Rich Transitions from indigenous counting systems to English arithmetic strategies: *Implications for Mathematics Education in Papua New Guinea*

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ABSTRACT: In the context of current curriculum reform being implemented in the primary and secondary education sectors of the national education system of Papua New Guinea (PNG), this paper explores the possibility of utilizing and building on the rich cultural knowledge of counting and arithmetic strategies embedded in the country's 800-plus traditional counting systems. This is based on the commonly accepted educational assumption that learning of mathematics is more effective and meaningful if it begins from the more familiar mathematical practices found in the learner's own socio-cultural environment. Based on the basic number structures and operative patterns of the respective counting systems from selected language groups, the paper briefly describe how the rich diversity among these language groups can be used as the basis to teach basic English arithmetic strategies in both elementary and lower primary schools in Papua New Guinea.

Introduction

It is probably true to say that there is no country on earth having a staggering cultural diversity like Papua New Guinea (PNG), a nation with well over 800 distinct known languages. Politically, such diversity is a good catalyst for fragmentation of any nation, but after almost three decades of nationhood since September 1975, its citizens are proudly accepting such diversity as the strength upon which to build the future of their nation's political, economic and social systems (Clarkson & Kaleva, 1993; Kaleva, 1992; Matang, 1996). The current education reform being implemented in the country is a significant testimonial to the above belief and is mainly aimed at not only increasing accessibility to education services but also advocates a reform in the nationally prescribed school curriculum. Though such diversity may seem problematic in other areas

of government, the need to develop a national education system that is both culturally relevant and inclusive reflecting the strength of its cultural diversity in its national curriculum, were factors that were considered much more fundamental and important. Subsequently, it is these principles that have formed the basis of the current education reform being implemented in PNG (Dept of Education, 2002; 2003). Moreover for almost three decades of nationhood, education has always been seen by both past and present leaders at different levels of government to be the single most important binding factor in maintaining national unity, an achievement not many other countries having similar cultural diversity have been able to do. It is with such background in mind that this discussion paper looks at the possibility of utilizing the rich cultural knowledge of mathematics or ethnomathematics in PNG as a means of bridging the gap between what school children already know about mathematics from their cultures and school mathematics. It is also a move taken to preserve the diversity of rich cultural knowledge, not only of mathematics, but also those indigenous knowledge systems that relate to other prescribed school subjects, much of which are orally kept and are fast disappearing (Kaleva, 1992; Lean, 1992; Matang, 2002).

From hindsight, if there is to be any school subject that is the last to talk about culture and its value systems, it has to be mathematics, particularly in the light of the current dominant view of the subject as being both *culture-* and *value-free* (Bishop, 1991; Ernest, 1991). Hence, the above dominant view has had greater negative educational impact on both the mathematics instruction in schools and the learning of school mathematics by school children in PNG. Given the country's staggering cultural diversity of 800-plus languages where both the mathematics teachers and the school students have very strong cultural ties with the value systems of their respective cultural groups, mathematics education

in PNG has never been easy. In fact almost all national teachers who currently teach mathematics in the National Education System (NES) have been trained under the educational assumptions of the current dominant view where mathematics is seen as being independent of any cultural values, practices and its knowledge-base systems. The situation is no different for PNG school children, because much of the teaching of school mathematics does not take into account the rich mathematical experiences that school children bring into every mathematics classrooms. Hence, almost all PNG school students come to view school mathematics as being of no relevance to what they do to survive in their everyday life within their respective communities, further increasing the mathematics learning difficulties in schools (Bishop, 1991a; D'Ambrosio, 1991; Masingila, 1993; Matang, 1996; 2002). The struggling experiences that every school child goes through in learning school mathematics are best described by Bishop (1991b, p. *xi*) that,

> Mathematics is in the unenviable position of being simultaneously one of the most important school subjects for today's children to study and one of the least well understood. Its reputation is awe-inspiring. Everybody knows how important it is and everybody knows that they have to study it. But few people feel comfortable with it; so much so that it is socially quite acceptable in many countries to confess ignorance about it, to brag about one's competence at doing it, and even to claim that one is mathophobic!

Given the above situation, many research articles in both ethnomathematics and mathematics education (e.g. Masingila, 1993; Bishop, 1991a; 1991b; D'Ambrosio, 1990; 1991; Matang, 1996; Saxe, 1985) have identified *culture, language* and *learning modality* as the three most significant factors responsible for learning difficulties in school mathematics. Hence, this discussion paper aims to address the impact of the above three factors not as separate contributing factors to

mathematics learning difficulties in schools, but to address them as relative factors. With such background in mind, the paper will specifically discuss how mathematically rich and meaningful counting structures embedded in almost all PNG traditional counting systems can be used to build on and link the teaching of formal English arithmetic strategies under the following sub-headings.

i. The diversity of PNG counting systems and its link to English arithmetic strategies.
ii. Implications for Mathematics Education.

The diversity among different PNG counting systems and their link to English arithmetic strategies

Like many other cultures around the world, the concept of number and its applications to all aspects of everyday life by members of a particular language group in PNG is rarely seen to be conducted in total isolation to every day cultural activities such as fishing, hunting, exchange ceremonies, etc. In essence, the development and use of some form of numeration system by any cultural group in PNG, irrespective of its primitiveness, is as old as the historical life of the cultural group itself. (Boyer, 1944; Lean, 1992; Smith, 1980). It is also important for the reader to take note that, like any spoken language which is not static, the fluidity in modifying the numeration system by the respective cultural groups to accommodate change in a cash economy like PNG (see Saxe & Esmonde 2001; Saxe, 1985; 1982a; 1982b) further gives rise to even greater diversity among these language groups and their respective counting systems.

Given the above background, the nature of diversity that exists between the different PNG traditional counting systems is by no means any different to the cultural diversity that exists between the 800-plus

languages of PNG. Hence, the selected counting systems shown in Table 1 below gives the reader a very brief run down of the nature and the extent to which these diversities exist between different counting systems in terms of both the *frame words* used in constructing other numbers, and the *operative patterns* like 6 being *5+1* and 12 being *2 fives plus two* (Lean, 1992). The selected counting systems were chosen not only because they represent a range of commonly used counting systems in PNG, but also because they possess many important features of the majority of these counting systems by linking them meaningfully to the teaching and learning of English arithmetic strategies in schools. Though the majority of PNG counting systems have an operation pattern that is based on what Lean (1992) describes as digit-tally system (see Kate and Gahuku in Table 1), there are also other types of counting systems (e.g. Oksapmin) that are classified as body-part tally-system (see Saxe, 1981).

Language Name	Counting System Features	Special features (Operative pattern) linking each system to English Arithmetic Strategies
Roro	10, 100 cycle system	Frame pattern: 1 to 5, 10, (40), 100 Operative pattern: 6=3x2, 7=3x2+1, 9=4x2+1, 12=1 ten + 2
Buin, Uisai	Cycle of 10, 100	7 is 3 before 10, 8 is 2 before 10, 9 is 1 before 10
Lindrou (Manus)	10, 100, 1000 cycle system	Frame pattern: 1 to 6, 10, 100, 1000 7=10-3, 8=10-2
Kate	2, 5, 20 cycle digit tally system	Frame pattern: 1, 2, 5, 20 Operative pattern: 3=2+1, 7=5+2, 8=5+2+1, 12=5+5+2, or 15=5+5+5=3x5
Gahuku (Goroka)	2, 5, 20 cycle system	Frame pattern: 1,2 Operative pattern: 3=2+1, 6 to 9 = 5+n
Hagen (Medlpa)	2, 4, 8, 10 or 2, 4, 5, 8 cycle system	Frame pattern: 1, 2, 3, 8, 10; 1, 2, 3, 5, 8 Operative pattern: 5 to 7=4+n, 6=5+1 or 4+2 or 4+3

Table 1 – Selected languages and structures of their counting systems

From Table 1 above, it is not difficult to identify the meaningful linkage that exists between the English arithmetic strategies taught in schools and the operative patterns of the respective counting systems as highlighted by the selected counting systems. For example, the operative pattern in Roro counting system for 7 is 3x2+1, in Buin counting system, 7 is 3 before 10, and in Kate counting system (the first author's counting system), 7 is same as 5+2. All these examples while equally correct in expressing 7, they are significant from the teaching point of view. Unlike the current English (Hindu-Arabic) counting system used in schools, these counting systems also provide the extra information on the relative number sequences in terms of their order of occurrences (Wright 1991a; 1991b). For example, 5, 6, 7, 8 in Kate is *memoc, memoc-o-moc, memoc-o-jajahec, memoc-o-jahec-o-moc* with morphemes that can assist children in easily remembering the order of numbers. This is because each Kate number word has meaningful linkage with their respective operative patterns of 5=5, 6=5+1, 7=5+2, and 8=5+2+1, an arithmetic strategy that is also important in addition of numbers as shown in Table 2 below).

The basic ideas of numeracy as embedded in the operative structures of each counting system can be extended further to cover other number concepts such as subtraction and counting in decades. For example, Buin and Lindrou languages in Table 1 have 7 as 3 before 10 and 10-3 or 8 as 2 before 10 and 10-2 using *ten* as the basis for counting numbers. In addition, this also helps with the representation of numbers and their relative positions on the real number line such as the one provided by the counting system of Buin (Uisai) language of Bougainville. It should be noted that, the ability of both the teacher and students to make mathematical inferences from basic number concepts such as those found in the respective counting systems in PNG is really the essence of what

mathematics is all about. Hence, it only requires the teacher to recognize and take advantage of the children's very own traditional counting systems because they provide meaningful link between the basic concept of counting and the respective counting strategies as represented by the number words. As indicated in Table 2 below, these are important number properties, features that are necessary for an effective learning of English arithmetic strategies.

The Roro counting system according to Lean (1992) is a Motu-type Austronesian Counting System where counting in twos is a common feature of quantifying items during important ceremonies. Moreover since the Roro Counting System, like Buin and Lindrou (Manus), is a 10-cycle system, it is not difficult for children to develop formation of decades with the assistance of a teacher because of the similarities it shares with English counting systems. The multiplication of *one-* and *two-digit* numbers in Roro counting system makes it easy for children to relate multiplication in English counting systems because the construction of large numbers in Roro is dependent upon its operative pattern that utilizes the idea of multiplication by 2 and of decades.

On the other hand the counting system from the first author's language namely, the Kate language, is an example of a Non-Austronesian digit-tally system that has 2 as the primary cycle, 5 which is *one hand* as the secondary cycle, and 20 which is same as *one man* as the tertiary cycle (Smith, 1980; 1988; Lean, 1992). Hence as shown in Table 2, the use of numbers 1, 2, 5 and 20 as frame pattern numbers by school children during the addition of *one-* and *two-digit* numbers in Kate counting system is not only seen to be efficient but also very meaningful. This is because the spoken number words for large numbers not only enable children to establish meaningful relationships among individual numbers in terms of their uniqueness, but more importantly they reinforce the

concept of addition as the *sum* of either two, three, or all four frame pattern numbers namely, 1, 2, 5, and 20.

English Numeral	Spoken KATE Number Words	Operative Pattern		Spoken RORO Number Words	Operative Pattern
4	jahec-o-jahec	2+2		bani	4
6	me-moc-o-moc	5+1		aba-ihau	2x3
7	me-moc-o -jajahec	5+2		aba-ihau hamomo	6+1 or 2x3+1
8	me-moc-o-jahec-o- moc	5+2+1		aba-bani	2x4
15	me-jajahec-o-me-moc me-jajahec-o-kike-moc	5+5+5 or 10+5		harauhaea ima	10+5
26	ngic-moc-o-me-moc-o-moc	20+5+1		harau rua abaihau	(10x2)+6
Note: In Kate, *moc* = one, *jajahec* = two, *me-moc* = five (hand), *ngic-moc* = 20 (one man)					

Table 2 – Spoken number words and Operative patterns for Kate and Roro counting systems

For example, the spoken Kate number word for numeral 8 is *memoc-o-jahec-o-moc* which in English translation means *one-hand plus fingers-two-and-one,* which is further more equivalent to the English operative pattern of *5+2+1*. Like many digit-tally counting systems in PNG, the use of frame pattern numbers 1, 2, 5 and 20 in Kate to construct larger numbers is a useful mental strategy for formal English arithmetic strategies taught in schools. It is also important to note that the visible absence of important operational and structural features in the English counting system makes learning even more difficult for a 4- or a 5-year old Papua New Guinean child enrolled for the first time in Elementary school learning to count in English, given that it is not their own mother tongue.

The above view is supported by the preliminary data from the first author's research conducted early this year (2004) assessing the early number knowledge of 5- to 6-year old elementary school children

learning to count and perform simple addition and subtraction tasks in the local vernacular of Kate language. The preliminary data analysis indicates that when children were given the choice to give their answers either in Kate followed by English or vice versa on three counting tasks involving the actual counting and summing up of two groups of concrete objects, 100% of the children got both answers correct in Kate and English. On mental addition tasks involving use of concrete objects (e.g. 7+3), 73% of the children got their answers correct in both Kate and English. Although further research is required to determine the extent of the impact of learning to count in Kate language on English arithmetic strategies, the current preliminary data somewhat suggest that counting in local vernacular is an advantage as indicated by the high performance rate of children on different early number assessment tasks. One of the notable advantages observed by the first author during the research is the children's ability to quickly switch between English and Kate counting systems when responding to questions on simple addition and subtraction tasks. This observation indicates that children would generally resort to using either of the two counting systems that they found easier to use in comprehending and computing numerical tasks. Hence this observation further supports the aims and rationale for the current education reform in PNG that strongly encourages the use of Indigenous knowledge systems to teach mathematics in schools.

Implications for Mathematics Education

The acceptance and acknowledgment of the use of children's very own out-of-school mathematical experiences by teachers in teaching school mathematics has implications for both the mathematics curriculum and the way mathematics is taught in schools.

In terms of the implication for mathematics curriculum in PNG, it is pleasing to note that the current education reform which is also aimed at curriculum reform in all nationally prescribed school subjects, has at least taken the first important step in encouraging the use of various local vernaculars as medium of instruction during the first three years of elementary school. As a consequence, there are strong indications suggesting a move towards the teaching of mathematics that takes account of the country's rich cultural knowledge of mathematics with a number of teachers' guides and syllabuses already written and produced for distribution to elementary and primary schools in PNG. In a move aimed at ensuring a culturally relevant and inclusive mathematics curriculum, the current reform encourages greater freedom and flexibility among elementary school teachers to explore the everyday use of mathematics outside of the formal classroom as the basis to teach school mathematics. This is an encouraging development because it enables the school children to relate school mathematics to everyday experiences thus portraying mathematics as a user-friendly subject.

One of the significant stumbling blocks to successful implementation of any curriculum reform in PNG in the past has been the reluctance of teachers to accept new changes. According to Clarkson and Kaleva (1993) the reasons for much of these failures were mainly due to an unwillingness by many experienced teachers to change their ways of presenting mathematics lessons particularly when these classroom practices have become so routine for many of them. However in the interest of meaningful learning of school mathematics by students, it is suggested that public lectures and seminars be organised by Curriculum Development Division to educate parents and teachers on the aims of the curriculum reform. This is because at the end of the day it is the teacher's action or inaction in implementing any curriculum reform will determine

the success and failure of any curriculum implementation process. Hence, the ability of an individual teacher to successfully implement any curriculum reform will depend on (a) the role of the teacher under the new curriculum reform process, (b) teacher beliefs and values about the new curriculum reform and (c) teacher background knowledge in mathematics (Matang, 1996). In other words, if teachers are to effectively utilize students' mathematical experiences gained from everyday encounters as the basis to teach school mathematics as proposed by this discussion paper, then they need to be made aware of their expected new role under the reform. In the context of what is proposed here, the role of the mathematics teacher will basically involve changing one's view from being an *authority* and *transmitter* of mathematical knowledge to that of a *facilitator* of the teaching-learning process (Matang, 1996; 1998). Secondly, if a teacher beliefs and values are not in line with the rationale for curriculum change then it can become a barrier to effective implementation process. Finally, in order for the teacher to fully execute his/her duties effectively, it requires a proper training program that gives opportunity for them to do an in-depth investigative study of the mathematics content knowledge. This is necessary to give them confidence to approach the teaching of mathematics in the immediate cultural context of school children as envisaged by this discussion paper.

Within the context of the actual classroom situation, it is envisaged that the culturally relevant curriculum will promote the role of students as equal partners of the teaching-learning process where they are encouraged to be active participants of information-sharing process rather than passive recipients of information transmission process. On the whole what is expected of a teacher to do under this approach is to firstly acknowledge school children as not empty cups that need to be filled up, but are unique social beings with the ability to think for themselves.

Hence it is the responsibility of the teacher to create a learning environment that promotes meaningful and interactive mathematical discussions not only between teacher and students, but also between the students themselves. A useful linkage established by the teacher between children's very own mathematical experiences and the formal mathematics classroom promotes self-esteem and ownership of the knowledge by students thus giving them that extra reason to learn school mathematics. This can be achieved by encouraging the children to describe the use of school mathematics in community-related activities such as the use of the traditional counting systems in important cultural ceremonies and other everyday community activities. This includes having the children telling the rest of the class mathematically related family stories or identifying the different types of mathematical ideas being used in pictures cut from newspapers or drawn by the teacher and children themselves (Masingila, 1993; Matang, 2002; 2003; Owens, 2002; Owens & Matang, 2003).

Conclusion

It is obvious from above discussions that one of the significant ways to reduce mathematics learning difficulties among school students is to develop the mathematics curriculum that takes into account the rich out-of-school mathematical experiences that children bring into the formal classroom. The use of traditional counting systems in teaching the formal English arithmetic strategies in schools is one such example that provide meaningful and relevant learning experience for school children at the same time bridging the knowledge gap between school mathematics and the existing Indigenous knowledge-base systems found in the respective cultures. The current reform in nationally prescribed school curriculum strongly encourages the use of Indigenous knowledge-base systems in

teaching respective school subjects. This approach would undoubtedly require the teacher to readjust his/her approach to mathematics teaching to accommodate out-of-school mathematical experiences of their students as means to not only ensuring mathematics learning is meaningful but also enabling students to relate what they learn in school into their everyday encounters in life making mathematics to be both culturally relevant and inclusive.

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