimbabwe (these two countries being closest neighbours of Namibia) but none was found to have been done in Namibia.

A search on the University of Namibia's publications list and online repository came up

with only one study that is closely related to NOS and scientific inquiry. It was conducted by Kandjeo-Marenga (2011). This study investigated the implication of two teaching approaches on the students' learning of process skills in Biology. The main focus of the study was "process skills" learning opportunities during practical work (p. 44). Such skills are typical components of scientific inquiry (Lederman, Lederman, Bartos, Bartels, Meyer & Schwartz, 2014). However, the study fell short of tapping from "inquiry processes as a model of scientific practices" (for a better theoretical grounding) as well as recognizing the relationship between inquiry-based approaches to enhancing students' understanding of NOS (Allchin, Andersen, & Nielsen, 2014, p. 467). Against the foregoing, the theoretical grounding of this study could be extended. Teachers' views of NOS are discussed in the following section.

### **Science teachers' conceptions of NOS**

Current teaching and learning practices follow the learner-centred approach that is underpinned by the constructivist view (Ministry of Education, 2010a). This principle advocates the provision of opportunities for students to construct new understandings for themselves at both individual and social levels (Brooks & Brooks, 1993). However, the teacher has a significant role to play in this endeavour (Lederman, 1992). The role of the teacher is that of a "guide, provocateur, creator-of-opportunity, and co-developer of understanding with the students" (Windschiffl, 1999, p. 191). Therefore, science teachers must possess an adequate understanding of NOS to effectively contribute to students' understanding of this concept (Lederman, 1992).

Nevertheless, it has been reported that teachers do not generally possess consistent or adequate conception about the NOS (Lederman, 1992; Abd-El-Khalick & Lederman, 2000a; Dogan & Abd-El-Khalick, 2008). Subsequently, it can be assumed that teachers cannot effectively teach concepts that they do not understand (Bell, Matkins, & Gansneder, 2011). However, Abd-El-Khalick, Bell and Lederman (1998) argued that even though teachers' understanding of the NOS can be assumed to be a necessary condition for effective teaching of

NOS to students, it is not sufficient to make NOS visible in their science classrooms. In corroboration of this argument, Bell et al. (2011) maintained that teachers with inadequate understandings of the NOS are likely to promote absolutist views while overemphasising vocabulary of the science content. Thus, suggesting that enhancing teachers' conceptions of NOS is a vital preliminary attempt to improve NOS teaching to basic education students.

Aslan and Tasar (2013) investigated science teachers' NOS views with the intention of determining how their views influenced their instructional practices. They used items from the Views on Science-Technology-Society (VOSTS) questionnaire, semi-structured interviews and classroom observations, to assess teachers' NOS views. Their findings were consistent with earlier studies. They found that the participating science teachers held naïve views on many aspects of the NOS and further found that teachers' views about NOS did not directly influence their classroom practices. Other intervening factors such as the high stakes examinations, expectations of school administrators, students and parents, influenced teachers' instructional practices.

The common conclusion that can be deduced from the studies reviewed is that both in-service and pre-service teachers do not possess adequate understanding of the NOS. None of the studies reviewed was done in Namibia though.

### **Conclusion**

The nature of science is a multifaceted and complex concept. To date there is no complete agreement among philosophers, historians, sociologists of science and science educators on how to define it. Notwithstanding this, there is less disagreement among philosophers of science and science educators about the general aspects of the nature of science that are deemed less controversial and appropriate for inclusion in the basic education science curricula. Those aspects are manifested as unanimous view of the nature of science objectives in eight international science education standards documents as presented by McComas et al. (1998).

The general characterisation of the nature of science has been criticised by some science

educators. However, the closing arguments that provided the way forward are that the disagreements among science educators are not necessarily relevant to basic education science students as such students do not study philosophy, history or sociology of science. The aim is to make NOS accessible to such students. Furthermore, the emphasis is that using the concept of general ideas about nature of science is an effective approach to introduce students to the nature of science.

NOS is an important component of scientific literacy. An accurate understanding of the nature of science is believed to help students identify the strengths and limitations of the scientific knowledge, develop accurate views of how science can and cannot answer all questions. Moreover, research suggests that teaching students the nature of science can facilitate the learning of science subject content and increase student achievement. Developing appropriate conceptions of NOS has been advocated as critical to acquiring scientific literacy by various science education reform documents worldwide, particularly in the United States, United Kingdom, Australia, Canada and South Africa.

Some aims of the science curriculum in Namibia were found to overlap with some objectives of international science education standards documents. Namibia envisions developing future scientists through the teaching of natural sciences. This dream can be realised if students acquire appropriate understanding of the nature of scientific knowledge. However, the science curriculum adopts the implicit approach to teaching the nature of science as is prevalent worldwide. However, research shows that this approach is not effective, hence the need follows explicit-reflective instructional approach.

Research results of students and science teachers' views of NOS consistently reveal that both students and teachers possess naïve (inconsistent) views about NOS. Studies of this nature have not been carried out in Namibia. This constitutes a gap that needs to be filled.

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National Institute for Educational Development

Private Bag 2034

Okahandja

Namibia

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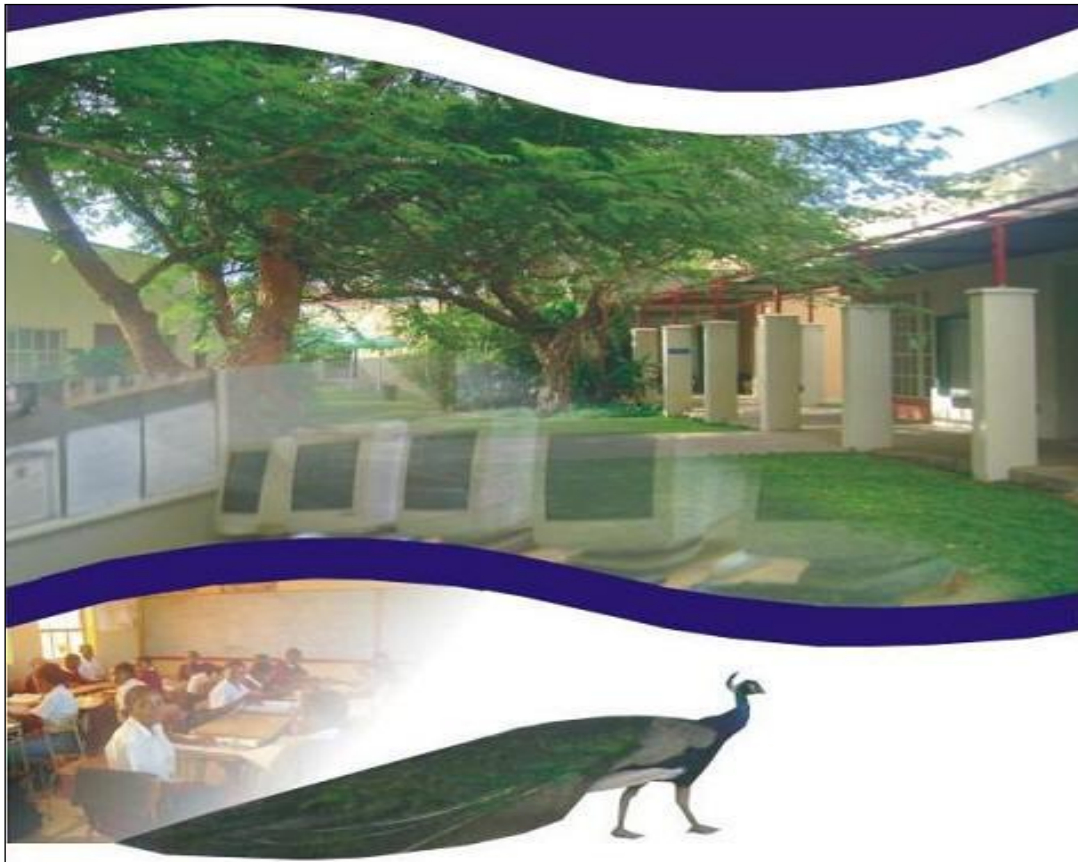
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**NIED**

National Institute for Educational Development

Private Bag 2034

Okahandja

Namibia

Telephone: +264 62 509000

Facsimile: +264 62 509073

Website: <http://www.nied.edu.na>