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Traditional Counting Systems and Their Relevance for Elementary Schools in Papua New Guinea

Kay Owens

Nearly 900 of the 1200 counting systems of Papua New Guinea and Oceania have been documented, at least to a basic level (Lean, 1991; 1993). These counting systems are quite varied and it is clear that each traditional Papua New Guinean culture had its own mathematics. The differences between counting systems makes the data rich, interesting, and useful for teaching at many levels of mathematics, but the basics in traditional mathematics like counting can provide meaning in elementary school mathematics education. For many Papua New Guinean teachers, there has been little opportunity to explore the relevance of culture and language and the basics of mathematics. It is difficult to come to grips with this relevance when you begin with the belief that mathematics is what you learnt in school and irrelevant to everyday life (Kaleva, 1998). Even when you are interested in traditional mathematics, it is still hard to incorporate it into the curriculum without further input from researchers. This article covers briefly the range of counting systems found in Papua New Guinea and provides some links with research on children learning to count. It is hoped that elementary teachers will be encouraged to research their own traditional mathematics and to teach basic mathematics concepts using Tok Ples words and traditional mathematics.

Analysis of Counting Systems by Cyclic Structure

Languages in Papua New Guinea are divided into two main groups, Austronesian (AN) and non-Austronesian (NAN) or Papuan languages. There are often similarities between Austronesian languages or between neighbouring languages in the counting systems. However, "each counting system has a unique set of number words from which all other number words in the system can be generated by combination, that is a complex number word may be analysed [in terms of] … simpler number words; we can infer from this the arithmetical operation(s) required to be carried out on the simpler numerals to obtain the complex numeral. For example, the number word for 10 might have the number morphs for 2 and 5" (Lean, 1990, p. 4) and is considered 2 x 5 or 5 x 2. For another system we can infer it is 5 + 5 or 6 + 4 or a distinct number word. The set of number words is called the *frame.* For example, a typical digit-tally system which uses hands and feet for counting may have the words for 1, 2, 3, 4, 5, and 20.

It is important to note that a base 20 counting system is better understood in terms of its cycles. For example, it may in fact have both a 5-cycle and a 20-cycle. (Cyclic structures were introduced by Salzmann, 1950, cited in Lean, 1990.) A (5, 20) cycle system, for example, has number words

1, 2, 3, 4, 5,
5+1, 5+2, 5+3,5+4,
10=2x5, (2x5)+1, (2x5)+2, up to 15=2x5+5,
2x5+5+2 up to 20.
Then 40 is 2x20, and so on.

These systems are generally **digit-tally systems** as the hands and feet are used to keep track of counting. It can be distinguished from systems having cycles (2, 5, 20) which are usually digit-tally systems too, or (2, 10, 20), or (4, 20) systems. (Cycles do not refer to modulo arithmetic which is also cyclical wirh numbers being repeated as they are on the clock as the hands move on.)

10-Cycle Systems

Even the base 10 systems can be classified into three groups: (a) the “pure” base 10 type with words for 10, 100, 1000; (b) the “Manus” type has 7=10-3, 8=10-2, 9=10-1; (c) the “Motu” type has 6=2x3, 8=2x4 (some also have 7=2x3+1, 9=2x4+1); (d) (10, 20); (10, 60). Most of the 10-cycle systems occur in Austronesian (AN) languages (189 out of 217). The Non-Austronesian languages with 10-cycle systems have been influenced by neighbouring AN languages. An exception to this is the Ekagi system in Irian Jaya which is unique in possessing a (10, 60) cyclic structure.

5-Cycle Systems

Their diversity can be shown by classifying them as: (a) the (5, 10) or (5, 10, 100) system which form the second most common kind of system in Austronesian languages; (b) (5, 10, 20) which are found in all languages in New Caledonia, and in both Austronesian and Papuan languages in PNG and Irian Jaya; (c) (5, 20) type which are generally digit-tally systems using hands and feet with 15 being two *hands* and one *foot*, and 20 being one *man*.

2-Cycle Systems

201 out of 231 of these systems are Papuan. The pure type uses just two basic numerals which are combined for all other numbers. There are 39 languages like this (2 AN) and most also have body-part tally systems. The (2, 5) or (2, 5, 20) type are usually digit-tally systems with a subordinate 2-cycle system (3=2+1, 4=2+2) and is the most common type in the Papuan languages, but there are 18 AN languages too. There are three more types with modified 2 system (these have 3=2+1 but 4 is a new numeral or 4=3+1) one of which is a (modified 2, 4, 8) system.

3-, 4-, 6- and 8-Cycle Systems

Some of the 4-cycle systems begin cycling from the first 4 but others (found in the Highlands of PNG) begin in the second cycle, that is after 8. There are superordinate cycles for some of these (28; 48; and 60). In other words, as counting continues new bases or cycles are developed. Frequently, 8 becomes the main cycle for systems with (modified 2, 4, 8) cycles. There is probably one 3-cycle system and the 6-cycle systems are restricted to small specific geographic areas.

Body-Tally Systems

These systems can have a range of different cycles depending on which body parts are included in the cycle—the most common is 27 but they range from 18 to 68. They occur now in PNG and Irian Jaya but seem to have occurred also in Torres Strait and Australian language groups. Tallying usually begins on the small finger of the left hand, to the wrist and then along the arm, shoulder, left ear and eye, nose or central part, and then down the other side of the body. If vocalised they tend to use the name of the body part (see Figure 1).

Classifiers in Counting Systems

In some areas, particularly on Bougainville but also in New Ireland and Milne Bay and to a lesser extent in other areas, a morphene may be used to distinguish different classes or groups of objects.This morphene is associated with number words providing a different set of counting words for different classes. In some cases, the counting cycle size and words change for the different classes of objects but this is likely to be a "borrowed" idea from a neighbouring language or trading partner.

Non-Counting Systems

In a few places the larger amount of objects is compared by the amount of space taken up rather than by counting objects precisely. This is not an area or volume idea per se but a recognition that approximation can be sufficient for a transaction.

Bases and Cycles

There are few counting systems that have a regular base in which numerals are used for powers of the base. For example, only some island languages have a true base 10 system with numerals for 100 = 10x10, 1000 = 10x10x10 etc.

For this reason, the recognition of cycles or patterns within the counting system will be more beneficial for the elementary school teacher.

The Patterns of the Counting System

Lean (1991) has recorded and documented the patterns of the counting systems in his collection. He uses the term *operative system* for regular patterns. Operative systems may include how the numbers between 6 and 9 are formed, the regular use of decades, that is 20=2x10, 30=3x10 etc. or digit-tally and body-tally.

The digit-tally systems with (2, 5, 20) cycles have the following operative system which combines the frame words 1 and 2. 3 = 2+1, 4=2+2, then there is a word for 5, then 6 to 9 are combinations of the word for 5 (or another morpheme) and the words for 1 to 4. Ten is generally two hands. Fifteen is generally two hands and one foot and 20 is a man. In a system like this, the counting frame is 1, 2, 5, and 20.

Developing Mathematical Concepts and the Counting Systems

Gelman (e.g., Gelman & Meck, 1983) was one of the first to record the various aspects of counting that students need for learning to count. Work by Steffe (e.g., Steffe, & Cobb, 1988), Wright (e.g. 1996) and others have developed how aspects of early number learning can be incorporated into the schooling of young children. The following subheadings form some of the principles of counting raised by these researchers

One-to-One Correspondence of Objects and Number Tags

An important aspect of learning to count is to be able to mark each object as you count with a number tag. It does not matter what system of number tags are used so long as they are used consistently. This would be the case for all known counting systems, at least for small numbers. (Only in a few body-part tally systems do informants give different orders of words for higher number tallies, e.g. Kewa). Fingers are regularly used to tag objects and to assist counting. Fingers are regularly bent in many PNG counting systems, especially those with digit-tally systems. For this reason, it easy to get students to develop one-to-one correspondence between fingers and counting words but it is then necessary to use counting words with other objects.

Knowing the Last Used Number Tag is the Number of the Group

This idea again is quickly gained by the use of traditional counting systems in which fingers and hands are readily used to express numbers or groups of numbers. For example, the hand may be a fist with all fingers bent to represent the number five but the hand is not a fist for numbers under five. This visual representation of 5 and numbers under 5 helps children to get the sense of the last number mentioned is the number in the group. However, there are two warnings: (a) objects can be matched in different orders, and (b) some clustering of numbers like 5 and 10 are often the numbers on which children stop counting whether or not that is the end of the group. Children need to count objects other than fingers and in different orders. They need to say many things associated with the number words so that many different groups of a certain number of objects can be associated with a particular number. For example, they might have 4 fingers, 4 children, 4 stones, 4 bottletops, any 4 objects but all the groups are 4.

One More or One Less; Bigger and Smaller

These ideas are critical for understanding that counting is giving a number that is a quantitative size. It is very important for students to develop the idea that, for example, 5+1 is bigger than 5. If digit tallying is the method of counting, then bending down the finger on the second hand must be seen as indicating the number is bigger than the first hand. Similarly, moving along body-parts is increasing the size of the number. Some activities involving matching sticks with numbers may be necessary to help students see how the number size is increasing.

Composite Units

In the base 10 counting system like English, 10 is a composite unit. We talk of ten as a group of ten or as one composite unit. Papua New Guinea is rich in composite units. Most common is the hand. However, some systems have recognised groups of objects also for counting. These may be a bundle of taro or coconuts or a bundle of sticks. The number in the bundle is fixed and it is a composite unit. In digit-tally systems, man as well as hand is a composite unit. These systems allow for counting with the composite unit. In a few places, 4 is equivalent to a hand. This composite unit is then 4. It does not matter which system is used, there is a composite unit. In body-part tally systems, man is the composite unit.

Once children understand the idea of composite units, it is easy for them to transfer this idea across to other counting systems including the base 10 system. It will then help them to understand the written place value system.

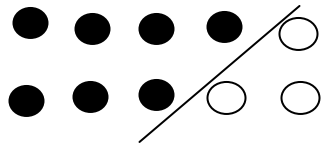
Of course, traditional languages do not have written systems, so place value systems do not really exist. Nevertheless it is still possible to record numbers in columns introducing them to the idea of place value before it is fully introduced with the written base 10 system.

For example, in a digit-tally counting system when 5 is reached then a hand or fist is referred to and when 20 is reached, the group of digits is often referred to as Man. Children might count their own pile of kau-kau, sticks or other acceptable items and record the number in their pile like the following example,

Number of *Hands*	**Number of Extra Digits**
2	3
1	2

Number Groups

A recently recognised aspect of efficiently learning base 10 arithmetic, is for students to recognise visual patterns and combinations of numbers for 10. For example, they might see a 10-frame with the following representing 3 + 7 =10. This is an important way in which many Asian languages learn arithmetic.



Because of the ready use of fingers in counting, number groups to five can quickly be established in PNG counting systems. So 2+3 is physically represented as 2 bent plus 3 unbent fingers. The physical, spatial representation is entrenched in the muscles and mind as children count. The language pattern is also transparent helping students to visualise the number groupings. (A non-transparent language word is eleven for 10 and 1.)

.In digit-tally systems, the natural combination of words for numbers between 6 and 9 is 5 plus a number from 1 to 4 have natural number groupings for numbers up to 20. Other systems have their own combination of numbers but if small number combinations are required then these can be represented by fingers or stones or bottletops in a similar way to that shown in the diagram.

Misleading Representations

For many teachers brought up with the use of fingers in a Western use of fingers may hold up their fingers to indicate numbers when getting children to add numbers. Teachers need to think carefully about this so they are not confusing children with the fingers bent down. When children have learnt to count and represent numbers traditionally, they can make the change to other finger representations such as holding up fingers in a non-traditional way.

Another aspects of society which has caused some problems in the past has been the transfer from pounds and shillings to decimal currency which is now kina and toea. When 20 shillings was a pound, traditional digit-tally counting systems in particular were easily able to identify with the composite unit being 20. In some places, there is now confusion in the use of words for numbers such as 20x20 which was 20 pounds. The number 20x20 often had a special word associated with it. Now a kina is only half the counting cycle. For this reason, the word previously used for 20x20 is (incorrectly) applied to 10x10. Some people have difficulty associating coins with numbers now that the kina is the basic unit and having a cycle of 10 when the traditional counting system has a cycle of 20.

Encouraging Children to Develop Their Own Representations

Traditionally, there may only be a few common additions. Addition is part of some number words, and may not be obvious in some language. For example, 8 may be 5 add 3. In some ways, teachers need to let children express additions and other operations with stones, sticks, and fingers in a way which is best for them to represent the problem. Teachers should encourage children to use number combinations as they wish. Many may add together numbers using the morphemes. For example, a child adding 8 and 2 in a language in which 8 is 5+3 will probably make use of the 3 and 2 making 5 so they change 8 + .2 to 5+3 + 2 to 5 + 5, two hands or ten as the language suggests. This is an opportunity for teachers to encourage children to reach answers in their own way and to share their methods among the class so that flexibility and comfort with the numbers is established in the classroom.

Subitising

This word describes the way in which people just recognise a small group of objects, dots, or fingers and give its number without having to count. Even small babies seem to recognise two dots or three dots as different without being able to count. Children might recognise the spatial pattern of fingers that represent 2, 3, 4, and 5 but they will need to also recognise these groups with other objects or symbols like dots. The patterns might be a familiar body marking or sand drawing but it might be presented as an unfamiliar pattern. In traditional contexts, young children may recognise quite large numbers of familiar objects such as birds flying by subitising (personal communication by S. Willis on an Indigenous Western Australian group).

Imagery Counting

When children begin to count especially when they begin to use fingers, they develop a visual and spatial image in their minds. This is very important for children. They can then use these images to count without objects being present. This imagery development should be encouraged. First it might be with the traditional finger counting patterns but later it can be encouraged by getting children to hide objects and to count on.

Counting All, Counting On from the First Number, Counting On from the Larger Number for Additions

Many children develop their concept of addition and their addition facts by having the opportunities to put groups of objects together and being able to count them. At first, a young child will tend to count them all. Then children may count on from the first mentioned number and later from the larger number as this is more efficient. Some children do not do this at all and just learn number combinations. For example, children may be presented with 3 stones and 5 stones and asked how many altogether. There are four common approaches:

- Some will need to count them all, 1, 2, 3, 4, 5, 6, 7, 8.
- Another child will count on from 3 saying 3, 4, 5, 6, 7, 8 as they keep track of the extra five stones (perhaps with fingers or by pointing to each stone as they count on).
- Another child will realise it is easier to start with 5 and just count on the extra three.
- Other children will count on in their minds, perhaps nodding or slightly moving fingers but not needing to say the words aloud.

Many languages (in which 8 contains the morphemes for 5 and 3) will assist students to quickly name the total number, but experience will be needed with additions of numbers not assisted by the language structures.

Order Number Words

All Papua New Guinea languages have number words for counting. However, some languages also have a clear way of expressing order, that is first, second, third etc. This may be by using a particular morpheme. Children need to learn these number words associated with order. In some languages, words for days of the week may suggest order. The words used for the sun in different phases of the day or for the moon in different phases of the month may also be a way of showing order. Similarly, position of the sun on rising compared to mountains around the village may be an appropriate use of order as the year passes. Certain Papua New Guinea people are more likely to use ordinal words for distinguishing the last object of a group such as a plant in a garden or row of shell money. Ordinal words are then used for comparing size.

Where traditional words do not denote numerical order, it is important that the idea of order is established in other ways. In some languages, it will be more in story form than simple word form.

I am not aware of the use of number words as codes for simply identifying different people such as teachers ID number within the Department of Education or for different objects like number plates on cars. There is neither order nor size intended by the different numbers used as codes. However, this use of numbers which give neither order nor size may occur, perhaps as names or nicknames for children or distinguishing specific places or trees.

Subtraction

Some languages, especially in Central Province, use a subtraction idea for the numbers from 6 to 9. These numbers are expressed as 10 take away 4, 3, 2, or 1. Alternatively, some languages use the form for 9=2x5-1, 8=2x4-1 or 7=2x3-1.

However, subtraction is often linked to adding on. For example, it is common for people to find 9 subtract 5 by thinking, "5 I need 4 more to get 9." This appears to be a likely way to develop the idea of subtraction having the meaning of difference. In some exchange ceremonies, items are matched. The differences between two rows of pigs or objects is a subtraction. This sense of difference is often more common in everyday activities than that of taking away which is the other meaning of subtraction.

Sense of Size

The number of fingers bent down increases when counting, and clearly represents the sense of size. Other representations of size for number can be seen in words used for large numbers that are often associated with making a loud or joyous noise like a rooster crowing or a specially large sun rising.

Some areas of Papua New Guinea, especially in Milne Bay, decide size by the amount of space taken up rather than by counting. This is a very important notion and various forms of representing and estimating diffference in size by spatial representations is an important aspect of developing the concept of size. Counting is one way of getting this but estimating or approximating size and difference is important.

Counting abstractly (or reciting number words in sequence) will not assist the sense of size. Counting concrete objects will assist this idea as the pile grows bigger as the number increases.

Pairs

A few langages have counting terms that encourage pairs. The emphasis is on a pair and one more or one less. Again this idea can be exploited in these counting systems. For example, some languages such as Motu have 6 as 2x3, 8 as 2x4, and 10 as 2x5. Some of these languages have 7 as 2x3+1 etc while one gives it as 4x2-1.

Equal Groups

Counting things in groups is a very common practice in Papua New Guinea. People have bundles of coconuts, taros, yams, tally sticks, or money fathoms etc which are counted in groups. Sometimes there are special words for counting these groups while other languages actually have a cycle system that reflects the number in the group. Nevertheless, it is valuable to have students make other groups of a different size. If traditionally these groups have 10 in each bundle, then the children need to make bundles of fewer objects in each bundle. Both the short-cut way of counting the traditional bundles and the alternatives need to be given.

Fractions

Half is a common idea although it frequently means two parts, not necessarily equal. It is important to establish the difference then between the mathematical concept of half and that of parts. Food is frequently distributed in the society and so fractions can be readily appreciated. Where bundles of food are counted, most languages have fractions for part of the bundle. For example, there are 5 coconuts in a bundle, then the language is likely to have a way of expressing one fifth. Some languages have well-developed terms for quarters, halves, and three quarters.

Classifications

Classification is a fundamental concept. Without classification or sorting many other mathematical ideas are difficult to develop. In schools, students might classify pictures of different kinds of objects or animals, shapes like triangles and squares, colours, and objects of different sizes. Several languages, however, in the New Guinea islands and in Milne Bay use different number words for different classes of objects. For example, they might have a specific morphene attached to the counting words when they are counting trees as opposed to shells or birds or people. These existing cultural classifications can be used to develop a child's concept of classifying and of size

Meaningful Stories

There are times in which students are given word problems that are not particularly relevant to their village or school. It is very important that this is carefully considered when a traditional counting system is used, especially if there is more than one counting system (e.g., counting systems involving classifiers). Sometimes taboos also limit possible examples.

Moving from the Concrete to the Abstract

One of the major issues for all elementary school teachers is that of moving the child away from the concrete to the abstract notion. This occurs when fingers are used extensively in counting. Teachers need to encourage children to imagine numbers. The children can hide their fingers, e.g. behind their back or on their head when representing different numbers and later when adding small numbers. Sticks and stones need to be covered when simple problems of additions or subtraction are introduced. For example, say to children there are 8 stones under my paper or in my plastic, how many will I have if I add these 3 more (these may be seen).

Multiple Counting Systems

Elementary schools may find that Tok Pisin or English counting is commonly used although everyday house, garden, village, and church discussions are in Tok Ples. In these cases, the teachers need to decide whether to pursue the traditional counting system or the introduced scheme. An important issue is that learning mathematical concepts such as numerosity, addition (joining together), subtraction (both difference and taking away), equal grouping (multiplication and division), and sorting are best learned in Tok Ples. The number words will have similar tones and sounds as the other Tok Ples words used to describe the various mathematical concepts. There will be a natural integration of the counting words or morphemes and the other mathematical concepts.

In some cases, the teacher may find him or herself codeswitching (in the mind) back to English at first because that was the first language he or she spoke with mathematics. However, we hope the generation of school children learning first in Tok Ples will either transfer comfortably to English later or, if necessary, codeswitch back to their Tok Ples for gaining greater understanding of new mathematical concepts in primary schools (Clarkson, 1996).

Reciting the counting words is not the main aim of mathematics in elementary schools. It is only a small part of it. Students are learning what counting means, to understand size, to carry out operations (e.g. addition) with numbers, grouping to count (composite units), and grouping for operations (e.g. multiplication and division and number relations).

Other Mathematical Concepts

Besides the concepts related to number, children will learn about classifying, ordering, sorting, describing position in space, lines and shapes, making objects to fill space, recognising and making patterns, measurement concepts such as length, area, volume, and mass, how to compare size by measuring, and concepts of time passing and temperature. However, it is likely that there will be important mathematical concepts in traditional cultures that are not necessarily described in Western texts. Teachers need to keep their minds open to these ideas. They may be important in specific cultural activities. For example, the idea of mounds in a garden, their size and arrangements can be linked to Western mathematical ideas of area and multiplication but they have their own significance and are not exactly the same as area (i.e., area has tiled or tessellated units (a metre square) without spaces in between whereas mound would have to be seen inside a square rather than a circle for this idea to be applied). Tallying, bundling, giving position, telling time, and measuring are all important mathematical concepts that can be dealt with in elementary schools using traditional mathematics.

What the Elementary School Teacher or Writer Can Do

1. Record the counting system at least to 20, any other special words, and how decades or other groupings are made. Ask as many older people as possible. Decide on the frame (basic counting words from which all others are derived). Decide on the cycles (basic and more advanced).
2. Record any body-part morphemes that are similar to counting frame words e.g., fist for five. These will be one of the composite groups. If this does not happen, find the counting word that is repeated in different words, e.g. a 10 morph or a 4 morph, depending on the counting system.
3. Record how the counting words are joined together to make new counting words, e.g. using addition or multiplication; 10 = 5+5 or 2x5.
4. Check any available records, e.g. Lean (1991) or Smith (1984).
5. Note any classifiers, groupings or composite units, number word operations.
6. Note cultural uses such as taboos for children counting. Also note collections of objects and fractions. Also note if sticks or objects are used for grouping or counting, and how size is portrayed. To what extent is counting important for deciding size.
7. List the mathematical concepts and associated student-learning outcomes to be achieved by making use of each aspect of traditional mathematics. For example, children will learn about classification as well as counting by learning classifier morphemes for different categories of objects. For another example, children will be able to know addition combinations to 10 by representing numbers using objects as well as fingers.

The teacher or materials writer first establishes the traditional counting system and its mathematical uses e.g., composite units (cf. cycle number) and number operations (e.g. operative system or pattern for adding numbers to get a new number). The teacher can then teach not only the traditional counting but also the number combinations embedded in the language. Each of these ideas can be extended to bridge the gap to the variety of uses that will later be encounted in English. For example, traditionally additions may only occur with small numbers in terms of the combinations in the counting words but later students might be required to add much larger numbers. The importance is for students to get the notion of addition, and the notion of how to handle larger numbers.

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