Enhancing the learning of formal English and Arithmetic strategies by Elementary school children through Indigenous Counting Systems of Papua New Guinea: *The Case of Kâte Counting System of Morobe Province*

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In the context of the current education reform which strongly encourages use of Indigenous knowledge-based systems and local vernaculars in teaching various school subjects in elementary and primary schools in Papua New Guinea, the research reported here is the first of an on-going longitudinal research project carried out to determine the long-term effects of teaching early arithmetic strategies embedded in the Kâte numeration system in Kâte language on mathematical achievement of elementary school children in the later years of their formal education. The sample consisted of 52 elementary school children, aged between 8 and 10 years attending Elementary 1 class from 3 different elementary schools located in the Kâte-speaking language area of Finschhafen District in Morobe Province, Papua New Guinea. The data on elementary school children's individual performances on 7 different arithmetic strategies were obtained via an individual-task-based interview. Contrary to the negative views held by many parents in Papua New Guinea on the use of various local vernaculars in teaching the prescribed school subjects, the results show that the use of counting and arithmetic strategies embedded in children's own traditional counting system using their own language is an added advantage in their learning of formal English arithmetic strategies normally taught in schools. In particular the results show that those children taught in the Kâte language performed better on 5 out of the 7 formal arithmetical tasks compared to those children who were mainly taught in Tok-Pisin and some English without the aid of the Kâte counting system.

Introduction

Most of the past and present mathematics curriculum for the primary-aged school children in Papua New Guinea (PNG) has been developed based on an analysis of the steps provided by the structure of mathematics that has its roots in Western cognitive psychology (Park, 2000; Saxe, 1982; 1983; Souviney, 1983) hence were interpreted according to Western, mainly Australian curriculum models (Bishop, 1991a; 1991b; Matang, 1996).

Recent developments in mathematics curriculum reform have however emphasised more the role of children's thinking in their learning of school mathematics thus advocating a mathematics curriculum that takes into account children's own development of number concepts based on a Social Constructivist Theory of Learning (Berk, 1994; Lerman, 1989; Wheatley, 1991). While many of these curriculum reforms were aimed at pursuing improvements to both teaching and learning of mathematics in schools, they have so often ignored the socio-cultural aspects of mathematics education. These concerns have been raised by a number of mathematics educators (e.g. Bishop, 2004; 1991b; Brown, Collins, & Duguid, 1989; D'Ambrosio, 1991; Matang, 1996) highlighting the urgent need to accommodate the educational needs of those children whose home and family cultures do not fully resemble the culture of the formal "western-style" education system as means to improving their learning difficulties and continued interest in school mathematics (Bishop, 2004; Matang & Owens, 2004; Seah & Bishop, 2001;).

In the context of mathematics teaching, there has been very little research carried out on the impact of cultural knowledge of mathematics on the teaching and learning of school mathematics in PNG since the early research work carried out on culture, language and mathematics (Clarkson, 1992; Lancy, 1983; Lean, Clements & Del Campo, 1990; Saxe, 1981; 1982; 1985; Souviney, 1983). While 600 out of a possible 800-plus traditional numeration systems of PNG have been recorded (Lean, 1992; Smith, 1980; 1981) including the publication of elementary and primary curriculum emphasising cultural mathematics (PNGDE, 2002; 2003a), only Paraide's (2002) research has attempted an evaluation of the Lower Primary Learning outcomes under the new curriculum reform. Hence the research reported here is motivated by the urgent need to continue the early research work in ethnomathematics (Bishop, 2004; 1991a; D'Ambrosio, 1991; 1990) and to conduct further research on its impact on the learning of school mathematics, hence it is highly significant in terms of both the implementation of the current education reform and the development of culturally relevant mathematics curriculum in Papua New Guinea (Matang, 1996; 2002; Matang & Owens, 2004; PNGDE, 2002; 2003a). While such a policy move is timely and is supported by a number of research literatures in mathematics education (e.g. Berk, 1994; Bishop, 1991a; 1991b; D'Ambrosio, 1991), many parents in Papua New Guinea on the other hand have displayed strong reservations even expressing negative views on the use of various local vernaculars in elementary schools claiming that it is one of the main factors responsible for lowering the standard of education in PNG.

Hence in order to address the above claim by parents, the research reported here was purposely conducted to answer the main research question, "Is the use of both the Kâte Language and Its Counting System in teaching early number knowledge enhance the learning of formal English arithmetic strategies normally taught in schools?" The analysed research data will also be used to address other pedagogical issues related to children's difficulties in learning school mathematics and assist the efforts of all important stakeholders in developing appropriate mathematics curriculum and teaching materials that are both culturally relevant and inclusive.

Linking the Kâte Counting System and the Teaching of Early Number Strategies

According to Lean (1992), the Kâte language is a Papuan or Non-Austronesian (NAN) language which has achieved considerable prominence in Morobe Province as a lingua franca used by the Lutheran Mission to carry out its Mission work extending as far as the five highlands provinces of Eastern Highlands, Simbu, Western Highlands, Enga and Southern Highlands, and part of Madang Province. While the language is now spoken mostly by the older generation throughout the Morobe Province, the home of the Kâte language is comprised of 8 core-Kâte villages surrounding the current Sattelberg Lutheran Mission station in Finschhafen District of Morobe Province. The earliest studies of the Kâte language were by Flierl (1895) and Keysser (1925) who was the author of the first Kâte-German-English Dictionary which was extensively revised to produce the first Kâte-English Dictionary in 1977 (Flierl & Strauss, 1977). Along with other Non-Austronesian languages of PNG, the Kâte language is now thought to be at least 20,000 years old (Lean, 1992). Hence being a lingua franca of the Lutheran Mission, conducting formal classes in the Kâte language is not a new experience for the Kâte people, because it all began about 119 years ago when the first Lutheran Missionary ,Reverend John Flierl landed at Simbang village on July 12, 1886 in Finschhafen District of Morobe Province.

Professor Edward Tylor of the University of Oxford wrote in 1871 that the practice of counting on fingers and toes lies at the foundation of our arithmetical science (in Lean, 1992). Accordingly, the Kâte counting system is classified as a digit-tally system (Lean, 1992) such that its counting structure includes the use of the counting words for hands and feet, and both fingers and toes to symbolise the counting words physically. Thus, the overall structure of the Kâte counting system is a combination of the variants of both the "pair system" and the "quinary vigesimal" system. It is made up of the frame pattern numerals (1,2,5,20) and cyclic pattern (2,5,20) having 2 as its primary cycle, 5 the secondary cycle and 20 a tertiary cycle (Schmidt in Lean, 1992). Hence an analysis of the Kâte counting number words (see Table 1) reveals that each number word is a compound of either 2 or 3 single number words chosen from the set of frame pattern number words for 1, 2, 5, and 20 so that for example, 3 is a compound of equivalent Kâte number words for "two" and "one", 8 is a compound of "five", "two" and "one", 24 is a compound of "twenty", "two" and "two" and so on. Hence when this number combination principle is used, the resulting operative patterns in Kâte are illustrated by 3=2+1, 8=5+(2+1), 24=20+(2+2) and so on.

Table 1
Relationship between English (Hindu-Arabic) and Kâte Numeration Systems

English numeral in figures	English number word	Equivalent Kâte number word	Kâte operative pattern for each counting number words
1	One	moc	1
2	Two	jajahec	2
3	Three	Jahec-â-moc	3=2+1
4	Four	Jahec-â-jahec	4=2+2
5	Five	Me-moc	5
8	Eight	Me-moc â jahec-â-moc	8=5+(2+1)
15	Fifteen	Me-jajahec â kike-moc	15=10+5 or 15=5+5+5
20	Twenty	Ŋic-moc (ngi moc)	20 (or 20=4x5)
23	Twenty-three	Ŋic-moc â jahec-â-moc	23=20 +(2+1)

It is important to note that unlike the disjoint nature of the individual number relationships found within the English (Hindu-Arabic) numeration system, the counting structure of the Kâte numeration system is such that the use of each Kâte number word automatically provides the important number relationships between the individual counting numbers in terms of their order of occurrence in any counting tasks. For example, the Kâte number word for 8 is *"me-moc â jahec-â-moc"* translated into its operative pattern is 8=5+(2+1) hence apart from emphasizing the relative sizes of the counting numbers 8, 5, 2 and 1, it also reinforces three important mathematical concepts associated with the operation of elementary addition. These are firstly the *concept of addition* as an operation implying the process of quantifying the counting numbers 5, 2, and 1, observing 8 as the resulting *sum* representing the total quantity of all the addends. Secondly, the *order of operation* whereby the operation inside the grouping symbol "( )" indicates that this operation must be performed first. In everyday counting tasks, when one counts up to 8 in Kâte, the emphasis is placed on the counting associations namely, "me-moc" and "jahec-â-moc" where the connecting letter "â" represents the idea of a *plus sign* (+) used in the English (Hindu-Arabic) system. Thirdly, the idea of 5 as a *composite unit* upon which numbers between 5 and 20 are built, likewise for 20, which is a composite unit for every Kâte numeral beyond 20.

From the teaching point of view, all of the above mathematical concepts are important pre-requisites to learning the formal number operations of addition and subtraction normally taught in schools. They therefore provide the all-important linkages between the Kâte numeration system and the teaching of the four basic number operations of addition, subtraction, multiplication and division (Matang, 2002; Matang and Owens, 2004; Park, 2000). Furthermore, the Kâte numeration system does take care of the idea of multiplication if taken either as a "repeated addition" or as a "grouping" operation. On the other hand, the division operation can be very comfortably treated as representing the idea of grouping as expressed in repeated composite units (e.g. 15 = 5+5+5) or as an operation representing the idea of "sharing equally". Sharing of material goods is a significant cultural activity because it both reinforces and consolidates the Kâte "kinship" systems hence in the context of mathematics teaching the notion of "sharing" can be meaningfully used for division operation because of its contextualised meaning hence is familiar to the Kâte children learning to perform formal operations of arithmetic. The idea of "equal sharing" also has cultural significance in the sense that when material goods are shared equally during special ceremonies it signifies "equality" of status of an individual within the Kâte cultural hierarchy. In terms of mathematics teaching, the idea of equality of any two sets is fundamental to teaching of set operations and set theory which in turn is a fundamental concept to doing any further mathematics at the University level.

If the above links have been intuitively or formally developed by the students, then students who learn basic counting strategies in Kâte should perform as well as or better than Kâte-speaking students who have begun their schooling in Tok-Pisin (the widespread lingua franca used in PNG, the Pidgin-English) or English.

Method

Participants

This research project involved a total of 52 children, aged between 8 and 10 years, attending Elementary 1 (E1) class from 3 different Elementary Schools within the Kâte-speaking language area of Finschhafen District in Morobe Province, Papua New Guinea. Hence the total number of participants also represented the total number of children in each E1 class. Both School A (N=17) and School B (N=17) conducted all their classroom teaching only in Kâte language, whereas School C (N=18) which is located at a Mission station, conducted all its classroom teaching mainly in Tok-Pisin and some English although 90% of the E1 children are native Kâte-speakers. All three schools are located within a maximum radius of about 1-hour walking distances of the children's homes.

Instrument

The main research instrument used in this research is the modified version of the *Schedule for Early Number Assessment* (SENA 1) taken from the Australian school text *Count Me in Too* used in the NSW schools (NSW DET, 2002). Though the instrument initially had 8 different numerical tasks, only 7 of these are used for comparative data analysis between each of the three schools in terms of children's performances on each numerical task. These numerical tasks are namely, *Forward number word sequence (FNWS), Backward number word sequence (BNWS), Subitising, Counting, Addition, Subtraction,* and *Multiplication/division* with each numerical task having at most 3 individual interview tasks (see Table 2) giving a total of 15 interview tasks for each participant.

Procedure

Each participant was interviewed individually on each of the 7 numerical tasks by the author, who is also a fluent native Kâte-speaker, using the modified research instrument SENA 1. All E1 children in both School A and B were interviewed firstly in Kâte and then in English with each child responding in the same language order on each of the 15 interview tasks while the E1 children from School C were interviewed mainly in Pidgin. The author also made observation notes on the type of counting strategies that each child used in arriving at a particular answer or response during each interview session, noting if each child used the straight mental calculation (MC), finger counting (FC), or verbal counting (VC).

In order to answer the main research question stated earlier, each question or interview task under each of the 7 numerical tasks (see Table 2) were given a score of one (1) hence the highest number of possible correct responses that each student participant was expected to score is 15 or 100% performance rate. That is, the closer a student's score is to 15 the higher is the participant's overall performance for all 7 numerical tasks. On the other hand the highest possible total score for School A and B is 255 (i.e. 15x17 students) or 100% performance rate, whereas for School B it is 270 (i.e. 15x18 students). In other words, the closer it is to the highest possible scores of either 255 or 270 for each participating school, the higher is the performance rate for each school.

Results and Discussion

Table 2
Children's Mean Performances for Individual Numerical Tasks in Kâte and English

No. Strategies	FNWS		BNWS		Subitise		Count		Add		Subtract		Multiply		Overall	
Language	KT	EN	KT	EN	KT	EN	KT	EN	KT	EN	KT	EN	KT	EN	KT	EN
No. of Tasks	x/3	x/3	x/2	x/2	x/1	x/1	x/3	x/3	x/2	x/2	x/3	x/3	x/1	x/1	/15	/15
Sch A	49	48	19	18	16	16	45	44	19	18	29	29	11	11	18	184

(n=17)															8	
Sch A %	96	94	56	53	94	94	88	86	56	53	57	57	65	65	74	72
Sch B															17	
(n=17)	37	39	20	23	14	16	48	49	22	21	25	25	7	8	3	181
Sch B %	73	76	59	68	82	94	94	96	65	62	49	49	50	57	68	71
Sch C			N		N		N		N		N		N		N	
(n=18)	NA	49	A	25	A	16	A	48	A	24	A	21	A	11	A	194
			N		N		N		N		N		N		N	
Sch C %	NA	91	A	69	A	89	A	89	A	67	A	39	A	61	A	72
Overall %	84	87	57	63	88	92	91	90	60	60	53	48	57	61	71	72

Note: FNWS = Forward Number Word Sequence BNWS = Backward Number Word Sequence

KT = Kâte EN = English NA = Not applicable

An analysis of children's overall mean performances (see Table 2) for all seven numerical tasks in English indicate that there is no significant difference between each of the three schools which is further supported by the one-way ANOVA test with p-value greater than 0.05 and the post-hoc Scheffe test. This result is also confirmed by the overall mean performances of each individual school where School A scored 72% (184/255), School B scored 71% (181/255), and School C scored 72% (194/255).

In terms of paired data comparison between combined Schools A and B against School C (i.e. Kâte versus Pidgin-English), there is no significant difference between the two overall means of 71.6% and 71.9% respectively. Based on the above results, it is reasonable to assume that for those children learning early number knowledge in Kâte language (i.e. Schools A and B) are not in any way disadvantaged in learning the formal English arithmetic strategies normally taught in schools when compared to School C children not taught in Kâte.

When comparing the performances of each E1 class on individual numerical tasks in English (see Table 2), it is significant to note that children from School A and B (Kâte) preformed better on 5 out of the 7 numerical tasks compared to performances of children in School C (Pidgin/English). Furthermore, all three schools on average did not perform well above the 60% mark on the subtraction tasks with each school scoring 57%, 49% and 39% respectively compared to their performances on other numerical tasks. The result in many ways is not surprising in the context of the everyday counting tasks of the Kâte people involve mainly involve counting and addition strategies hence supporting the claim by Brown, Collins, and Duguid. (1989, p. 32) that, "knowledge is situated, being in part a product of the activity, context, and culture in which it is developed and used."

Although this is the first of an ongoing longitudinal research project that will further verify the above results, they however provide an important information that has significant teaching implications for mathematics education in PNG in terms of children's acquisition of mathematical knowledge. That is, the results somewhat challenge the current psychology of mathematics learning that uses the analysis of steps provided by the structure of mathematics with the dominant view that mathematical knowledge is independent of both the culture and its value system

(Brown, et al, 1989; Park, 2000; Bishop, 2004).

Table 3
Paired Sample Correlation of Children's Performances between Kâte and English

School	N	Correlation	Significance
A	17	0.992	0.00
B	17	0.921	0.00

An analysis of the *t*-test results performed on the paired data sample for each of the children from School A and School B (see Table 3) between Kâte and English also reveals a high correlation between children's performances on each of the 15 interview tasks. The result basically means that if a child performs well in Kâte there is a good chance that she/he is most likely to also perform well in English. In the context of mathematics teaching, the result is significant in that it supports the educational assumption that students who learn in their own vernacular will perform the basic arithmetic strategies well in English.

Conclusion

Though the research results reported here is limited to only 3 elementary schools in the Kâte-speaking language area of Morobe Province at one specific time, hence it is not conclusive, in the context of the implementation of the current education reform the results are significant in that they provide support for the use of Indigenous counting systems in teaching early number strategies in elementary schools in Papua New Guinea via the local vernacular languages.. This is contrary to the popular view held by many parents in Papua New Guinea. While the preliminary discussion in this paper suggests possible reasons why students will satisfactorily learn English arithmetic strategies, further research is needed to confirm this, and to find out how the elementary teachers can best use the vernacular counting systems to improve their teaching of formal English arithmetic strategies in Elementary Schools in Papua New Guinea.

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