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Formalizing Indigenous Number and Measurement Knowledge

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Abstract

This paper aims to illustrate that mathematical knowledge is embedded in languages and cultures, and that it is applied in practical ways. Similarities between number and measurement knowledge in the indigenous and Western mathematical constructs, and how these could be linked to formal mathematics teaching constitute the focus of discussions in this paper. ***Tabu***, the currency of exchange among the Tolais of East New Britain Province in Papua New Guinea (PNG), is used to illustrate some of these similarities in the use of number and measurement.

Ascher (1991; 2002) discussed the practical application of mathematical knowledge in indigenous people's lives, also pointing out the similarities between indigenous and Western mathematical knowledge. Ascher stressed that linking indigenous and formal mathematical concepts and knowledge in formal learning environments can strengthen the students' understanding of mathematical concepts. However, such knowledge links must be formalised in school curricula (Battiste, 2002) and supported by adequate teacher training (Paraide, 2014).

Constructivist theories (i.e., Piaget's) generally guide the development of school curricula which include mathematics teaching/learning strategies. These theories support using languages that students know best in formal instruction (which includes the teaching practices/learning of mathematics). They argue that people produce knowledge and create meaning based upon their lived experiences. These principles are manifested in learning theories, teaching methods, and education reforms the world over. Vygostsky (1962) and Crotty (1998) are also of the view that people generally construct knowledge and master various skills through social interactions. The constructivist theory states that, during formal learning, building on what the students already know can advance and strengthen their cognitive development.

Key words: Indigenous mathematical knowledge, Western mathematical knowledge, number, measurement, formal learning, school curriculum, learning theories, teaching strategies, ethnomathematics.

Introduction

Lean (1994) discussed Tolai counting of *tabu* (shell money) in his writings. This author builds on his discussion of *tabu* by linking it to the children's ability to associate numbers with objects as they grow cognitively in their social environment (Piaget, 1977). *Tabu* is still used by the Tolai people in their communities for purchasing goods, paying fines, and exchange of valuables during bride price and death ceremonies. Its value is still strong among the Tolai people. Wealth among the Tolai is measured by the quantity of *tabu* a person accumulates - not by the accumulation of the modern currency and Western goods alone. No other groups of people in PNG use *tabu* for such purposes. Tolai children learn mathematical concepts, such as *number* when counting coconuts (Paraide, 2008 & 2009) and *measurement* through exposure to the processing and use of *tabu* (Paraide, 2009). Ojose (2008, p 26) added to this discussion by stating that:

> Piaget's work on children's quantitative development has provided mathematics educators with crucial insights into how children learn mathematical concepts and ideas.

Teachers' possession of cultural knowledge may enhance their understanding of how students learn mathematical concepts and may encourage them to use the students' indigenous mathematical knowledge to build on when introducing learning areas in formal mathematics (Paraide, 2009).

Link to formal number and measurement curriculum

The development of school curricula is generally guided by constructivist theories which discuss how people learn and master skills. Piaget's theory is one such theory which is widely acknowledged in the field of education. This theory guides curriculum development and teaching and learning practices. The theories of constructivism generally argue that people produce knowledge and form meaning based upon their lived experiences. These standpoints inform learning theories, teaching methods, and education reforms. Other theorists, such as Vygostsky (1962) and Crotty (1998), also support this position in their discussion of the notion that people construct knowledge as they interact with and interpret their social environments and the world around them.. From this perspective, it can be stated then that the Tolai people and especially children learn and apply numbers and measurements knowledge when participating in their everyday activities and special occasions.

Therefore, from the constructivist perspective, it can be argued that there are important linkages between ethnomathematics, constructivism and situated cognition and classroom mathematics knowledge. These thoughts can be meaningfully utilised when appropriate teaching strategies are used to tap into ethnomathematics as a stepping stone to introducing /teaching similar and new formal mathematical knowledge in the classroom environment (Bishop, 2004, Matang 2009 & Matang and Owens, 2004). This approach to teaching formal mathematics is based on the commonly accepted educational assumption that learning of school mathematics is more effective and meaningful if learning is linked to familiar mathematical practices found in the learner's own socio-cultural environment (Matang, 2009). This also supports the view that learning in a language that students know best can make learning more meaningful because knowledge is embedded in their languages (Paraide, 2009, 2014). It also supports the stance on ethnomathematics, situated cognition and social constructivism which refutes the view that mathematics is free of influences from culture and its value systems (Brown, et al, 1989; Bishop, 2004). As Paraide (2008, 2009 & 2014) stated in her discussions on indigenous counting and measurement, mathematics is applied in practical ways in indigenous home environments. Additionally, as Ascher (2002) argued, mathematics is applied by various populations worldwide in many cultural activities and practices.

Formal school curriculums prescribe that formal teaching of subject content should begin with the known before moving on to the unknown knowledge. Therefore, it is generally assumed that educators teach subject content to their students by linking what they already know from their learning environments with unfamiliar subject content. This strategy is particularly important when teaching formal mathematics. Building on what the students already know develops a firmer foundation for understanding new knowledge being taught. However, Bishop (2004), Matang (2002), and Paraide (2009) found that, in practice, teaching mathematics in formal learning environments is rarely linked with the students' indigenous mathematical knowledge. D'Ambrosio (2001), Bishop (2004), Matang (2002 & 2009), and Matang and Owen (2004) observed that this has generally been largely influenced by the view that mathematics classroom practices and curriculum development activities throughout the world have been dominated by the view that mathematical knowledge is both culture- and value-free knowledge. As a result, the relevance of culture has been significantly absent from formal mathematics content and instruction. D'Ambrosio (2001) cautioned that this view of mathematics has led many students and teachers to accept without question that there is no connection between mathematics and culture which has led to the accepted view that mathematics is a-cultural, a discipline without cultural significance.

The view that mathematics is cultural and value free has also been challenged by mathematicians and mathematics educators, such as D'Ambrosio (1991); Clarkson (1992, 2006 & 2009); Clarkson & Galbraith (1992); Masingila (1993); Zavlavsky (1998); Bishop (2004); Matang (2002; 2009), and Owen (2012; 2014). They have argued that mathematics is fallible, changing, and, like any other body of knowledge, is the product of human inventiveness. Their stance is supported by Saxe (1991) and Saxe & Stigler (1996). They stressed that there is an interplay between culture and mathematical cognition. Bishop (2004), Matang & Owens (2004), and (Matang, 2009) noted that, for a long time, many researchers in mathematics education had focused their attention on the difficulties students encounter in learning school mathematics, mostly confined to the formal classroom environment. Zavlavsky (1998), Abreu, Bishop & Presmeg (2002), Bishop (2004), and Matang and Owens (2004) emphasized that, outside of the formal classroom, there also exist other educationally significant factors that have the potential to enhance effective learning of formal school mathematics. Children's indigenous mathematical knowledge, such as that of the Tolai children, can be used as a stepping stone to formal number and measurement concepts in formal instruction.

Valuing of *Tabu*

Piaget (1977) discusses children's ability to link numbers to objects as they develop cognitively when learning and exploring objects and activities in their various environments. The Tolai children are able to link numbers to objects when, for example, they are learning to count *tabu* shells while working with their parents and other adults in the processing of *tabu*. The processing and valuing of *tabu,* and its uses are discussed here to illustrate this learning process.

Valuing of *pala tabu* or individual *tabu* shells begins with five (*a ilima na pala tabu*). This is the lowest value. In the past, three ripe bananas or three betelnuts could be purchased with five *tabu* shells. The next value is ten *tabu* shells. The *tabu* shells are counted in twos and valued as fives (*a tip na ilima*) so the total *tabu* shells in each set of five is ten, as illustrated in picture 2. In the past, one bundle of peanuts (or greens, or beans) could be purchased with sets of *tip na ilima*. The next value is a *tip na laptikai* which is twelve tabu shells. In the past, sets of *tip na laptikai* could purchase a thicker bundle of peanuts, greens or beans, or three small fish. The next value is twenty *tabu* shells (*a tip na arivu*), and this is currently the accepted base value for purchasing goods, because the value of *tabu* has increased as a consequence of high demand. These small amounts of *tabu* are broken off from longer lengths of threaded *tabu* to purchase these items. The *tabu* pieces in the pictures below have been marked off in sets for purchasing purposes. Their visual appearance informs both the buyer and the seller of the quantity of goods to be purchased for the correct price. The sellers set the price for their goods. They may be *a tip na ilima*, *a tip na laptikai* or *a tip na rivu.*

Picture 1: a utula ilima na palatabu (5 x 3 = 15)

Picture 2: a utula tip na ilima (10 x 3 = 30)

Picture 3 ***a utula tip na lapikai*** (12 x 3 = 36)

Picture 4 ***a utula tip na rivu*** (20 x 3 = 60)

In the present day, almost everything that is sold begins at the value of *a tip na rivu* (twenty shells) price.

The next value is forty *tabu* shell, called *a vartuku*. Sets of forty shells are used to purchase food and other items. After the *vartuku* value, the *tabu* is valued by length. *Tabu* is strung together on thin strips of cane. The spacing between the shells adds value to the *tabu*. The *pala tabu* have to be a tip of the middle finger (1 centimetre) apart and must be evenly spaced for them to be valued as a *boina na tabu* (valuable *tabu*). The *tabu* is then measured using the arms of an adult. The different lengths of *tabu* have different values — the longer the *tabu*, the more valuable. *Tabu* is measured from the tip of an adult's middle finger to the elbow or shoulder, or chest or to the other shoulder or two adult arm lengths, and used for buying various items, depending on the price.

Picture 5. *A tura malimalikunu*

For example, *a tura malimalikunu* is a length of *tabu* measured from the finger tips to the elbow, as illustrated in the picture 5.

A viloai is a length of *tabu* measured from the finger tips to the shoulder as illustrated in Picture 6. Please note that the slackness seen in the pictures means generosity because a more than the required length is given.

Picture 6

A bongabongo is a length of *tabu* measured from the finger tips to the chest as illustrated in picture 7:

Picture 7. ***A bongabongo***

A leke is a length of *tabu* measured from the finger tips to the other shoulder as illustrated in Picture 8:

Picture 8. ***A leke***

A pokono or *tikana pokono* is a length of tabu equivalent to an adult's two-arm lengths as illustrated in picture 9. This measurement is a bit more than a fathom

Picture 9

Picture 10

A pokono or tikana pokono

A *vinunu na poko* is a length of tabu equivalent to an adult's two- arm lengths x 10 x 1 which is called *a rivu*, as illustrated in picture 11. This is a measurement of a bit over 10 fathoms. *Aura rivu* is a measurement which is a bit over twenty fathoms, as illustrated in picture 12.

Picture 11. Tikana arivu/arivu (10 x 1)

Picture 12. Aura rivu (10 x 2)

Tikana mari na poko is a length of *tabu* equivalent to two adult arm lengths x 10 x 10 which is called *a mari* or *tikana mari* a measurement of a bit more than 100 fathoms. The picture 13 shows three lots *a mari* -10 x 10 x 3- a measurement of a bit more than 300 fathoms. This amount of *tabu* was used to pay bride price witnessed during one of my research field trips for this study. In this particular case, the *tabu* exchange was expensive, according to 'normal' standards in this particular community. Bride price, a few years ago, only cost *tikana mari* (a bit more than 100 fathoms). I was astounded by how expensive the bride was in this particular case. I learned during the ceremony that the bride's family demanded this amount. A lower price had previously been set, but that decision was overturned during later negotiations. This caused some conflict during the ceremony, but the groom's family took up this challenge to show off their wealth, which is 'normal' in such ceremonies. A show of wealth and the strength of a particular clan are displayed through 'quantity' and 'quality' of bananas, taro, pigs and *tabu*. The quality of *tabu* in the picture is 'good,' according to the experts in *tabu* processing.

Picture 13. ***A utula mari*** **(10 x 10 x 3)**

Picture 14. ***A ura loloi (*****two rings of *tabu*)**

Picture 14 shows the *tabu* like that paid for the bride price in Picture 13 but rolled into rings (*loloi)*. The two *loloi* in the picture have different values. The smaller one contains *a mari na tabu* (10x10x1), and the larger one of two *tabu* rings contains *aura mari na tabu* (10x10x2). *Tabu* is done up this way, so that it is put away (like banking) and won't be used until it is needed. This *tabu* is not accessible for everyday purchasing of goods, paying fines or other expenses. Other *tabu* has got to be made for that purpose. The loloi are usually undone during the owners' or clan leaders' death ceremonies to be distributed to the people, while some are displayed during death ceremonies to show the wealth status of the deceased or the wealth of the deceased's clan. Wealth is measured by the number and size of *loloi*. Wealthy people and clans own thicker and heavier *loloi*, as there are more *tabu* in them. The heaviest and thickest *loloi* is *a ilima na mari* which is equivalent to an adult's two arm lengths (10 x 10 x 5). This is called *a tutunana* (meaning, *man*).

Trading in *tabu* is still very much a part of the Tolai peoples' lives today. The Tolais have to make *tabu* for future spending, such as bride price payments, distribution during death ceremonies, paying for fines, manual labour and traditional doctors' fee. The *tabu* made from trading are pulled out of the bits of cane, rethreaded, and then kept for future spending. The cane strips prepared for threading the *tabu* are measured out in *tura* *malimalikunu* (measured from the fingertip to the elbow). Four of these are joined together to make a *pokono*. When the *tabu* reaches *a mari,* then they are shaped into giant wheel-shapes, wrapped in special leaves and kept for future use. Some people wait until they make one *a tutunana* before the *tabu* are wrapped. The *tabu* rings called *loloi* are displayed during death ceremonies and *tubutubuani* to show an individual's or a clan's wealth. Some of these *loloi* are unwrapped and distributed to the people during *kututabu* (death ceremonies). The deceased's children and relatives inherit some of these *loloi,* if it is the wish of the deceased. The non-Tolais who are aware of the value of *tabu* shells, sell *tabu* shells in 380 gram cylinder-shaped tins for K15.00 to K20.00 to the Tolai people. Currently, there is trading of *tabu* between the Solomon Islands and the Tolais in Papua New Guinea. The author has bought *tabu* from the Solomon Islands, as the *tabu* shells from there are of better quality than those harvested in Papua New Guinea waters.

In current times, imported and local goods are also sold to Tolais for *tabu* in Tolai communities. If the *tabu* are threaded too far apart, or are unevenly spaced, then the *tabu* usually loses in value or is even rejected. People in the communities will avoid trading with people who do not thread their *tabu* well. The use of *tabu* as currency is restricted to trading among the Tolai people. The Papua New Guinea currency is used when trading with other Papua New Guineans, as they do not value *tabu*.

The type of counting and valuing of *tabu* is unique and used exclusively for this currency. The application of multiplication and division, addition and subtraction concepts is used during the processing and use of *tabu*, just like in the case of modern currencies. For example, five shells, then ten shells, then twelve shells, then twenty shells, then forty shells and then *tabu* measured by length, as the value increases after forty shells. Five shells, ten shells and twelve shells are no longer used, just like in many world currencies, including PGK, the lower denomination coins (one and two cents /pennies or *toeas*) have been phased out.

Implications for mathematics education

The discussion of *tabu* and ethnomathematics reinforces theories of cognition and social constructivism which have implications for mathematics education. These theories support the world view that knowledge is socially constructed by individuals through social interactions with their environment, and that learning through interaction with everyday activities strengthens and emphasises the meaning of concepts that are being learnt in the formal classroom environment. The absolutist stance, on the other hand, claims that mathematical knowledge is value-free (Ernest, 1991); this belief has dominated current mathematics classroom practices which disregard the rich everyday out-of-school mathematics that school children bring into the formal mathematics classroom. The students' practical mathematical knowledge can, and should be tapped into, to strengthen their understanding of complex mathematical concepts. The ‘absolutist’ practices fail to acknowledge the social aspects of mathematics that have provided the necessary motivation for the development of academic mathematics throughout human history (D’Ambrosio, 2001; Eglash, 1997; Masingila, 1993, Ojose, 2008; Matang, 2009 and Rauff, 2003). They also undermine the students’ natural ability to make important mathematical connections between the school mathematics and their everyday practical use of mathematical concepts. This disconnect between the students’ practical experiences and formal instruction can hinder their understanding and appreciation of the power of mathematics (Bishop, 2004; D’Ambrosio, 2001 and Eglash, 1997). The benefits of integrating indigenous and classroom mathematics were evident in teaching grade 3 children the concept of multiplication (Paraide 2009). When the concept of multiplication was linked to how they count in sets of numbers in their home environment, the children found it easier to understand that multiplication adds *groups* (sets) of numbers. It was found that these children, in their home environments, routinely organized coconuts in sets of 12, and counted *tabu* in sets of 12 (*a tip na laptilai*). So when the problems 12 x 12 and 12 x 14 were presented in the classroom environment, it was emphasized that x 12 is similar to grouping coconuts and to valuing *a tip na laptikai*. It was found that the children used this information to group twelve sets of twelve stones first to get the answer 144. Then they added two more sets of twelve stones to the twelve sets that they had grouped earlier to solve the problem 12 x 14 = 168. One of the children in this particular group also disputed the written answer for one problem which was written 9 x 6 = 56 on the board. The other children agreed with her. When she was asked to justify why she believed that the answer was not correct, she and the other children pointed out their nine sets of sixes, and counted them out to show that the answer should be 54 and not 56. This group of children also counted items in sixes when harvesting taro and grouping coconuts. This demonstrates that the children understood well the concept of counting in sets. It also illustrates that the children relied on what they already knew to answer the multiplication problems in this particular case. They were actually thinking through the process of counting in sets when they were working out the answers to the problems. All discussions about the problems in this particular case were in the children’s first language, not English. This signifies the fact that the use of the children’s first language and the use of indigenous mathematical knowledge as a stepping stone to teach formal multiplication enhanced the children’s cognitive development. The children’s other indigenous knowledge such as trade, medicine, agriculture, technology, conservation, plant, birds, fish and other animal habitats and communication can also be linked to formal subjects, using similar teaching strategies as those used in this particular case.

If mathematics, as an important cultural tool, is to have a greater impact on the future survival of any particular society, especially for ‘today’s children, living in a civilization that is dominated by mathematically based technology and unprecedented means of communication' (D'Ambrosio, 2001, p.308), then the idea of integrating and incorporating the kind of mathematics that is used by the students in their homes and cultural environments into the formal mathematics school curriculum must be taken into serious consideration. There is now more literature written on the advantages of integrating ethnomathematics into the formal mathematics curriculum, and on the disadvantages of current mathematics classroom practices (Abreu, 1995; Abreu, & Cline, 1998; Abreu, Bishop, & Presmeg, 2002; Bishop, 2004; Brewer and Daane, 2002; Clarkson, 1992, 2006 & 2009; D'Ambrosio, 2001; Eglash, 1997; Masingila, 1993, Ojose, 2008; Rosa & Orey, 2011; Owens, 2012 & 2014, Saxe,. 1991; Saxe & Stigler,1996 and Zavlavsky, 1998). As these authors emphasise, using background information on students' ethnomathematical knowledge in the classroom can enhance formal school systems worldwide. This strategy helps students make sense of abstract mathematical concepts through association with familiar to them practical mathematical tasks, thus preparing them for functioning well in our increasingly complex and technologically-oriented society. This teaching strategy enables the younger generations to appreciate the significance and relevance of their indigenous knowledge in their present and future life.

Establishing support for using ethnomathematics as a stepping stone to build on, when teaching formal mathematics, can only be achieved through sound awareness of the merits of this strategy amongst the general public and politicians. Most importantly, the successful implementation of this strategy is dependent on the political will to invest in the production of necessary resources required in order to develop a culturally relevant and inclusive mathematics curriculum (Matang, 2002 & 2009 & Matang & Owens, 2004). A growing consensus of expert opinion increasingly calls for the development of culturally relevant mathematics curriculum and appropriate teacher training programs, in order to enable teachers to use their students' enthnomathematics as a stepping stone, thus enhancing their students' understanding and application of advanced mathematical concepts (Matang, 2002 & 2009; Matang & Owens, 2004 and Paraide, 2009). It should also be stressed that the inclusion of the integration of enthomathematics and formal mathematics in the teachers' colleges' curriculum, sound professional training and preparation for current teachers in the field to teach such mathematics curriculum, continuous professional support for teachers in the field and regular monitoring of its implementation can enhance the successful implementation of any new curriculum (Paraide, 2014).

Conclusion

Number and measurement knowledge is used during the processing and use of *tabu* in the Tolai communities. While number and measurement knowledge may be the same universally, their application in various groups of people's lives may be different.

However, they can be used as a stepping stone when teaching the formal concepts of number and measurement.

The use of number and measurement in the processing of *tabu* is an example of ethnomathematics. Ethnomathematics can be used to bridge home practices with classroom instruction. This approach rests on the constructivist theories, which are widely acknowledged and accepted in the education field. Therefore, to apply the constructivist theories in a Papua New Guinea situation, the processing of *tabu,* a form of currency still used by the Tolai people of East New Britain Province, can be used as a stepping stone to build on in teaching the number and measurement concepts in schools that are located in Tolai communities. Also, the use of *tabu* (for trading, bride price and fine payments, and *tabu* distribution to the people during death ceremonies) is similar to how other currencies are used. Therefore, the *tabu* concept can (and should) be used in formal mathematics instruction in Tolai community schools, with the aim of linking traditional trading practices with modern reality.

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