 Stud Tribes Tribals, 11(1): 83-88 (2013)

Traditional Knowledge in Curricula Designs: Embracing Indigenous Mathematics in Classroom Instruction

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KEYWORDS Indigenous Knowledge. Mathematical Knowledge. Traditional Artifacts. Curriculum Development. School Mathematics

ABSTRACT In this article, the knowledge of traditional artifacts used by the Tchokwe tribe in Angola is explored and then related to the mathematical content learned in the classroom. Examples of artifacts provided in this article illustrate how knowledge extracted from the traditional artifact structures can be used to generate knowledge of concepts for the school mathematics curriculum. These illustrations show the advantage of the use of artifacts to develop ideas that lead to the determination of mathematical rules and principles. The process illustrated is contrary to the teaching of mathematics that involved remembering or following of the rules to obtain solutions. It is concluded that through illustrated processes, learners can learn and develop mathematical interest through reflecting and appreciating on what exists in their traditions. It is recommended that curriculum designs processes should include indigenous knowledge in school curricula for clear understanding of concepts and for long-term retention of knowledge.

INTRODUCTION

In various tribes around the world, there exists indigenous knowledge that can be integrated into the school curricula. The artifacts that are available in the traditional environments are important tools that can be used to bridge the gap between what is usually taught in the classroom and what exists outside the classroom, that is, in society. The indigenous knowledge that exists in society has historically been ignored, from the colonial times to present regimes, where the school curricula are designed without including such knowledge. Thaman (2000) argued that education cannot exclude cultural knowledge, since the content of education has value underpinning it, associated with a particular culture, which he defined as a way of life that included particular ways of knowing, knowledge and wisdom, as well as ways of communicating these. Lawton (1974) defined curriculum as a selection of the best of a culture, the transmission of which was so important that it was to be entrusted to specially prepared teachers to handle the curriculum from the same culture. The school curriculum then had to take into consideration the way students think, learn and communicate with one another from a cultural perspective (Thaman 2009). Schooling and the curriculum have been portrayed as both an extension of a society's culture (Reynolds and Skilbeck 1976; Goodson 1994; Mel 1995). Morris and Ling (2000) explored the relationship between curriculum and culture and emphasized the interaction of the two for significant reform of the Hong Kong's primary schools curriculum.

A number of studies have emphasized the significance of integration of indigenous knowledge in classroom instruction in teaching and learning of mathematics. Mathematical indigenous knowledge has been regarded as 'frozen' knowledge because it 'lies' with the 'traditions' without its exploration for full utilization for educational, social and even economic development in these societies (Gay and Cole 1967; Powell and Frankenstein 1997; Gerdes 1997; Kaino 2011 and others). In the past two decades, what has emerged and been known as *Ethnomathematics* has shown some powerful insights in mathematical sciences and cross-cultural analysis (Asher 2002; Eglash 2002). For example, studies done in New Zealand that examined mathematics achievement and the professional development of mathematics teachers emphasized the development of a national program of traditional knowledge (Aspin 1994; Smith 1999 in Sandoval 2007; Rogers 2003). Traditional knowledge is not used or acknowledged in mathematics curricula in most coun-

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tries and a few studies like those done in Alaska show the strides made in the development of curriculum materials. In Alaska, the development of curriculum materials utilized Alaska Native constructs such as fish rack construction, egg gathering, salmon harvesting, and star navigation as an avenue for teaching mathematical content that prepares students to meet national and state standards and related assessment mandates (Adams and Lipka 2003).

In their study of the mathematical learning difficulties of the Kpelle people (in Liberia), Gay and Cole (1967) concluded that what happened in the classroom was that the contents did not make any sense from the point of view of Kpelle-culture; moreover the methods used were primarily based on rote memory and harsh discipline. Experiments showed that Kpelle illiterate adults performed better than North American adults when solving problems like the estimation of number of cups of rice in a container that belonged to their indigenous mathematics. A study by Mosimege (2004) identified various mathematical concepts from activities and artifacts exhibited in *cultural villages* of Lesedi and Basotho tribes in South Africa. The mathematical concepts identified were on various mathematical topics such as Counting, Estimation, Straightness of Lines, Shapes and Patterns, Angles, and many others. The integration of such knowledge into the mathematics curriculum can be useful in the teaching of these topics whereby students can relate what they experienced outside to mathematical concepts learnt in the classroom. Nkopodi and Mosimege (2009) identified various mathematical concepts using the indigenous game of *morabaraba* played widely in the South African culture. It was found by the authors that the use of this game promoted the interaction amongst learners and the game was not restricted to a specific cultural group, which suggested that it could be used to teach mathema-tics in multicultural classes.

The above developed ideas and findings from a number of studies show that a closer link between the development of a mathematical construct and its social significance can provide the opportunity for learners to reflect on their own unique cultural heritage and understand better mathematical concepts (Hughes 2000). These findings also contradict Horsthemke's (2004) view that indigenous knowledge involved some questionable understanding or conception of knowledge.

METHODOLOGY

In this paper, the researcher derives knowledge of numeric and geometric patterns from the Tchokwe tribe. Tchokwe people originate from Angola and their culture is spread in the South African region. The knowledge derived is related to mathematics topics on *Patterns, functions and algebra* taught to high school students in most schools in the South African region and countries in Africa, South of the Sahara. First, the traditional activities are outlined and the mathematical knowledge involved is explored. Second, the mathematical content taught in the school related to the traditional knowledge explored is presented and mathematical ideas are generated to establish concepts in the topics taught at school.

DEVELOPING PATTERNS

Tchokwe Traditional Numeric and Geometric Patterns

The Tchokwe people draw with their fingertips an orthogonal net of equidistant points on various events such as during hunting, conversations, on leisure times (sitting in a circular form). The drawings from such events are also found in decorations and drawings. The Tchokwe people add second net in such a way that the points of the second one are the centres of the unit square of the first as illustrated in Figure 1. These unit squares shall be refereed in this paper as 1x1, 2x2, 3x3 squares etc.

Figure 1(a) shows 4 dots at equidistant forming a square (2x2). The diagonal line draws across shows 1 dot on the upper side and the other on the lower side. In Figure 1(b) they form a 3x3 with 3 dots below and above the diagonal line. The next 4x4 figure forms 6 dots below and above the diagonal. If we continue building up larger figures, we can make a generalization of the number of dots built up as follows:

$1+2+3+4+[5]+1+2+3+4=25=5^2$ ……………………..(i)

$\rightarrow (1+2+3+4)+(1+2+3+4)=5\cdot5$ ……………………..(ii)

$\rightarrow 2(1+2+3+4)=5\cdot5$ ……………………..(iii)

$\rightarrow 1+2+3+4=(5\cdot5)/2$ ……………………..(iv)

Expression (iv) above means the sum of the dots below and above the diagonal is equal to the total number of dots in a square minus the number of dots in the diagonal. In a general form, expression (iv) can be written as

$1+2+3+(n-1)=(n^2-n)/2$ or $n(n-1)/2$

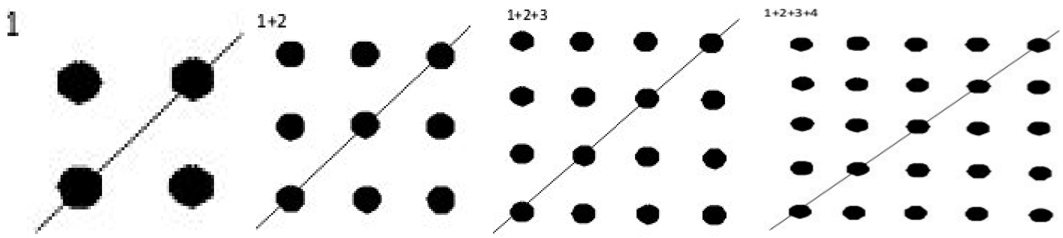


Fig. 1. Tchokwe drawings

The expression above can be used to obtain addition of large numbers within a short time as shown below:

For example, the addition of 1+2+3+…..+ 10 can simply be obtained as follows:
$(11^2-11)/2=55$ or more simpler $11(11-1)/2$

The sum of dots in the triangle formed (including the diagonal) can be determined as follows:
$1+2+3+4+5= [(5+1)^2 -(5+1)]/2=(36-6)/2=15$

When extended to the nth number, the expression on the L.H.S. gives

$1+2+3+4+5+.......+n=n(n+1)/2$ which is a general formula for obtaining the sum of natural numbers. In Figures 1(a-c) the array for the sum of natural numbers can be viewed as shown.

Significance of the Patterns

At high school level, students are expected to acquire knowledge on sequences of odd and even numbers and develop a sequence of square numbers as well. This knowledge is found in most topics on Numeric and Geometric patterns in South African region school curricula. The teaching of this content can be approached as illustrated in the activity above using pre knowledge of students on drawings with fingers as done traditionally. Learners without such pre knowledge can be drawn into the conversation as a preparation for introducing the lesson and then later into the activity. In this activity students develop knowledge on sequences before using the theory to develop it as taught in the traditional approach. Through this process, students develop knowledge from the traditional context as stipulated in the syllabus utilizing the mathematical knowledge that exists in the local environment. Establishment of the formula would not be necessary for example to Grade 7 students (about 12 years of age) but the process that arrives at the structure to determine the answer would be appropriate at this grade. The established formula to determine the sum of natural numbers can be suitable for Grades 8 and 9 (about 13 and 14 years of age). In the next activity we develop further the unit squares to establish the Pythagoras Theorem for Grades 8 and 9.

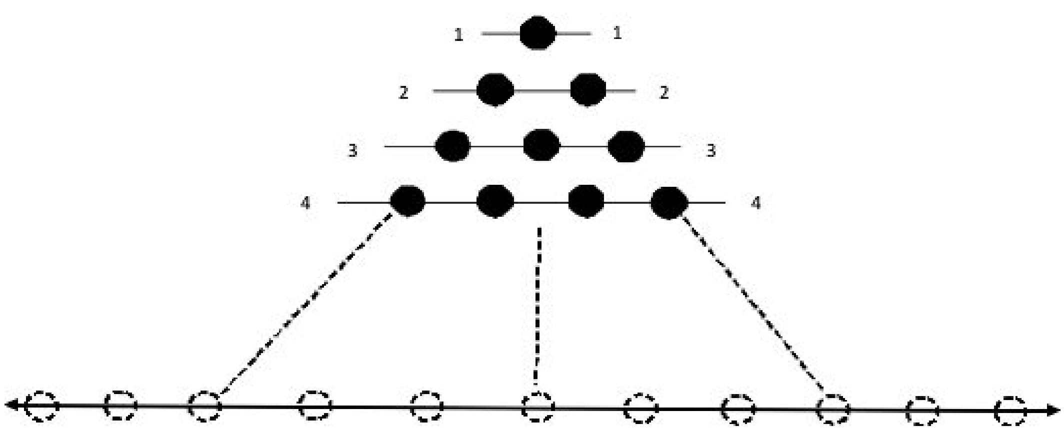
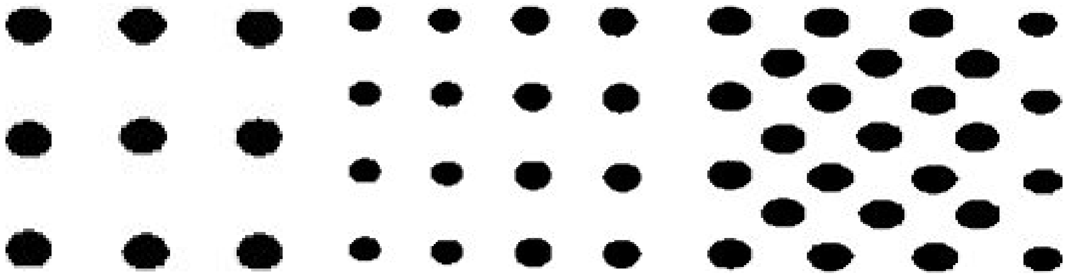


Fig. 2. The structure for the sum of natural numbers



3^2 (a) 4^2 (b) $3^2 + 4^2$ (c)

Fig. 3. Squares forming Pythagoras Theorem

Development of the Pythagoras Theorem from the Traditional Perspective

Traditional Unit Squares that Form the Pythagoras Theorem

Let us consider a 3x3 and a 4x4 squares developed by Tchokwe people in Figure 1 (b) and Figure 1 (c) presented in Figure 3 (a) and Figure 3 (b). By insertion of a 3x3 square into the 4x4 square we get Figure 3(c) producing the total sum of 25 dots. This structure forms the Pythagoras triplet (3,4,5) where $3^2 + 4^2=5^2$.

The number of dots below and above the diagonal is 1+3+5

The total number of dots in the structure is 1+3+5+[7] 1+3+5=25

→ 2(1+3+5)= 25-7 or 5^2-7

→ 1+3+5=(5-7)/2…………..(i)

The L.H.S. expression forms a simple sum of odd numbers that can be easily determined by the R.H.S. expression.

The extension of the L.H.S. can lead to the general formula for determination of the sum of the odd numbers which is an arithmetic progression with a common difference of two (Figure 4). This derivation is beyond the level of schooling considered in this chapter.

Proof of Pythagoras Theorem

From the Pythagoras triplet (3,4,5) we can generate Figure 5 to construct squares on the sides of 3, 4 and 5. The construction can be done in various ways and the simpler one can be done by students using square papers. The total areas of the three squares would be easily determined to be 25 square units, that is, $3^2 + 4^2=5$

Significance of the Structure that forms the Pythagoras Triplets

The experience in the build up of the 3x3 and 4x4 structures to form the Pythagoras triplets provides students (especially those at Grade 8 aged 13 years and above) with knowledge on development of theorem concept when a 5x5 structure is formed. The development of the se-

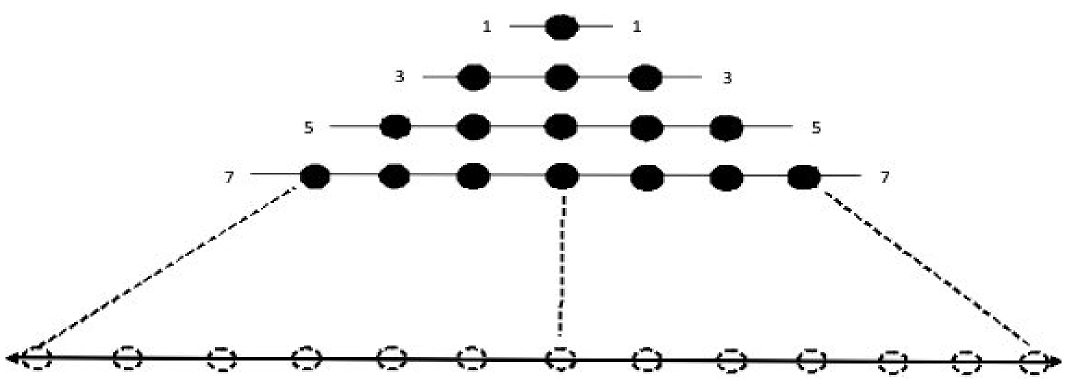


Fig. 4. Structure of the sum of odd numbers

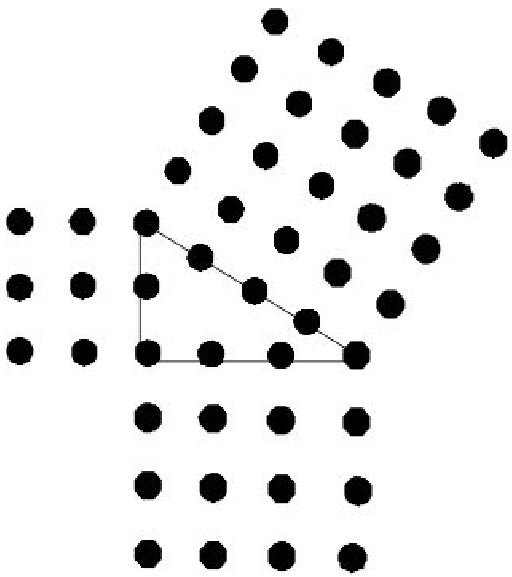


Fig. 5. Structures forming Pythagoras Theorem

quence also gives students the opportunity to determine the sum of the first three odd numbers. To achieve stipulated objectives at this level, investigation of the relationship between the sides is realized from the construction of squares on each sides of the right angled triangle and comparison of the areas formed on the three sides that proves the theorem. Students can also measure sides of different right angled triangles to establish the relationships. Students of 14 years of age and above can use the formula freely after getting knowledge from previous activity.

DISCUSSION

The activities illustrated show how the indigenous knowledge can be structured and get related to the mathematical knowledge taught in school. This knowledge, that can be derived from various forms of the Tchokwe tradition, is abundant in traditional decorations, paintings, story-telling and many others. The development of mathematical patterns to form particular sequences in natural and odd numbers, gives students the opportunity to derive knowledge from the local artifacts they are familiar with and relate these to mathematics content learnt in class. For grade 7 learners (mostly in the last year of primary school), the structures developed to establish patterns and sequences can provide them with prior knowledge before they develop more advanced knowledge of proving the formulas for determination of the sums of natural and odd numbers when they join secondary schools. The approach provided in these activities is spiral in approach, that is, the topic at each stage has pre knowledge elements of the previous activity that have connection with traditional artifacts introduced at a lower level. Thus, the introduction of the process to learn about Pythagoras theorem would not be new to students at secondary schools to develop the patterns and prove the Pythagoras formula by relating to the squares formed.

The visualization of the beauty of developed patterns in the activities illustrated, gives students an appreciation of the explorations of the cultural practices. Appreciation of the material learned stimulates interest among students to learn. This approach of teaching means students access the mathematical knowledge that exists in their traditions by reflecting on the traditional practices to learn mathematical concepts. It would not be necessary for all students to have experienced the traditional materials from their own localities to use them in learning. The approach should be to use these materials to encourage and stimulate students to explore and learn mathematical knowledge that exists in the environment related to content taught in the classroom. The process of teaching the concepts in these topics would provide students with long term retention of mathematical knowledge. Using approaches that involve exploration of indigenous mathematics tend to build *effective bridges* from the mathematical knowledge that is 'unfrozen' to *new* mathematics usually learnt in the classroom (Gay and Cole 1967).

Developed ideas in this article provide a contrasting view by Horsthemke (2004) that indigenous knowledge contained unclear conception of knowledge that could not be used in classroom instruction. The knowledge illustrated in above activities provides a framework for the construction of knowledge that will not only empower traditional communities to participate in their own educational development (Higgs 2003; Louw 2009) but also should provide a process to determine the national curriculum based on the traditional knowledge that exists in a particular country.

CONCLUSION

In this paper, the indigenous knowledge extracted from traditional artifact structures has been used to generate concepts in selected topics from the school mathematics curriculum at high school level. The illustrated structures showed the advantage of the use of traditional artifacts to develop ideas that lead to the determination of mathematical rules and principles. The procedures used can provide the opportunity for long-term retention of knowledge; contrary to the 'traditional' ways of teaching mathematics that involved remembering or following of the rules to obtain the answers. Constructing and reconstructing of the indigenous knowledge is the process to 'unfrozen' existing knowledge from the local environment that should be integrated into the mathematics school curricula. It is believed that through such procedures learners can also appreciate indigenous knowledge that exists in their traditions and develop interest in mathematics subject that is also considered by many people to be difficult.

RECOMMENDATIONS

It is recommended that (i) the exploration of the indigenous mathematical knowledge should be part of the curriculum design process and (ii) indigenous mathematical knowledge should be integrated into the school mathematics curricula for clear understanding of concepts and for long-term retention of mathematical knowledge.

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