Indigenous Languages and Mathematics in Elementary Schools

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Indigenous languages are used for instruction in elementary schools in Papua New Guinea, but teachers have generally received their own education in English. The challenges of identifying terminology to use in mathematics include many-to-one correspondences between English and the vernacular languages, and different grammatical structures. Guidelines to assist teachers need contextualised examples. Teachers also need sufficient mathematical understanding themselves.

Teaching mathematics in vernacular languages continues to be a contentious issue in Papua New Guinea, as in many other parts of the world including Australia. As with Australia, English is widely perceived to be the prime language that provides access to social and educational capital. Papua New Guinea has recently shifted policy away from teaching in the vernacular in the early years of school towards starting with English at elementary school (Years Prep through to 2). However, in many parts of Papua New Guinea, teachers themselves are not fluent in English. Vernacular languages continue to be the main mode of communication in many villages and their elementary schools. As the teachers have generally undertaken their own studies of mathematics and pedagogy in English, they are not automatically equipped to teach mathematics in their first language (Wildsmith-Cromarty, 2012). We are implementing a project designed to improve the teaching of mathematics in elementary schools in Papua New Guinea by using local languages and cultural practices. In this paper we report on the first phase of the project with respect to developing guidelines to assist teachers to identify mathematics vocabulary in their local languages.

The Project

The three year study is exploring how best to identify and use cultural mathematical proficiencies to assist young students to transition to school mathematics in Papua New Guinea. The project uses a design research methodology to design and refine guidelines to assist elementary teachers to recognise and use these cultural mathematical proficiencies, and to develop vernacular phrases for school mathematics. The guidelines have been trialled in case study workshops, and refined and used in three Provinces with different cultural ecologies. The initial design of the guidelines was developed from past research into Papua New Guinean mathematics such as Lean's (1992) categorisation of counting systems and extended by others such as Owens (2012) and Matang and Owens (2014).

The project overall involves guidelines and training materials that can help teachers to developed their professional skills in ways that require a minimum of resources. The guidelines for language therefore need to be easy to understand and follow. This paper

2014. In J. Anderson, M. Cavanagh & A. Prescott (Eds.). Curriculum in focus: Research guided practice *(Proceedings of the 37th annual conference of the Mathematics Education Research Group of Australasia)* pp. 207–214. Sydney: MERGA.

presents data from workshops in Hela Province and National Capital District, and reports on how these workshops inform the refining of the guidelines.

Literature Review

All cultures include mathematical practices and therefore all languages include mathematical language. However, not all languages have a history of teaching school mathematics in them. Hence, they do not all have an established or stable mathematics register. A mathematics register is the meanings, words and grammatical structures used in talking about, learning and doing mathematics (Halliday, 1978, 1996). Although not all languages have a mathematics register, they all appear to have the mechanisms to develop one when the need occurs (Edmonds-Wathen, Trinick, & Durand-Guerrier, in press). While the current paper focusses on developing linguistic guidelines for elementary and to some extent *ad hoc* development of mathematical language, the literature of register development in indigenous languages is particularly relevant.

The development of mathematics vocabulary and a mathematics register has been undertaken in other indigenous languages over the past few decades, to varied extents. One well known case is that of the development of an entire mathematics curriculum from primary through secondary levels in *te reo Maori*, the Maori language (Meaney, Trinick, & Fairhall, 2012). The extensive documentation of the development of the Maori mathematics register and curriculum provides many details useful for developing mathematics registers in other languages. However, Maori is a single language spoken throughout New Zealand, and despite some dialectal variations in the Maori spoken across New Zealand, the country does not have any other indigenous languages.

A multilingual country such as South Africa shares some contextual factors with Papua New Guinea. Although English is generally the language of school, particularly at higher levels, it is not the first language of many students and teachers. Indigenous languages including Setswana, Zulu and Xhosa are often used informally in the classroom through the practice of code switching (Setati, 2005). Recently, resources have been developed to assist teachers in how to use African languages in mathematics teaching (Schafer, 2010; Wildsmith-Cromarty, 2012).

A recent project in the Northern Territory of Australia looked at processes for identifying language to use in specific early number contexts (Wilkinson & Bradbury, 2013). The project involved working with paraprofessional Indigenous teachers to develop a suitable approach in Djambarrpuyŋu and then creating a resource to assist teaching teams in other places to achieve similar outcomes in other languages. Both the Maori and Djambarrpuyŋu projects have found that for some mathematical concepts much care and time is required to find or develop appropriate terms (Meaney, Trinick, & Fairhall, 2012; Wilkinson & Bradbury, 2013).

There are some key differences between Papua New Guinea and the examples discussed above. With close to 850 languages spoken, Papua New Guinea is widely recognised as the most linguistically diverse region of the world (Lewis, Simons, & Fennig, 2013). Papua New Guinea is also economically undeveloped, with schools being very poorly resourced, often with little access to books, and no electricity, hence no computer technology. While it would be an admirable goal to develop a mathematics register in all the languages that are used in schools in Papua New Guinea, this is not currently feasible. Developing guidelines on how to identify and use mathematical terms in the vernacular means that a significant intellectual task will still remain with teachers in following and implementing the guidelines at a local level. Owens and Kaleva (Owens, 2012; Owens & Kaleva, 2008) have documented many mathematical words related to comparing and measuring from around 350 languages of Papua New Guinea. However, word lists alone do not necessarily provide a full description of how concepts are understood and used in languages. Words that initially present as good translations for a mathematical term may have different scope of use in indigenous languages (Edmonds-Wathen, 2013). Furthermore, some concepts which are understood in practice do not have single-word representations.

The week-long workshop was designed to cover the project's key principles: mathematical ways of thinking; early mathematical thinking; assessing, planning and reporting on learning; cultural capacity and partnerships; cultural activities; language treasures; activities appropriate for children; and learning experiences to promote children's efficient mathematical thinking. Language was thus a topic for attention throughout the entire workshop, but the primary focus of only a part. In the case of the Hela workshop, the researchers and participants noted points of interest regarding the Yuna language as they arose throughout the week.

The project has language goals at two main levels: the goal for workshop participants to investigate how they can use their own languages for the teaching and learning of mathematics, and the goal of generalising from this process to guide other groups and individuals to use their own languages in mathematics education.

Hela Workshop

Hela Province is one of the most remote provinces of the Papua New Guinean Highlands. Tropical rainforest-clad mountains are separated by river valleys. The geography supports many small scale farmers who grow kaukau (sweet potato) and other crops in their gardens, gather food and hunt for small animals in the nearby forests. The rugged terrain has contributed to the relative lack of development in this part of the country. The village in which the workshop took place is located near the end of the Southern arm of the Highlands Highway. The highway at this point is a single lane unsealed road traversed by a few PMVs (public motor vehicles) and private vehicles. Most people continue to travel on foot.

The workshop was delivered by two team members, one a Yuna speaker, over five days. There were nine keen participants, elementary school teachers from the village and other local villages. Those who lived too far to walk every day to the workshop stayed for the week in the village. All the participants were Yuna speakers (one had Hula as first language) and most were related to each other in a complex and extended manner. Although the workshop was delivered in English, much discussion occurred in Yuna. The participants varied in their level of English fluency and sometimes another participant would translate something into Yuna for someone who had not understood it in English. Elementary school teachers must have completed a minimum of Year 10 at school but may lack practice in English. Some of the teachers had completed this as mature adults. The course to qualify as an elementary teacher is as short as six weeks. In general the teachers had previously associated teaching mathematics with English.

Developing a list of mathematical terms in Yuna was the focus of much of the last day of the workshop. Throughout the week, as much discussion and activity focussed on local cultural activities that involved mathematics, Yuna words with mathematical meanings had been used and discussed. The scope of some of these words had also been discussed, as many of the Yuna words are more specific in meaning than the English words used in mathematics. The fact that there was not a one-to-one correspondence between English and Yuna words had also been a part of this discussion. For example, the word *lo* 'row' had been discussed as a group of participants focussed on the cultural activity of making *bilum* 'string bags' for a mathematics weekly learning plan. Counting the length of each *lo* in terms of how many knots or holes, as well as the number of *lo* had been a central part of these activities. However, the group had also talked about other words for 'row' such as *honde* 'straight row in garden'. Both *lo* and *honde* translate to 'row' in English. They both have specific meanings embedded in cultural practices. The issue of which would be more suitable to use in a mathematics class to talk about a row of numbers had not been thoroughly discussed. To find which term would be suitable to use for describing the rows in a table drawn on the board, it was necessary to discuss concretely a table that was drawn as part of another activity. That is, terms needed to be put in their mathematical context to find which was suitable.

The process chosen by the participants was to go through the list of possible words in the workshop handbook. In most cases a word was quickly offered from the group for each English term. Sometimes this word was immediately accepted by the rest of the group and with others there was disagreement and discussion. In some cases, it took extensive discussion to arrive at a word, and there were a few English words for which a satisfactory Yuna term could not be found.

Another way in which Yuna words could be more specific than their English equivalents appeared to be due to structural differences between English and Yuna, particularly in the case of verbs. English has some general verbs which are made more specific by the addition of prepositions. For example, *add* is made more specific in the phrases *add to* or *add on*. In Yuna, there are separate verbs *sagoga* 'add', meaning bring two groups together and *paraga* 'add on' meaning add one quantity to another.

"Add these two, add this and that."

hayane	*sagoga*
two groups/this that	add

"Add on some more to this."

huniada	*mbatia*	*paraga*
this one	some more	add on

Of course, English also has multiple words and phrases that are used for arithmetic operations. The difference is that in English historically the different ways to describe the action of adding have been grouped together under the nominalisation 'addition', whereas this grouping of concepts and words for mathematical purposes has not yet occurred in Yuna.

In many cases, Yuna verbs are specific to their objects. There are many words meaning 'divide in half' that are specific to what is divided in half. *Yalepa* applies to the division of money:

"What is half of eight?"

pou	*hanita*	*yalepa*
eight	equal	divide

However, when dividing long items such as a rope, *legapa* is used. *Gandupa* is used to describe the breaking of cooked food such as scones and kaukau. To ask for half a quantity of liquid *yoromangi* is used when one is providing a container for the liquid whereas *noayangi* means 'give me half the water to drink'. There is a noun *gagi* 'half' that applies to pigs, pande nuts, pumpkin, pineapples and other bulky edible objects. *Hani* 'half' on the other hand refers to the middle. Hence while to concept of halving appears to be strongly developed in Yuna, there is no one term that can be applied in all contexts that might arise in the mathematics classroom.

The word list included the term 'adjacent'. A term such as 'next to' might have been more suitable for this concept in elementary level mathematics education. However, this term prompted an interesting discussion. The word that was first offered was *sera*, which describes a proximate location at the base of something high, and is particularly applied to the base of a mountain:

"The river Yandi is coming out from the foot of the mountain Yandi."

iba	*Yandi*	*kari*	*Yandi*	*sera*	*rugana*
river	name	mountain	name	near base	come out

With increasing use of metaphor, *sera* also means 'roots' or 'philosophical concept'. The group eventually agreed that *sera* was not actually a suitable term for 'adjacent', partly because it was limited in meaning by the height dimension, but also because it was a term that already has a rich network of metaphorically related meanings which are unrelated to adjacency. A more suitable term for adjacent was found in *pagu* 'next to' which can be used as shown:

"We are sitting next to each other."

Keno	*pagu guriye*	*reinia*
We	next to	sitting

Comparatives, Superlatives and Intensifiers.

Comparative and superlative constructions are extensively used in mathematics to compare quantities and sizes. There was initially some confusion about which terms were comparative and which simply included intensifiers. For example, we present forms related to the term *puga* 'big'. This is combined with the intensifier *kone* 'very' to make *puga kone* 'very big'. 'Bigger' was given as *pugao* and 'biggest' as *pugao kone*. However, *pugao* cannot be used in a comparative construction such as "Ten is bigger than seven". In English, participants said that this can be expressed as "Seven is small, ten is big. For *kete* 'small', no term for 'smaller' was given; 'very small' is *kete kone* and 'smallest' is *kete kone kone*. Owens (2012) summarised a number of ways in which comparison could be expressed in Papua New Guinean languages. Intensifiers such as in Yuna, or suffixes are used in some languages; reduplication is another common method to create an intensified form.

The difference between comparative terms and comparative grammatical constructions is important. Although comparative constructions are frequent in English and used extensively in mathematics, not all languages have them. Many indigenous Australian languages do not have them. Wilkinson and Bradbury (2013) discuss "slippage" in activities exploring the concepts of 'smaller than' and 'larger than' with Djambarrpuyŋu language speaking paraprofessional assistant teachers. They note that these constructions do not occur in Djambarrpuyŋu, and that some of their participants were not confident with their meanings in English. A term that they eventually identified and employed to mean 'larger than' with respect to numbers is *djulkmaram*, a transitive verb meaning 'overtake, pass'. Is *kete kone kone* truly a superlative or does it just mean 'really really small'? Is a more overtly comparative construction such as "Seven is big, ten is bigger" possible? There are clearly more subtleties that need to be teased out of these terms. In these cases, simply translating the terms in the word list was not sufficient to determine whether the terms are going to be useful in the mathematics classroom.

Motu Workshop

National Capital District surrounds the Nation's capital, Port Moresby, and many villagers work in the capital or rely on family members with income. Family relationships and culture are extremely important and influence the economy of the village in complex ways. Motu, an Austronesian language, is spoken widely in the villages of the district although many villagers can also speak English. Villages often have some power and rely on fish, sago, kaukau and other staples as well as store goods such as tinned fish and rice. In the large village school where the workshop was held, the school had power from time to time and had been supplied with computer and classroom equipment. Material resources were limited, and teacher-prepared aids were common including reading material. The Papua New Guinea Syllabus was used for preparing lessons. Lessons were often in Motu with board work copied by the children in English. Children generally spoke Motu but some were able to understand or speak English. Twelve keen teachers and the principal from the nearby school attended the workshop, together with three Curriculum Development and Assessment Division Officers. One of the two team members could speak Motu. Discussions in small groups were often in both languages with considerable code-switching.

Two particular features are of particular interest. The first is the effect of transliteration. English has been common in the area for more than 150 years. Today, there are many transliterations for mathematical words, that is, the English mathematical term is adapted into the phonological and grammatical system of Motu, a small change to make it flow in a sentence and sound like a Motu word. A similar occurrence happened in New Zealand with *te reo Maori*, although many transliterations were "purged" from *te reo Maori* during the development of the Maori mathematics register (Meaney, Trinick, & Fairhall, 2012). In Motu, original counting words from one to nine in Motu are used but 'ten' has been transliterated from English. In some cases, the combination of the transliteration and rote learning meant that students had little understanding of the mathematics concept. For example, students did not understand multiplication as equal groups. Thus it would be helpful for expressions in Motu for multiplication to incorporate the idea of equal groups or rows that could be counted in groups. Division was understood as sharing equal groups. However, sharing is not always equal such as when 24 fish are shared between four families depending on their size and needs. Addition was rote learnt with little thought to regrouping in addition. Thus the meaning of addition as joining together was not well grasped. Paraide (2010) made similar comments when she discussed Tinatatuna, the Tolai language of East New Britain, another Austronesian language, in which groupings of objects were significant in the ways that people could envisage multiplication and could also apply group counting.

We also note that the words used for 10 varied according to the nature of the group of fish, group of coconuts, or group of people. Nevertheless, the importance of the complete group of 10 in base 10 counting was not yet being linked to the group notion in Motu even though the words currently differ. The group was also seen as roughly 10.

Another relevant discussion at the workshop was about the word 'unit'. It was clear that teachers understood the meaning of the word, such as using footsteps to measure length, although the word itself was not used. This measuring was carried out to demonstrate the meaning of the word unit in a volume lesson. Participants suggested that the word 'counting' in Motu might be an alternative to unit. The act of counting or the verb took precedence, as is common in many Papua New Guinean languages (Capell, 1969). The importance of the type of unit or the equality of standard units was not necessarily appreciated.

Considerations for Guidelines and Conclusion

Although the workshop handbook advised that the grammatical contexts of words need to be considered, and gave the specific example of a comparative construction, this was not addressed by participants without guidance. A word list to be translated therefore needs to include example sentences using mathematical terms which should also be translated. In this way teachers can test for themselves whether their initial ideas of which words to use will be practical in the classroom. In some cases English mathematical phrasal terms should be regarded as units of meaning rather than trying to translate each word. Hence 'add on' needs to be seen as a unit of mathematical meaning rather than as the compound of 'add' and 'on'.

Is vocabulary to be derived in extended focussed sessions or on an ad hoc basis from lesson to lesson or week to week? We suggest that the best answer to this is both: groups of teachers working together in extended sessions grapple with the issues that arise through discussion, example and counter-example. However, short term planning on the teachers' part needs to include consideration of the specific language that will be needed in the lessons on a particular topic.

We are also already working with carefully chosen examples from languages that have been previously documented. The examples demonstrate to teachers a range of likely possibilities for their own language as well as demonstrating how different languages can be to each other. Since there are not the resources for developing standardised terminology in all the languages that must be used in Papa New Guinean schools, such a comparative technique can assist teachers in their work on their own language. Further refinement of these examples will increase their usefulness in guiding teachers to determine or develop the required mathematical terminology in their own languages.

The limitations of many of the teachers' own mathematical understandings also constrains their ability to determine appropriate mathematical terminology. Thus, the meanings of English mathematical terms also need to be illustrated for the teachers. This was possibly what occurred in the case of looking for a translation for 'adjacent', where the teachers' understanding of the English word may have been incomplete. This need for many contextualised examples was also seen in South Africa (Wildsmith-Cromarty, 2012).

The workshops confirmed the importance of local languages to teachers both as essential parts of their cultures and pragmatically, as the primary language of communication between teachers and students in many cases. Although the teachers had previously associated mathematics teaching with English, they were eager to unearth the mathematical concepts in their own languages and work out how they could be used. The workshops demonstrated the need for detailed and contextualised examples to assist teachers in deciding upon terminology. Mathematical, pedagogical and linguistic skills and knowledges are all needed for this task, and we cannot expect undertrained teachers to be experts in all these areas. Working together as opportunities permit enriches the skills, knowledges and insights brought to the task.

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Acknowledgements: The project is funded through an Australian Development Research Award. The views expressed in the publication are those of the authors and not necessarily those of the Commonwealth of Australia which accepts no responsibility for any loss, damage or injury resulting from reliance on any of the information or views contained in this publication.