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Bringing ethnomathematics to elementary school teachers in Papua New Guinea: A design-based research project[1]

Trazendo etnomatemática para professores do ensino fundamental em Papua Nova Guiné: Um projeto de pesquisa baseada em design

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Abstract

After 40 years of ethnomathematics research in Papua New Guinea and policies encouraging ethnomathematics in schools, it was time to look at professional learning for teachers so they could effectively implement the policies. Within a design-based research methodology, we designed a set of interlinked principles, tried them in several workshops for teachers, and revised the principles to take account of needs based on reflexivity and evaluations. We developed a manual to use in the workshops. We are continuing this research through several different phases, moving from direct delivery of the professional learning to teachers in various provinces and ecologies to delivery to trainers who then teach the teachers in three provinces, and finally by technology delivery. Early evaluation data suggest that the key principles showing the importance of culture, language and mathematical thinking in the teaching of early mathematics are sound. Workshops have been well received as teachers inquire into the mathematics of their own cultures. The need for a stronger understanding of early mathematics learning in general has been identified. The use of video of cultural practice and of young children learning to count and investigate has had a significant impact.

Keywords: Cultural Mathematics, Inquiry, Professional Learning, Elementary Mathematics Education

Resumo

Após 40 anos de pesquisa etnomatemática em Papua Nova Guiné e políticas de fomento etnomatemática nas escolas, era hora de olhar para aprendizagem profissional para os professores, para que pudessem efetivamente implementar as políticas. Dentro de uma metodologia de pesquisa baseada em design, foi elaborado um conjunto de princípios interligados, tentou-los em diversas oficinas para professores, e revisto os princípios a ter em conta as necessidades com base na reflexividade e avaliações. Nós desenvolvemos um manual para uso nas oficinas. Nós estamos continuando esta pesquisa por várias fases diferentes, movendo-se

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a partir da entrega direta da aprendizagem profissional para professores em diversas províncias e ecologias, em seguida,de entrega para instrutores que ensinam os professores, e, finalmente, pela entrega de tecnologia. Dados de avaliação iniciais sugerem que os princípios fundamentais que mostram a importância da cultura, linguagem e pensamento matemático no ensino da matemática fundamental são sadios. Oficinas foram bem recebidos como professores investigar a matemática de suas próprias culturas. A necessidade de uma maior compreensão sobre os primeiros aprendizagem da matemática em geral foi identificada. O uso de vídeo de prática cultural e as crianças aprendem a contar e investigar tem tido um impacto significativo.

Palavras-chave: Matemática Cultural, Inquérito, Aprendizagem Profissional, Educação Matemática Fundamental

PAPUA NEW GUINEA

Papua New Guinea (PNG) is a country with 850 languages and cultures. There are high, steep mountains with deep ravines, broad mountain valleys, wide coastal plains and narrow coastal strips flanked by mountains, sago swamps, coral reefs, as well as hundreds of large and small islands. Coastal languages are mainly Austronesian while languages in the mountains on both the mainland and large islands are the diverse Papuan languages, with many different language families and isolates. Over thousands of years, cultures have adapted differently to diverse environments, notably in values, beliefs, myths, dances, songs, house building, artefacts, and reciprocal relationships. Today, the population is increasing rapidly. So too is access to education. Increased communication between groups of people has furthered the spread of Tok Pisin, a creole language with much of its vocabulary derived from English. It is spoken by many Papua New Guineans as a first language, as well as being a widely used lingua franca between speakers of different vernaculars. Tok Pisin is displacing traditional languages in many places and is today the home language of many children in towns. Nevertheless, many villagers still use their own language for communication although switching between languages is also common. Many people can speak or understand the languages of neighbouring groups, and children will hear both parents' languages if they differ. This complex and diverse linguistic and cultural scenario provides a unique context for mathematics education.

ELEMENTARY TEACHERS' TRAINING FOR *CULTURAL MATHEMATICS*

With a rapidly increasing population, Papua New Guinea has densely populated rural areas with school-age children who have little or no proper learning facilities. The government's

goal for universal education by establishing village elementary schools for the first three years of schooling has not yet been achieved. These schools are set up and maintained by the community with the government paying salaries and for consumables. In rural areas, there are no facilities like electricity, phone lines, or running water and often no road access. Schools are often built of bush materials. There are few facilities and schools are maintained by the community. Schools have little equipment and the board might be the only material aid in the classroom. Class sizes generally range from 30 to 50 for a single grade, although smaller schools may have mixed grades. The core domains of universal basic education are access, retention and quality (Kukari & Jones, 2013). In a recent universal basic education conference at the National Research Institute, it was predicted that achieving universal basic education by 2015 is impractical.

While the O'Neil-Dion government's 'free education' concept is encouraging younger children to go to school, little consideration is given to training elementary teachers. Many teachers who volunteer to teach in the classroom lack proper training which is defined as two weeks each year accompanied by self-instruction units. These units barely touch on teaching mathematics to young children. Plans for two or three years of training at a Teachers College have not come to fruition but some teachers have now completed a diploma in Early Childhood at the University of Goroka. Many teachers fall back on how they were taught in primary school with 'chalk and talk', children copying from the board and rote learning addition and multiplication facts.

The outcomes-based syllabus is brief and considered insufficient for teachers. Additional teachers' guides assist, but not all teachers have them. Some outcomes were also confusing such as one that covered the concepts and units for both volume and length. While it drew on cultural practices such as measuring pigs, it confused the mathematical concepts of volume and length. A new syllabus is being written incorporating standards and more details.

While there has been professional development for teachers in literacy at elementary schools such as through the Voluntary Service Overseas *Strongim Tisa, Strongim Sumatin* and *Buk Bilong Pikini* programs (Kukari & Jones, 2013), little or no proper training has been done on cultural mathematics at the elementary level. Papua New Guinea's numeracy

standard has dropped significantly (Kukari & Jones, 2013), hence the need for this research project. The research study reported in this article is called "Improving the teaching of mathematics elementary schools by using local languages and cultural practices (Papua New Guinea)". It is exploring whether a culture-based professional learning for elementary teachers in Papua New Guinea can be effective in assisting teachers to recognise cultural mathematics and its strengths and importance for school education. Teachers learn to recognise the mathematics embedded within familiar or less familiar cultural activities and plan engaging mathematics lessons incorporating cultural mathematics using an inquiry method. An inquiry method was chosen because it can improve students' opportunities for inquiry learning which will be an advancement at the child's earliest learning experiences (Gerard, Varma, Corliss, & Linn, 2011).

MATHEMATICS AND CULTURE

Mathematical activities involve mathematical thinking processes such as explaining, measuring, designing, locating, problem solving, and enumerating (Bishop, 1988). Mathematical practices develop along with language in response to peoples' circumstances (Barton, 2009).

In Papua New Guinea, these mathematical thinking processes are affected by the Indigenous cultures and the need to live closely with the environment. There is considerable diversity in the language associated with mathematics. For example, while the Austronesian languages, which are more recent arrivals around the coastal regions, generally have a base 10 counting system, others are best described as having cycles of 2 and 5 and maybe also 20. There are also languages with main cycles of 5 or just 2 with a few having 4 or 6. There are also body tally systems which are generally symmetrical about a central point of the body, which vary in the number of tally points from around 13 to 59 (Lean, 1992; Owens, 2001). Diversity can also be found in descriptions of position and movement and in measurement. Left and right maybe only used to describe parts of people rather than directions. While east and west are widely used, the direction of river flow is also used in many areas.

Due to the diversity of languages and cultures, teaching in elementary schools has previously been supposed to be in local vernacular languages which are known as Tok Ples. A transition to English was supposed to occur in Years 2 and 3. In practice, Tok Pisin is also widely used. In 2012, the PNG government decided the language of instruction in elementary schools should be English, supported by Tok Ples or the home language. However, many elementary teachers are not proficient in English, and nor are their students.

The Reform in Education established a *Cultural Mathematics* Syllabus for the first three years of schooling in elementary schools, to be taught in Tok Ples. Teachers are supposed to draw on the mathematical practices of their culture and place in their teaching. Elementary teachers each have a cultural identity associated with the cultural practices of their families, developed through cultural activities and dialogue. A teacher may develop as a mathematical thinker through his or her cultural activities. However, their cultural identity may not recognise the mathematics of their cultural practices. While school and western-oriented activities may be seen as involving mathematics, teachers may not recognise the mathematics of their own culture as mathematics. Involvement in out-of-school activities may or may not be seen as involving mathematics (Wager, 2012) or the mathematical processes may be intuitive, tacit, nonverbal knowledge that is not explicated (Frade & Falcão, 2008). Mathematical identity seems to be primarily developed in school or in other educational institutions (Owens, 2014). Hence cultural mathematical knowledge may not be used in school mathematics or may be used superficially.

THE RESEARCH PROJECT

Given the diversity of languages and cultures in PNG, the lack of teacher education, the tacit nature of their cultural mathematics, the challenge was to develop appropriate professional learning for teachers to improve children's learning of mathematics. The intention was to provide in-service workshops that showed how to recognise cultural mathematics, good ways of teaching counting and early arithmetic building on cultural counting practices and noting key concepts of measurement and geometry. The workshops would stress the importance of maintaining cultural knowledge and identity for children as

they transition to school. In order to do all this effectively, a workshop design that was flexible and pragmatic was required. Our research question for this part of the project was:

1. What are appropriate guidelines for elementary teachers to recognise and use cultural mathematical proficiencies for transition to school mathematics?

We had three sub-questions:

a. Can past research be converted to guidelines for the many languages and ecologies of PNG?
b. Can linguistic guidelines be developed to guide communities to determine appropriate vernacular phrases for school mathematical concepts?
c. How do the guidelines need refining for elementary teachers to understand?

Research design

Our previous research into cultural mathematics provided a beginning theoretical position around recognising and using cultural mathematical proficiencies (Glen Lean Ethnomathematics Centre, 2008; Owens, 2012, 2014). The four initially expected prongs were mathematical processes, language support, community involvement, and linking to school mathematics. The intention was to design a set of key principles which would cover these prongs and implement them with teachers through a professional learning workshop.

We needed a developmental methodology to research the design of the training guidelines and their implementation through remote teacher professional learning. It was anticipated that the design would need to be revised after each implementation. For this reason, we adopted a design-based research approach, a relatively new research method where model based on theory and research is iteratively designed, improved and validated (Bell, 2004; Collins, Joseph, & Bielaczyc, 2004). According to Wang & Hannafin (2005), the five basic characteristics of design-based research are: it must be pragmatic and based on reality; grassroots but research based; interactive, iterative, and flexible; integrative; and contextual. The flexibility and adaptability of a design-based research approach is proving suitable for the project (Kravia & Owens, 2014)

There are four phases to the project:

- Phase 1: initial development;

- Phase 2: implementation with schools and groups of schools;
- Phase 3: by Provincial Education Trainers with groups of schools; and
- Phase 4: by mobile technology using an e-resource with a group of schools.

This article reports primarily on the first three phases. Our theoretical design continues to be developed by evaluating the implementation of the professional learning during each phase of the research.

Data collection

The project was designed with several approaches to collecting data during different phases. Reseachers' reflections upon facilitating workshops together with evaluations by teachers at the end of the workshop are used to refine the design. In phase 1, we held one preliminary one-day workshop with eight teachers and in phase 2 we held four workshops (one in each of Hela, Simbu, Madang, and Central Provinces for 4 to 5 days) generally with two researchers and varying in size from 12 to 60, totalling 97. The third phase involved three more workshops with some responsibility for the workshop being taken by Teachers-in-Charge or cluster trainers (total number of teachers was 66). Feedback from four senior education department personnel participating in the workshops has also contributed to this refinement. The design provides for further data to be obtained from teachers several months after the workshop. Teachers are asked to complete reflective questionnaire to see how they have incorporated the professional learning in their practice. They are also asked to conduct diagnostic interviews with two children from their class using an early mathematics schedule and an interview with a parent or group of parents to see how they are being involved in the schooling. All of these forms of data gathering are new to the participants and so they are discussed in the workshops. Some of this data have been collected but have not yet been sufficient to draw analyses (communications with teachers in PNG is very difficult). We have also realised the need to make follow-up visits to some schools to collect this data.

PHASE 1: DESIGN OF KEY PRINCIPLES

Our key principles needed to assist teachers to appreciate their cultural mathematical proficiencies, building especially on measurement and spatial knowledge and how teachers

could connect these cultural mathematical proficiencies to mathematics in elementary school. They also needed to involve consideration of language usage for ideas that are important in school curriculum.

The initial design was developed by the team of experienced PNG mathematics teachers who are now lecturers, an early childhood specialist, and an Australian with 40 years of experience in PNG including previous research on cultural mathematics. The team first listed all the important aspects of mathematics education for PNG. These points were then collected under five headings with arrows showing how each related to the implementation and then assessment which was seen as feeding back into cultural practice and language, as shown in Figure 1.

Workshop design

The professional learning workshop was designed around these key principles which also incorporated a version of Murdoch's (1998) Inquiry Model for integrated teaching. The steps of this model are:

- tuning in (including a cultural basis and planning to find out),
- finding out,
- sorting out,
- going further,
- making connections,
- taking actions,
- reflecting, sharing, and discussing.

We used this model as a framework for the workshop, and also as a planning model for the lessons on cultural mathematics because it has been widely used in Australia for integrating subjects like social studies with other subjects. It encourages investigation and reasoning, collaboration, deeper thinking, and a sense of ownership; all of which are important for mathematics.

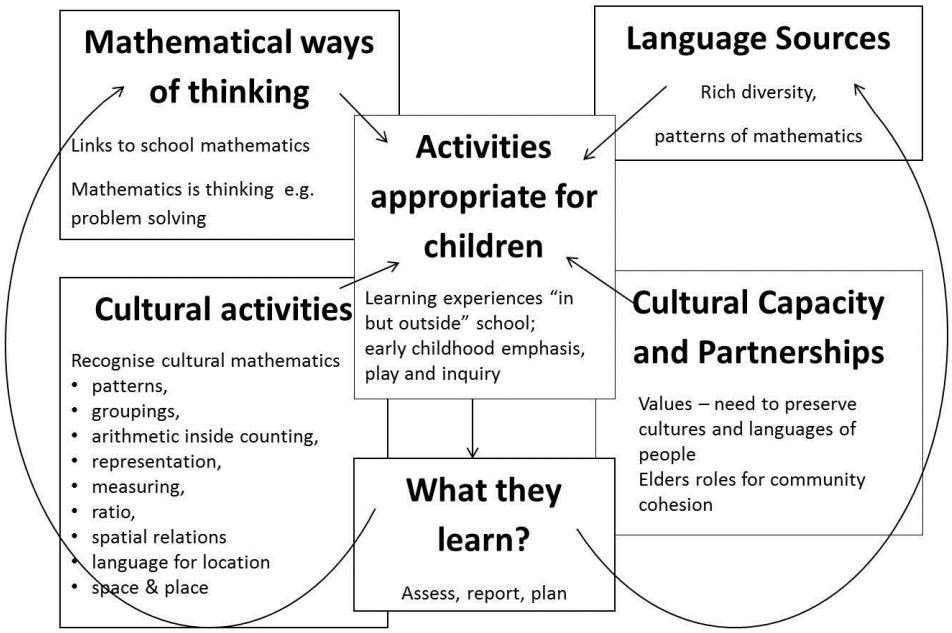

Figure 1. Initial design of key principles for teacher professional development in Cultural Mathematics

The professional learning material includes a workshop manual for participants. As well as informative content on each of the principles, the manual contains mathematical games and activities, and exemplar lesson plans modelling the inquiry approach to cultural mathematics. It also includes interviews to administer to children as diagnostic assessment, which form part of the data collection for the project, as well as interviews for teachers to conduct with parents and reflective questionnaires for the teachers themselves. The workshop is supported by the use of video material, which will form a substantial component of the technology-enhanced Phase 4. Past research was made available as stimulus videos for discussing cultural mathematics. A series of mathematical readers have also been produced for the project which integrate literacy and mathematics.

Workshops are planned for five days intensive professional learning. *Tuning in* begins with a small mathematical introductory activities which involves personally significant numbers chosen by participants which set the scene for interaction and showing how simple tasks can lead to people talking mathematics. An overview of the project is also provided.

Finding out begins with a video of a PNG cultural activity relevant to the workshop context (Owens, 2012) and a discussion of the mathematics involved. Small groups, varying in size

depending on languages involved but generally of four teachers, then choose a cultural activity to discuss, investigating the mathematical thinking involved. This activity really engages teachers as their cultures are important to them (Owens, 2014). In *sorting out*, groups share their discussions and the framework of principles is introduced.

In *going further*, one activity is discussed in terms of what mathematics the children might learn using the *Cultural Mathematics* syllabus and how that relates to knowledge of children learning and of early childhood education, play and inquiry (Department of Education Employment Workplace Relations, 2010). The workshop continues with *making connections*, looking at early arithmetic in detail and playing some games using simple equipment designed for early mathematical development.

Taking action introduces the inquiry method and exemplar learning plans. Small groups read the example plans, looking at the cultural tuning in, the use of questions, and how the plans get children to go further in their understanding, and then share their discussions with another group. We use the readers on measurement and patterns. Teachers make up a few questions to use as they read. One of the group practices reading interactively with the rest of their group with as many teachers as possible in the time available having a turn at reading one of the six books. These books were written with beginning English around a specific concept such as area. Suggestions for teaching literacy and numeracy associated with the book are given at the back of the book. Groups prepare a learning plan using the inquiry method. Teachers develop key questions for observation of cultural activity and extension to school mathematics and ways of developing the ideas for school mathematics. Where possible, teachers teach their lessons to a class or to peers, followed by a reflection. Language is discussed, drawing out Tok Ples treasures to help with school mathematics concepts. Assessment includes the use of the children's interviews, which they practice on each other after a demonstration. This activity reinforces much of what is discussed on mathematical concepts and children's learning during the workshop. Where possible the teachers test a child next morning.

For *reflecting, sharing and discussing*, we discuss working with community in the classroom or in the outdoor 'classroom', and setting up dictionaries for concept understanding. The questionnaire for teachers and parents are provided for data gathering

and reflection. Finally there is an evaluation of the workshop covering the principles and a celebration.

The key principles and workshop design was discussed with eight elementary teachers from the area around the University of Goroka, up to 50 km away, and a senior Provincial Education Officer and then with 11 teacher educators at the PNG Institute of Education. The questionnaires were completed as part of the trial together with an abbreviated version of the workshop using the design, a preliminary manual and a reader. A full workshop manual was then produced taking account of the feedback from this phase. We have tried to keep the language in the manual accessible for teachers who may have low personal literacy.

PHASE 2: WORKSHOPS WITH TEACHERS

Care was taken to implement the model taking account of diversity. Workshops were planned to be held in remote but accessible areas. To take account of diversity of cultures and ecologies, we have deliberately selected to hold workshops in areas with three different ecologies: *highlands* areas, *coastal* stretches, and *hinterlands* such as mountains in coastal provinces. Similarly we have selected different language types. These include both Austronesian and non-Austronesian languages and languages from different non-Austronesian language families. Facilitation teams were planned to include both an Australian and a Papua New Guinean, with at least one researcher or assistant familiar with the community and language. Prior negotiation with the community has been essential for negotiating purpose and partnerships, contacting teachers, organising a welcome in the area, and security of researchers. All have been in small centres with no shops except for a house-style trade-store in some cases. Access has generally been by rough unsealed roads or long dingy rides. Most of the workshop venues have not had electricity so we have had to use generators, usually at night. Where one venue had access to the power grid, supply was intermittent.

We held four workshops in this phase with a total of 97 teachers. Two team members facilitated a coastal school workshop in Central Province and another two in a remote highlands village in Hela Province. A third larger workshop was held in a remote coastal

district centre in Madang Province. This workshop involved teachers from at least thirteen language groups (teachers often had more than one home language) and both coastal (Austronesian) and hinterland (non-Austronesian) languages. In one case the early childhood Papua New Guinean lecturer had to take her workshop to her village area without the Australian as a landslide on the road, deaths, and subsequent strife delayed the workshop. Other workshops that were planned were cancelled due to strife around elections and road damage.

We found that the teachers needed more knowledge on how children learn arithmetic and the key concepts of measurement. It was evident that neither the syllabus outcomes, the teachers' guides nor their teacher training (if any) had adequately unpacked for these teachers the key foundations of early number and arithmetic or measurement. Patterns were seen as spatial designs, but not as linking to number. The teaching of the use of non-counting by ones techniques was a high priority for efficient arithmetic strategies. There was no systemic approach to establishing multiplication as equal rows and groups, and how to develop number knowledge using cultural groupings, rhythm counting and group counting. For measurement teachers needed to know what attribute they were measuring, how to establish this attribute through activity, what a unit was for this attribute and how it is used to measure. Work on area and area units was new to the teachers. The use of open-ended questions for learning and practice was also critically needed.

We introduced some of these elements as needed within the first five-day workshop, and then modified the key principles for following workshops. We added and elaborated principles on early mathematical thinking and learning experiences to promote children's efficient mathematical thinking. We dropped one-way arrows between elements of the design as we felt the principles were interrelated in more complex ways than single arrows could show. These changes and elaborations are shown in Figure 2.

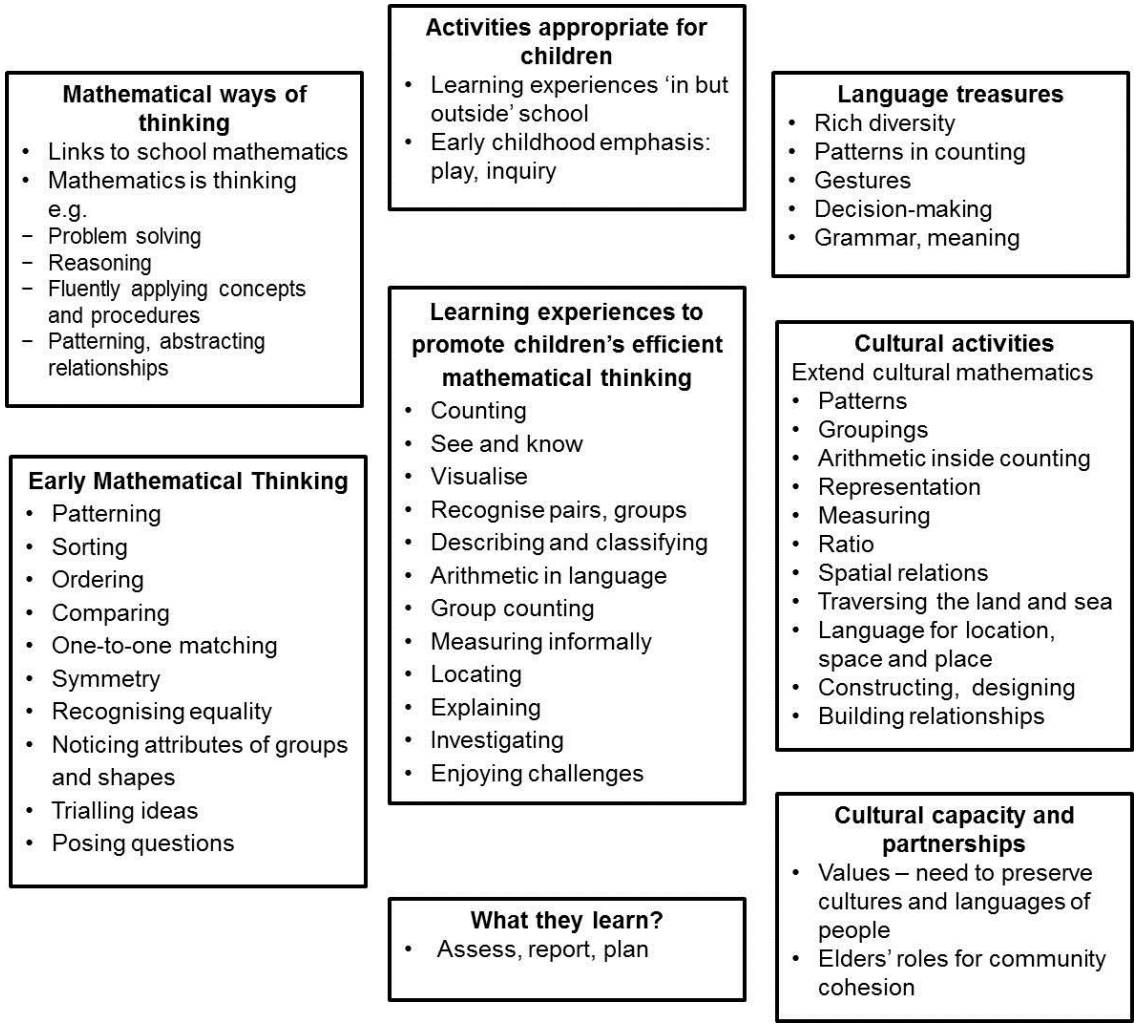

Figure 2. Design of key principles for teacher professional development in *Cultural Mathematics* after the second implementation in Phase 2.

Teacher evaluations

Workshops were concluded with evaluations from participants. There was an overwhelming positive response, with teachers commenting that they had learnt a great deal about teaching mathematics, asking questions, providing group activities, linking between cultural mathematics and school mathematics, and how to teach children arithmetic more efficiently. The evaluations indicated that the strengths of the workshop include both the language and culture focus and the use of the inquiry method. By the end of the workshop teachers could prepare an inquiry learning plan for a week of lessons with adequate resourcing, questioning and activities for children to speak mathematics and develop

efficient mathematical proficiencies. This was evident from the learning plans they prepared and their implementation in either the classroom or with peers. Many of the teachers asked for more workshops like this, which was pleasing since our focus is on providing teaching ideas at a theoretical and planning level (Bino, Sakopa, Tau & Kull, 2014).

Negotiating the relationships between cultural practices and school mathematics

A significant challenge of the workshops was negotiating the relationships between cultural practices and school mathematics. We, like others, recognise the importance of both; as Mukhopadhyay, Powell and Frankenstein say:

> We would recommend that mathematics instruction start from the points of cultural familiarity, brought out in the curriculum in a deep way connected with the entire context of intellectual activities of the particular culture. But we also recommend that all students learn about … the "current academic math" culture (2009, p. 77).

The learning plans developed in the manual and by participants followed the inquiry method with cultural activities prominent at the *tuning in* and *finding out* stage. Our approach was similar to the four-stage stepped model described in Barta and Brenner (2009): 1) utilise local experts and elders to engage with a significant cultural activity; 2) explore connections between the activity and the mathematics curriculum to find teaching points; 3) plan lessons to teach the relevant concepts; and 4) assess. To some extent, the process that we are requiring of the teachers and researchers is a form of group internal mutual interrogation (Adam, Alangui, & Barton, 2010). They are both cultural representatives with an embedded and practical knowledge of the cultural activity and mathematicians to the extent that they are expected to teach mathematics.

An extended example illustrates the interrogation of one cultural activity, the making of bilums (string bags). This was a focus in workshops in both Hela and Madang. The workshop in Hela included visits from Elders who were experts in the creation of various cultural artefacts, including a woman who is recognised as an expert bilum-maker. The participants then discussed the mathematical aspects of the activities. Mathematical features of bilum-making discussed included the number of rows, the number of loops in each row,

the nature of the relationship between the number of loops in each row – a decreasing and then increasing pattern, and the bi-sided symmetry of each bag.

The challenge occurs in moving from the *finding out* stage to the *sorting out* stage, where the mathematics becomes foregrounded, and the cultural artefact is backgrounded. This is a leap into abstraction; so for example, bilum-making might lead into other activities involving number patterns, particularly decreasing patterns. The question was how to make this leap without disconnecting the bilum or house making from its cultural context. It was particularly challenging because the teachers were not solid with the key foundations of early number. The step towards abstraction was mediated by the creation of a mathematical model.

In the case of bilum making, the rows were modelled with lengths of cane. The Hela and Madang bilums are made in different ways. For the Hela group, they began with a set of lengths and chose one to represent the first row. The next row was then modelled by breaking off a small piece from each end. Subsequent rows were formed through breaking longer pieces off each end. Interestingly, for each row the participants broke off two pieces to represent the decrease in number of loops at each end of the row. They did not ever break off one longer piece to represent the total decrease in length of the row, reflecting the symmetry inherent in making the bilum. The numbers of loops in each row was talked about each time as a total and the number of loops decreased. However, using cane strips for each row presents a series of continuous lengths. The cane lengths have a relationship to the actual bilum-making, as for each row, a cane strip is used to hold the loops open until the next row is added, ensuring regularity of size, much like a knitting needle is used. One of the researchers suggested using small stones in rows to represent the loops. The participants appeared to agree that this was a possibility but did not take it up.

However, a similar suggestion in Madang resulted in extensive discussions on equal groups using stones to represent the equal part rows that formed squares. After the teacher demonstrated the various ways of creating and storing the twine, the teachers developed a plan that linked to measurement of long and short lengths of rope followed by the pattern of coloured rows and natural rows in the bilum design. They represented this in terms of number patterns that they then extended in the *going further* aspect of the learning plan.

Teachers wrote numerical patterns in the *making conclusion* sections and discussed finding out other bilum patterns in the *taking action* section of their plans. These teachers were connecting the mathematical ideas of culture and school and developing mathematical learning plans.

The teachers required substantial guidance to enable them to see both the mathematical significance of the bilum-making and the mathematics of the bilum-making as related to other mathematics. It had to be stressed that the goal was not to teach lessons on how to make a bilum. As well as the demands of the process of mutual interrogation, it is this role of mathematician that presents such a significant challenge, due to the teachers' limited understandings of many key mathematical foundations.

The notions of patterns and relationships proved to be a key to making links between cultural and school mathematics. Unpacking practices and discussing key aspects of practices was necessary for the recognition of cultural mathematics. The inquiry method provided an extended development of the mathematical notions to go from cultural mathematics to soundly developed school mathematics with all the appropriate investigation and consolidation required of young children learning to count and do arithmetic, including in a language additional to their home language.

Language

Language issues continue to be a real but important concern that had to be addressed if students were to develop sound English mathematical concepts. For example, words like unit, especially area unit, are not easy to identify in many of the languages. Although many teachers are multilingual and adept at switching between languages, the specific language required to teach mathematics in their Tok Ples is not always readily accessible.

Several guidelines and suggestions have been made. A word list and what to record and discuss have so far proved valuable in furthering discussion on these issues. In many cases, mathematical phrasal terms need to be regarded as units of meaning rather than trying to translate each word (Edmonds-Wathen, Sakopa, Owens, & Bino, 2014). Given the diversity of languages, further development of the guidelines would remain as general principles with examples appropriate to different language structures and ecologies. Teachers are well

aware of the benefit of teaching in children's home languages in terms of readiness of understanding.

PHASE 3: THE PROVINCIAL EDUCATION TRAINERS

For Phase 3, the design of the key principles was re-simplified by giving only the principle headings. The manual was reorganised so that it clustered the work into the three sections beginning with the culture and language cluster which is now shown on the left of the design followed by the mathematical thinking cluster on the right. Both clusters inform actual teaching practice which is presented in the middle. This design is presented in Figure 3.

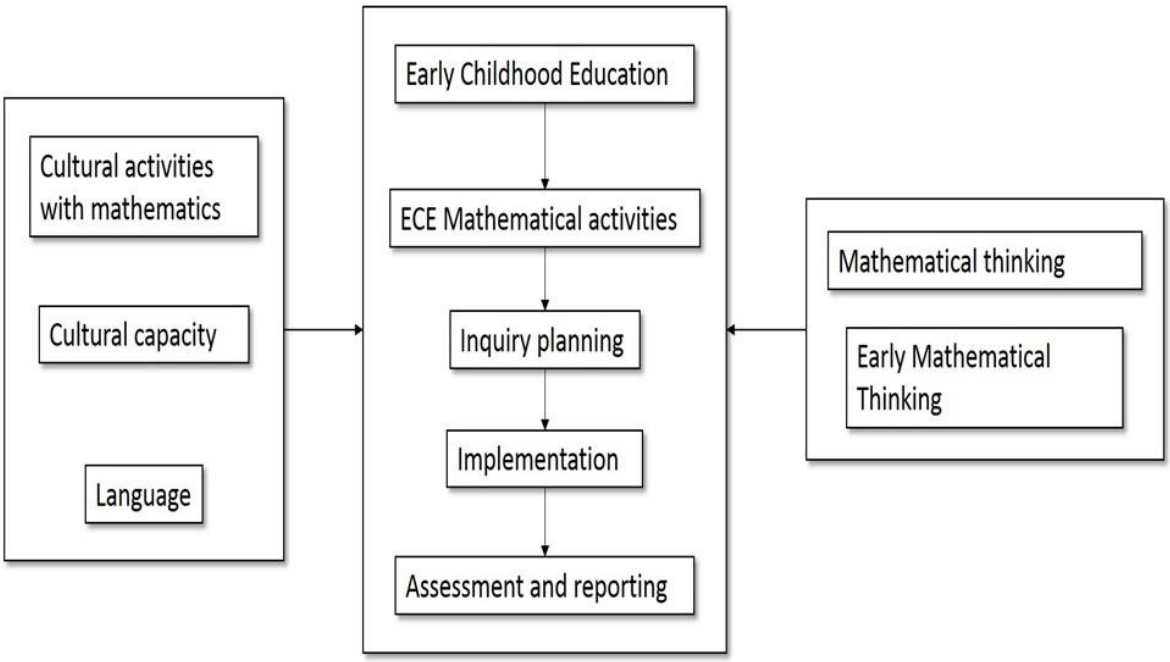

Figure 3. The design for implementation in Phase 3.

This phase has involved workshops in Jiwaka Province with Provincial trainers who then assisted training teachers, in Central Province with a workshop for Teachers-in-Charge who are expected to share their learning with other teachers, and one in the Eastern Highlands Province with trainers assisting with group work for two weeks, the longer workshop being more worthwhile. The first workshop was fraught with difficulties such as a clash of workshops and deaths while difficulties with communication were generally a problem.

Nevertheless, the Education Officers, trainers and teachers did their best and 66 more trainers and teachers attended training.

It was evident that there is a further need for simplifying the manual so that the trainers can deliver the materials. There were words that the trainers could not read and they only partially picked up on the principles in terms of practice so they could teach them as if they fully understood them. This was partly due to the lack of time available for their own training. Further delivery of the program with the trained teachers should make considerable difference to their effectiveness. For the teachers and trainers the principles required a change of understanding and practice. In particular, the language and style of teaching had to change but so also the incorporation of cultural mathematical knowledge. We will continue to simplify the manual but retain the principles.

PHASE 4: DELIVERY WITH TECHNOLOGY

The final phase will involve the delivery of the workshop using a technological platform or e-resource. To achieve the last phase, we are trialling the use of computers and solar panels in remote schools. The e-resource has been developed but so far its use has been to display the video-materials to accompany the workshops. Its use by teachers with initial input on computing has not yet been carried out. By the time of this last phase of the research new mobile technologies may be more appropriate than computers such as using SD cards for mobile phones. Delivering the resource via the internet is not yet feasible given that in general access to the internet is still not cheap or easy. Mobiles can only be used in some places and there is no 'cloud' access and hardly anyone has an operating fixed line including Education Department divisions and teachers colleges, let alone a school or teacher. In many places, even access to power to charge a mobile is problematic.

CONCLUSION

Appropriate guidelines for elementary teachers to recognise and use cultural mathematical proficiencies for transition to school mathematics were developed and proved to be meaningful to teachers. The modifications made to the principles included emphasising how young children learn counting and arithmetic and some simplification in presentation. Design-based research provided a means to establish an appropriate, flexible,

contextualised, interactive, and adaptable design of principles for professional learning for elementary school teachers in PNG. The design was developed and implemented by Papua New Guineans for Papua New Guineans and evaluated by the teachers as well as the seven researchers (two are Australian expatriates) familiar with the strengths and diversity of Indigenous cultures.

The principles and information have impacted on the teachers' understanding and at least immediately on their preparation for teaching. Teachers now have simple reading material to stimulate discussion about mathematics topics that have previously been difficult to develop. Discussion of the role of Elders in school was relatively new to teachers' thinking although they may have just accepted they had the necessary knowledge or the hegemony of the view of what is school mathematics and what is past (and often implied as not relevant) cultural knowledge was hard to overcome in some cases.

The initial materials were found to be extremely valuable if not fully understood by teachers. It was possible to present the guidelines so they were meaningful to teachers but it was clear that the videos and activities provided the main way in which the ideas of the professional learning could be appreciated. Reflection by researchers has led to further refinement in presentation both of the principles and of the accompanying manual.

Approaches to teaching counting and early arithmetic were previously limited and so this new knowledge is particularly important when teachers have had little or no training and resort to teacher demonstration or just talk (sometimes with chalk) teaching. The value of inquiry in early childhood and the introduction of many activities and games for transition from home to school knowledge is particularly relevant for these elementary school teachers. The use of readily available materials to encourage group work as well as the unpacking of mathematical processes or thinking within cultural activities were particularly motivating for the teachers.

We have yet to obtain sufficient data to know the final outcome in terms of implementation in schools. We hope that in future the trainers can work with teachers in their own schools as facilitators or at least visit for follow-up professional learning.

It is apparent that there is a real need across the few institutions training elementary teachers and senior departmental officers for spreading the principles of culture and

language; understanding of what mathematics really is especially in terms of cultural mathematics and how it links to school mathematics; and early childhood education and in particular how young children actually learn mathematics and the teacher's knowledge required for assisting this development. More widespread dissemination has been requested by these institutions both of the theoretical principles that drove the practical implications and the supporting materials.

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