Abstract: Design-based research is used to evaluate an appropriate design for teachers’ professional learning on improving the teaching of mathematics in Elementary schools in Papua New Guinea using local languages and cultural practices. It builds on research into mathematical cultural practices in PNG societies, knowledge of children learning mathematics, perspectives on equity in education, and understanding of language complexities and how they relate to mathematics education. The design is implemen ...
Improving the Teaching of Mathematics in Elementary Schools in Papua New Guinea: First Phase of Implementing a Design

Vagi Bino  
*University of Goroka, Goroka, PNG*  
binov@uog.ac.pg

Kila Tau  
*Curriculum and Assessment, National Department of Education, PNG*  
Kila.Tau@education.gov.pg

Kay Owens  
*Charles Sturt University, Dubbo, NSW, Australia*  
kowens@csu.edu.au

Mirou Avosa  
*Curriculum and Assessment, National Department of Education, PNG*  
Mirou.Avosa@education.gov.pg

Martha Kull  
*Curriculum and Assessment, National Department of Education, PNG*  
Martha.Kull@education.gov.pg

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Design-based research is used to evaluate an appropriate design for teachers’ professional learning on improving the teaching of mathematics in Elementary schools in Papua New Guinea using local languages and cultural practices. It builds on research into mathematical cultural practices in PNG societies, knowledge of children learning mathematics, perspectives on equity in education, and understanding of language complexities and how they relate to mathematics education. The design is implemented in a professional learning workshop and then evaluated and modified. This paper presents the results from the first phase of implementation of the design and how it has been slightly modified for future implementations.

**Introduction**

Elementary education is dependent on the understanding of teachers to build on cultural knowledge and to assist students to transit to school mathematics without dysfunction and loss of identity. The research design used in this study is design-based research. Design research is a relatively new research method (Bell, 2004; Collins, Joseph, & Bielaczyc, 2004). A model based on theory and research is designed, tried, improved and validated. The methodology is deliberately developmental in approach as it provides a way of researching designs. A design is developed from research, chosen perspectives on education, and experience in the field. It is implemented and evaluated. The design was of key principles to assist elementary teachers to recognise and use cultural mathematical proficiencies, to develop their knowledge of how young children learn mathematics, to consider language usage for ideas that are important in school curriculum, and to develop vernacular phrases for school mathematics. A small number of case study conversations with communities and teachers are undertaken as part of the evaluation of the design and its implementation in workshops. Each case study will be evaluated and inform later ones for a validated design. The design will be modified during several phases. This paper reports on results from the first implementation in phase 1, involving teachers from one school, within one language group, and in one ecological region. The research will also develop a design for professional learning with technology which is not a focus of this paper. The research will improve education for students in more remote areas where
vernacular languages are strong, to maintain respect for Elders and hence strong values in society.

Through the Glen Lean Ethnomathematics Centre (GLEC) (last updated 2008), University of Goroka (UoG), and other researchers, eg. Paraide (2010) at National Research Institute, Smith (1984), Lean (1992), and Owens (2001), there is a growing body of research about different PNG language groups and their mathematical proficiencies, mostly about counting. Matang (Matang, 2008; Matang & Owens, 2006) and Paraide (2003) show how well vernacular education can improve conceptual learning for early arithmetic strategies. Muke (Muke & Clarkson, 2011) showed Year 3 teachers look to use vernacular in their teaching.

While the ways of thinking about counting and the counting words have been reasonably well disseminated, there is still work to be done on building on the vernacular words and arithmetic strategies (Owens, 2000) and for other mathematics concepts. Further, the ideas on space and measurement have been less well disseminated. Through GLEC, UoG in recent years, Owens and Kaleva, with the assistance of numerous participant researchers especially Muke, Sondo, and Matang, have gathered data on measurement and analysed the data for a range of different cultural groups across Provinces (Owens, 2010, 2012b, in press-a; Owens & Kaleva, 2008a, 2008b). Data from written records, questionnaires, interviews, papers by participant researchers, and village field trips come from around 350 language groups and are supplemented by over 60 village stays by these researchers (over a 40 year period). GLEC houses 250 projects by preservice and inservice teachers that illustrate how village activities such as gardens, building bridges, traps, canoes, weaving walls, games, and exchanges as well as counting can be linked to mathematics. There was a strong recognition from these student teachers that this would strengthen students’ learning and understanding of mathematics and revitalise cultural practices (Owens, 2012a, in press-b).

In addition, without conversations between Elders and teachers in a language group, there will be a colonisation of thinking (Tuhiwai Smith, 2005; Owens et al. ) and a transliteration of language rather than a conceptual development of language (Meaney, Trinick, & Fairhall, 2012). By contrast, there are ways of linking cultural knowledge with school knowledge as the Yolngu did at Yirrikala, Northern Territory (Thornton & Watson-Verran, 1996). Unlike the Maori in Aetoroa, New Zealand, the issue for PNG is that there are many language groups and so a system that facilitates quality continuities between home and school is required.

Research Questions

The two foci for this research were:

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

1a. Can past research be converted to guidelines for the many languages & ecologies of PNG?
1b. Can linguistic guidelines be developed to guide communities to determine appropriate vernacular phrases for school mathematical concepts?
1c. How do the guidelines need refining for elementary teachers to understand?

Focus 2: How can technology assist professional learning?

2a. Has technology, infrastructure, costs changed sufficiently to permit this?
2b. How can technology/video enhance this understanding?
First the research team used mathematics education theory and experience to develop important points necessary for successful professional learning. These seemed to cluster into four key areas to influence teachers’ preparation of activities for children for learning. This design is evaluated through a trial, modified to improve the design and tried again. We intend to trial it in different ecologies of PNG: coastal, highlands and hinterlands (behind the coast). This report builds on only the first trial in one school. This preliminary design is illustrated in Figure 1.

![Figure 1. Preliminary design of key principles for guiding Elementary Teachers on Cultural Mathematics.](image)

By trialling a workshop that made use of this design, we can determine how effective it is. We have done this by observation, evaluation of the work of participants during the workshop, reflective journaling and discussion, informal comments from teachers, and some preliminary testing of 18 children in Grade 2. We also have an evaluation to obtain responses from participants to assess the design. This is an open-ended questionnaire which could be completed in groups. It covers: the relevance of the 4 key principles, the importance of aspects of activities for children (purpose, nature of children’s mathematics learning, inquiry planning approach, and role of assessment), what was something new they learnt, how they used the principles in planning, the suitability of the workshop plan, their sense of involvement, change of perspective, and suggestions for improvement. After

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1 From University of Goroka, Dr Samuel Kopamu, Mrs Priscilla Sakopa, Mrs Geori Kravia, Mrs Vagi Bino, Mr Kevin Kemito Me’e, Ms Susie Daino. From Charles Darwin University, Dr Cris Edmonds-Wathen. From Charles Sturt University, Dr Kay Owens.
time has passed for implementation of ideas, teachers will submit a questionnaire, test some children, and interview some parents. This will extend our preliminary evaluation of the design.

**Workshop Context**

Tubusereia is a very large village on the coast about 40 minutes by road from Port Moresby. There are many houses out over the water with others spreading inland and along the coast for more than a kilometre. The village uses its Tok Ples Motu constantly although there are many words related to mathematics concepts that are transliterations of English words (or as they say modern Motu). They will also use English counting words in Motu sentences especially on reaching 10. It depends on what has been bundled (roughly in tens) to select a Motu word for 10.

The school is built on the side of a hill in permanent classrooms within the primary school grounds. The teachers all speak good English as well as Motu. Basketball is a favourite game for some of the teachers who are all mature-aged with families. Three male teachers and 8 female teachers attended a workshop on improving the teaching of mathematics in Elementary Schools by using local languages and cultural practices (PNG) held on 9 – 13 September, 2013. Except for one teacher who has had other work experience, they have all completed the short 6-12 week courses (at least one) for elementary teachers with follow up by distance and in different formats. They are generally grade 10 graduates.

We were joined by the head teacher of the neighbouring school for the whole week and by one of her teachers for a day at a time. The school Board chairperson (who might like to become a teacher) joined for the whole week and a Local Government Councillor who was a former lecturer from PNGEI also attended briefly during his busy schedule. We were also joined daily by three staff from the Curriculum and Assessment Unit – responsible for mathematics and community living curriculum. The two team members stayed in the village with relatives. The family also provided lunches daily.

**Results**

The school really accommodated the workshop. Teachers’ attendance for the whole week from 8am to 4pm was very high. They permitted us to observe their lessons on the first morning. This provided us with good insights into the teachers’ strengths as people and teachers as well as some of the areas in which they lacked knowledge on mathematics education. This was partly a result of an unclear syllabus, teachers’ guide, prior training, and their own schooling experiences which followed fairly rote methods of learning. Teachers were able to give answers to addition, multiplication and division questions and knew some shape names but they felt that counting was a good way to go for children solving addition problems even in Grade 2. They were not aware of the importance of equal groups or rows for multiplication nor the use of group counting as a process for learning. Patterns were mostly about design and they had not experienced how patterns can be used for establishing numeracy. This was evident from their teaching, my teaching of a class, and from the responses from children on the numeracy questionnaire. As in many elementary schools, children copied from the board with or without understanding. Teachers were limited in their use of questioning especially open-ended questions in mathematics.
The workshop began with a small mathematical introductory activity which set the scene for interaction and showing how simple tasks can lead to people talking mathematics rather than just listening. It also showed the use of a question that has multiple answers. Then, in groups, they talked about community activities that involved mathematics. They responded to a series of relevant questions and then reported on their discussions. They discussed tattoos, gardening, canoe racing and basketball. They enjoyed beginning with their culture which is truly rich with skills to adapt to their environment. We then looked at mathematics and in particular early childhood mathematics. We did activities and watched videos that illustrated the development of young children learning. We emphasised the links to culture as well as to play and investigation as key approaches to learning.

We then looked at an inquiry method for planning for a week (Murdoch, 1998). The steps for this are: Tuning in; finding out; sorting out; going further; making conclusions; taking action; and sharing, discussing, and reflecting. Small groups looked at early mathematical readers and example lesson plans that illustrated what this learning plan looked like in practice. The grade groups then took a cultural activity and prepared a weekly learning plan which they taught the following morning from 8am-12noon. From observations, we were able to see how much the teachers had developed and also where there were still some needs. For example, the mathematics in the cultural activities was drawn out strongly by the teachers. There was a greater ability at having children talk to the Elders and to observe attributes of the garden, the tattoo pattern, and the yams. The children were all actively involved in the lessons. Resources were carefully planned for group work. There was still some need for teachers to encourage more child talk and less teacher talk. There was some need for the Grade 2 to have a greater focus on mathematics through a more open-ended question. The intention of the lesson “to find how 24 fish might be shared among 4 families, not necessarily equally did work in one class” but open-ended questions, patterns, and open-number lines to help visualise and find answers to addition problems was evidently a relatively new idea for teachers and children. There was less direct copying from the board or from other children in this lesson showing that the new approaches were appropriate for the children.

We then discussed language sources and realised the value of the dictionary and the multilingual teaching approaches. The teachers were keen to make use of language for mathematics. We also discussed the importance of cultural activities which were amazingly strong and the variety of possible sources of culture. They agreed that using Elders was an important way forward, not just to engage children but also to ensure good cultural practices.

We then modelled the one-to-one interview with children, they practiced it on each other and we also quickly looked at how to prepare learning stories to share with parents about the children’s learning. In the morning they were ready to test 18 grade 2 children. This took longer than anticipated and other aspects for this testing we will modify, noting in particular that this is for assessment and not for teaching. All participants assisted in the testing.

The final session, we worked in Grade groups on their chosen cultural activity planning a learning experience on A3 paper using a format for developing a learning plan for a week. They did not want to stop working on this. It was so much more detailed than the previous planned learning experience. The teachers said they had learnt so much from the workshop unlike their training from which they felt they had just prepared teaching aids. There was a good link between the activities, the workshop explained the syllabus more, and the theory on how young children learn mathematics.
The assistance of the three staff from Curriculum and Assessment and Vagi Bino in group work should particularly be noted. They really guided the discussions in the group work and are to be commended. At the same time, they made it clear in discussions that they themselves were learning much more about how young children learn mathematics, appropriate activities, and how cultural activities can be linked into the children’s learning.

At the end of the day, the teachers had sketched a learning plan for a week as illustrated by one of the plans given in Figure 2.

<table>
<thead>
<tr>
<th>Grade 1</th>
<th>Context and Resources, further resources for extending and prompting</th>
<th>Purpose</th>
<th>Key ideas</th>
<th>Key steps, prompts, questions</th>
<th>Assessing processes – what to observe and question about</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultural activity with mathematics</td>
<td>People involved in the activity</td>
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<tr>
<td>Harvest of yam garden</td>
<td>Lahui’s mother-in-law</td>
<td>Syllabus 1.1.1 Follow and give directions to move from place to place</td>
<td>Space – direction</td>
<td>Tuning in</td>
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<td></td>
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<td></td>
<td>• Tell a story or share your experience of your yam harvest. Show some yams from a good or bad harvest.</td>
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<td></td>
<td>Mainly women who garden.</td>
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<td></td>
<td>• Ask where the main yam gardens are for the village? Why are they there?</td>
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<tr>
<td></td>
<td>Key questions: When do you plant yam garden? When do you harvest yam garden? What feasts or village activities do you use the yams for? How many yam mounds</td>
<td></td>
<td></td>
<td>• Sometimes we want to explain where places are to others who may not have been there before. How do we do that?</td>
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<td></td>
<td>• Give children directions in terms of east and west and how many strides (normal walking) and left and right. See if they can guess whose house. Then</td>
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<td></td>
<td>• Children follow the directions to a teacher’s backyard yam garden.</td>
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<td>• At the garden ask questions related to the other topics (measurement, chance, pattern and number)</td>
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<td>Sorting Out</td>
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<td></td>
<td>• Give direction of main yam gardens using east and west and using physical geography like river, coconut, mango tree)</td>
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<td>• Explain direction – hiri east (to Tubusereia houses, &amp; Gaire villages and where the sun rises). West – sun sets; south where southern cross pointers are pointing, north opposite.</td>
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<td></td>
<td>• Locate Prep classroom, toilet, gate,</td>
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<td>per garden? Do some people do it differently?</td>
<td>UC big church using bearings.</td>
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<td>---------------------------------------------</td>
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<tr>
<td><strong>Going further</strong></td>
<td><strong>Taking Action</strong></td>
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<tr>
<td>• Ask direction of places further away like going fishing at Loloata, driving to Port Moresby, looking up at the mountains behind the village.</td>
<td>• Children in pairs plan a route telling their other two friends how to go from the classroom to some other part of the school using east, west, south, north and number of paces (strides). They write it down – e.g. turn east, go 5 paces, turn north, go 6 paces etc. The other two friends follow the route to see if it works.</td>
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<tr>
<td>• Look at a map of the village that the teacher has drawn. Children help teacher to put landmarks on the map.</td>
<td>• Children draw a simple map of how to go from their home to school. Putting in landmarks. (This is not a copy of the teacher’s map but their own idea).</td>
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<tr>
<td>• Children locate places east, west, north, south of one place compared to another.</td>
<td>• Children draw a simple map to show how to go from their home to the yam garden.</td>
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<tr>
<td><strong>Sharing, discussing, reflecting</strong></td>
<td><strong>Other Topics</strong></td>
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<tr>
<td>• Find someone who got lost hunting and fishing but found their way home.</td>
<td><strong>Shapes of yams</strong></td>
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<td></td>
<td>• Children describe the yams.</td>
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<td></td>
<td>• They compare with more straight faced and curved shapes. They imagine cutting through yams to make the cylinder or rectangular prism (box), or cone.</td>
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<tr>
<td></td>
<td><strong>Number</strong></td>
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<tr>
<td></td>
<td>• Count yams per mound</td>
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<tr>
<td></td>
<td>• Do groupings per mound – for equal groups for multiplying (skip counting, or adding)</td>
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</tbody>
</table>
Measurement
- Length of yam, getting lengths that equal other lengths by joining
- Mass of yam
- Groups yams according to size of masses
- Areas of garden

Pattern
- Number of yams per mound
- Compare area with number of yams per garden.

Chance
- Is it possible to dig 6 yams from one mound in this garden?

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**Figure 2.** Example from workshop of final planning of weekly learning plan using the Inquiry Method.

Reflective evaluations\(^2\) were coded for critical points and common ideas were noted. These can be summarised as follows. The key principles were regarded as “relevant and vital for identification of mathematical concepts that exist in the everyday life of a child in the community.” “They are the very core of planning and delivering meaningful mathematics in the early grades and progress-bridge into the next higher level. … The listed principles and the inquiry approach can be used across different cultures to teach mathematics.” They encouraged questioning and responses to questions that “reflected mathematical ideas, skills and languages present in the cultural and community based activity/ies.” These were easily “linked to the national curriculum for mathematics at elementary level.” The key purposes were evident in “The lesson plans and resources were used to teach students mathematics” and yet “the importance of culture, traditions, customs and language/s of the society and to live by the expectations of all these is very real. … to be literate in the local language so as to interpret the mathematical language meaningfully (provides) for satisfactory results.”

“The [cultural] activities are the ones they already knew and they were learning new things in mathematics,” “building on from the home knowledge to the formal school setting.” “Inquiry planning to teach mathematics is very important … the use of questions to stimulate (teachers to think critically) and create a range of learning activities in a cultural activity was very influential.” The inquiry method (simulated in the workshop) led to questions, discussion, and “the group into identifying the maths concepts and suggest activities for the knowledge to be gained and identify the suitable skills to solve the problem and of course suggest how assessment can be conducted. … Using inquiry approach to plan teaching and learning makes it easy to also plan assessment for the purpose of monitoring individual learners’ progress and achievements in mathematics.”

Participants learnt many new things including:

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\(^2\) At the time of writing 3 evaluations from Curriculum and Assessment Officers has been received. Quotes are from their very comprehensive evaluations. The others were not received by post at the school.
• how to use the inquiry method for effectively teaching mathematics;
• how “to use the cultural activities and turn them into formal units of work and use the process the children know and are able to comprehend and express their experiences well in the languages they know well to be the basis of teaching mathematics in the early years of formal learning”;
• how to use “mathematics learning situations to teach language” in play, in procedures, in narratives (like in the readers), and in activities;
• how “to understand the simplicity and the complexity of the particular cultural activity;
• “to think critically about what mathematics are inside the activity, … identify the kind of knowledge they want to acquire and the skills to be equipped with and practice to solving problems, … to make teaching and learning stimulating and meaningful”; “the explicitness of the inquiry learning method that exposed a lot of mathematics concepts that could be learnt within a short space of time”;
• “questioning techniques used to bring out reasoning abilities of students and mathematical concepts within the cultural activities used”;
• “motivational ways of teaching – keep students focused … teachers are also motivated to stay with students’ learning”;
• “formula should not be taught or drilled without developing activities to build the formulae”;
• “preparation of questions and using them to help students to do mathematics appropriately”;
• “the use of cultural activities were planned well to unpack the mathematics concepts”;
• “the terms and descriptions of mathematics concepts used and units identified”;
• “selection of cultural activities and resources within the community are easily accessible”.

Participants felt very involved, enjoyed themselves and had a sense of ownership and felt confident “to draw up good cultural mathematics content scope, plan and delivery … for a school year.” Indeed, the respondent provided an example for their own place. “My participation … has given me insights (knowledge) to view elementary cultural mathematics in a new way.” Following the discussions on cultural activities of sharing fish and yam planting, the respondent wrote, “I believe teachers have now realized the rich resource which can be utilized to teach mathematics meaningfully.” Among the critical inputs were the unpacking of activities of yam planting and fish sharing to link to addition. “I found the approach very interesting and fulfilling. The mathematical ideas extracted from the cultural activities were intriguing. They were amazing. Students and teachers were intrigued by the math knowledge that were extracted from the community activities.” “The resource manual used in the work shop contains rich resources to help teachers teach cultural maths in schools.” “I can now plan for cultural maths with this rich knowledge I acquired from the workshop” using the inquiry model of teaching. Assessing the children was a culmination in the questionnaire of the various activities and points raised in the workshop.

One respondent suggested the workshop could have been improved by a balance of activities to encourage the use of mathematical languages in learning situations. “There were activities on number and measurement, space and shape, area and length, time and patterns. … It would be very helpful to have teachers identify the terms in their local
language that relate and reflect the concept of mathematics e.g. operation words, comparison words, grouping or sets, direction, positional words, probability etc. This is one of the weakest areas I have observed in the elementary and lower primary classrooms.” (We did provide a beginning for a mathematical dictionary but time was against us to develop this.)

The venue was very suitable thanks to the village women who prepared the meals and the relatively well-appointed school (power on some days and a few desks and chairs). The equipment and venue was “simple but well utilized with simplicity and humility.” Hopefully, this means it can be reproducible too. However, time was seen as an issue both for discussing things that were found out in assessing the students and later “after the research questionnaire participants could come together discuss and present solutions to problems faced by students and teachers in the research and discuss way forward. Eg. Bright students cannot understand the word pattern and find a word for pattern in their language. Solution: identify activities that can rectify the solution.” The workshop was seen to be advantageous to the children, the teachers, and the curriculum officers since the teachers could find out ‘problems faced by students in learning mathematics so that solutions can be based on evidence of students’ presentation in the research questionnaire”, teachers could “plan interesting cultural mathematics lessons and teach well connecting the cultural lesson to conventional mathematics”, and the curriculum officers could “write suitable curriculum instructions”.

As facilitator, it was evident to me that neither the syllabus outcomes, the teachers’ guides, nor their teacher training had adequately unpacked for these teachers the key foundations of early number and arithmetic or measurement. Some of the keys for early arithmetic are reflected in the interview schedule presented in Appendix 1. The teaching of the use of non-counting by ones techniques is a high priority for efficient arithmetic strategies. Having open-ended questions for learning and practice is also critically needed. Finally, for measurement teachers needed to know what attribute they were measuring, how to establish this attribute through activity, what a unit was and how it is used to measure. Work on area and area units was new to the teachers. Some books that could be read to the class or become readers for the children on these topics were provided to assist teachers to improve these ideas in future (see also the comment above in the evaluation on learning not to use formula before establishing concepts). The work on patterns and their links to number were also unknown. Patterns were seen as spatial designs. There was no systemic approach to establishing multiplication as equal rows and groups, and how to develop number knowledge using cultural groupings, rhythm (e.g., 1, 2, 3, 4, 5, 6, … has every third number stressed) and group counting (3, 6, 9…). Hence we covered this but made it more specific in the design of key principles for future workshops.

The evaluations also emphasised the importance of making changes at a broader and higher level. “The content of the resource material is sufficient. Carry out research in different settings like, urban, rural and semi urban settings to make meaningful conclusions. Also utilize the trainings with relevant groups like teacher training college, teacher education NDoE, elementary trainers etc throughout the country. A comprehensive report be written to the Department of Education for policy development purposes.” While this first workshop was in a semi-urban setting with strong local language, three workshops in remote areas have been also undertaken. We hope to write a more comprehensive report following this first phase of implementation.
Discussion and Conclusion

The first point to note about the project was the willingness to participate in the workshop and the importance of both the setting up of the workshop by Vagi with the school and community, the gaining of permissions by Kila and Kay, and the clear sense of need for such learning by the participants. We all learnt so much from each other.

The second point was that teachers were learning how to involve the children in talking about the mathematics of the experiences. They realised how important the cultural mathematics was for learning and transitioning from home experiences to school mathematics. They knew how important child activity was but began to see how this worked effectively in terms of investigating and not just rote practice. They appreciated how children would be engaged in learning through the planned, detailed activities.

Teachers also began to realise the steps by which children learn arithmetic, how they learn to add and what multiplication is. It became clear that teachers lacked this detail from their previous teacher training. This understanding was assisted by participating in activities and actually undertaking the testing of children and seeing what they were able to do. Teachers were learning that counting (by ones) was not the most efficient thing for children to understand addition or to explain the number facts they may or may not learn by rote drill methods currently being used. The teachers needed to assist children to move away from concrete object counting (including of stones and fingers and toes) towards visual counting and using relationships between numbers (e.g. doubles and pairs that add to ten) to improve children’s arithmetic.

On reflection on the design in Figure 1, it was decided to modify the design so that there was a frame that overlapped the mathematical ways of thinking and activities for children. It was on how young children learn mathematical ways of thinking and the kinds of activities that assist this. This revision is shown in Figure 3.

Of particular importance was how the geography and activities that took place on different spaces of the village assisted children to learn about direction and other mathematical ideas. This was evident in the lesson on yam gardens given during the week and in the final learning experience plans about fishing, gardening, and the wide variety of cultural activities that the teachers noted as appropriate for cultural mathematics.

Finally, it was felt that these ideas need to be spread at this opportune time to Elementary Teachers so that children will have a strong basis for primary school mathematics and later education. It was realised that the strength of mathematics in village was important to harness in young children beginning their school mathematics.

The key principles included:

- Mathematics as a way of thinking
- Young children thinking and learning to think mathematically
- Mathematics in cultural activities
- Cultural capacity
- Language sources
- Activities and learning of young children to maintain identity and including play and inquiry

These result in

- appropriate learning experiences for beginning mathematics in schools.

The inquiry method is expanded in Appendix 1. Its use of tuning in, finding out, sorting out, going further, making conclusions taking action, discussing, sharing, and reflecting
proved to be amazingly appropriate for cultural mathematics and readily implemented by the teachers in planning and in their initial attempt to use the approach to teach.

**Mathematical ways of thinking**
- Links to school mathematics;
- Mathematics is thinking e.g.
  - problem solving
  - Reasoning
  - Fluently applying concepts and procedures
  - Patterning and abstracting relationships

**Activities appropriate for children**
- Learning experiences “in but outside” school;
- Early childhood emphasis, play and inquiry

**Learning experiences to promote children’s efficient mathematical thinking**
- Counting
- See and know
- Visualising
- Recognising pairs and groups
- Describing & classifying
- Arithmetic in language
- Group counting
- Measuring informally
- Locating
- Explaining
- Investigating
- Enjoying challenges

**Language sources**
- Rich diversity,
- Patterns in counting
- Gestures
- Decision-making
- Grammar and meaning

**Cultural activities**
Extend cultural mathematics
- patterns,
- groupings,
- arithmetic inside counting,
- representation,
- measuring,
- ratio,
- spatial relations,
- traversing the land & sea
- language for location,
- space & place
- constructing and designing
- building relationships

**Early Mathematical Thinking**
- Patterning
- Sorting,
- Ordering
- Comparing
- One-to-one matching
- Symmetry
- Recognising equality
- Noticing attributes of groups and shapes
- Trialling ideas
- Posing questions

**What they learn?**
Assess, report, plan

**Cultural capacity and partnerships**
- Values – need to preserve cultures and languages of people
- Elders roles for community cohesion

*Figure 3. Learning design of key principles following first trial.*

Critical to the effectiveness of the workshops was total involvement of participants in the inquiry method. They participated in critical thinking in group work, asking and answering questions especially about the mathematics used in cultural activities, observing children, planning learning experiences. It was strongly recommended that this method be used as a basis for teacher resources for elementary school. It was presented in the workshop and materials in terms of a summary (see above), with many ideas for different strategies for each step, and with example lesson plans which acted as stimulus for the participants actually planning their own learning experiences for a week around cultural
activities. This was therefore a stepped process with initial questioning about activities, planning learning experiences for 3 hours on a cultural activity, putting it into practice, reflecting critically on that and then planning a further sequence. All planning was collaborative occurring in groups of teachers of the same grade with the inquiry structure and mentoring from the workshop facilitators.

It is also important to recommend that teachers be more familiar with young children learning arithmetic, measurement, seeing and using patterns, and about shapes. As mentioned earlier, ideas for this were presented through activities that participants undertook, in the manual, through videotapes of young children, and through testing children in an interview questionnaire. The expected ways of learning need further development and an example of the testing for Elementary Prep together with the recording sheet in Appendix 2 illustrates this development with which teachers need to be familiar.

In summary, one participant wrote:

The inquiry approach to planning, teaching and learning drove the workshop content, making learning very student centred. This approach has brought to light new ways to plan the content of the elementary cultural mathematics in our elementary schools. The experience was very educationally valuable. The future developments of cultural mathematics curriculum content support materials should ensure that students and teachers are encouraged to use the inquiry approach to design the relevant content for each grade level. (Mirou Avosa, 2013 evaluation)

Acknowledgements

The materials prepared through our research has been funded by AusAID through the AusAID Development Research Awards Scheme under an award titled Improving the teaching of mathematics in elementary schools by using local languages and cultural practices (Papua New Guinea) and Charles Sturt University, Australia.

The views expressed in the publication are those of the authors and not necessarily those of the Commonwealth of Australia. The Commonwealth of Australia accepts no responsibility for any loss, damage or injury resulting from reliance on any of the information or views contained in this publication.

We particularly acknowledge the teachers and community in Tubusereia who made us feel welcome, participated fully in the workshop and assisted us to evaluate the design. We also acknowledge the support of the PNG Department of Education, Superintendent Operations Elementary, Central Province Department of Education, Curriculum and Assessment Unit for their support and permissions. The staff of the University of Goroka, especially the Printing Division, for responding quickly to the needs of the project.

Appendix 1

Weekly Learning Plan for Mathematics

This is an inquiry learning approach (Murdoch, 1998). It may take more or less time to cover each step.

**Purpose:** Children are expected to think and do mathematics through activities linked to cultural practices. Children are expected to have a sense of belonging with the new ideas in culture and school through a good transition that links cultural ways of thinking with school ways of thinking.

**Key Ideas:** e.g. What is the new pattern and relationship? How does the thinking lead to problem solving?

**Prior knowledge:** What do they know? How do they think and feel?

**Resources:** Places to visit; materials for exploring, comparing, measuring, recording, modelling; game cards,
spinners; people for demonstrations and questioning

**Assessment:** Observing ways children try things, what they say, how they problem solving, what they write, what they ask to make clear or to extend their exploring

Day 1
- **Tuning In**
  - Motivating, real world experience e.g. outdoor; telling a story
- **Finding Out**
  - Observing, noticing, comparing, measuring, discussing mathematical patterns

Day 2
- **Sorting Out**
  - Discussing, modelling, comparing, making a table, drawing a diagram, finding same and different,

Day 3
- **Going Further**
  - Applying to other numbers or another situation, reading and discussing the maths reader, using symbols, playing a game, solving an open problem,

Day 4
- **Making Conclusions**
  - Summarising the mathematics, whole class discussion or story writing,
- **Taking Action**
  - Share at home, solve a real problem,

Day 5
- **Sharing, discussing, and reflecting**
  - Children explain the mathematics, write a maths story, write their own summary, say what new mathematics they have learnt.
  - Teacher reviews and decides where to next.

**Appendix 2**

Children’s Questionnaire – Prep

Sit the child next to you so you both face the same way. Have all the material ready, the questionnaire, the recording sheet, your pen, and a pencil for the child. Ask the question in English, wait. If the child is unsure, ask in child’s Tok Ples. If there is still no response ask in Tok Pisin. Record the language you and the child use.

Ask the questions, tick the response of the child. Add a comment if interesting method.

This is for assessment so you can wait, say question another way, and ask how they were thinking but avoid teaching and move smartly through the questions. You approve responses and even unspoken tries with happy ‘mm’ and smile but avoid praise. If children can’t answer the oral questions just make a note rather than let them see or use stones.

**Items are required**

- **At least 10 stones or other small objects** (6 need to be different to the others) (if the child can do all the Elementary Prep questions then try the grade 1 questions for which you will need 20 stones)
- **Two cloths or cardboard** to cover groups of stones as required.
- **A shape** made from cardboard or paper or dried bark or leaf: it can be traditional e.g. of a zigzag in a blind, a fish-shaped dish, a hook or sinker, or classifying group like “long, thin object” or “flat, round object”. It can be a school shape e.g. a right-angled scalene triangle.
- **Two thin ropes (string)** about 2 and 3 hand spans long
- **A picture of a rectangle for a yam garden** (if you do not grow yams in a rectangular array of rows, choose another plant that you might grow in this way e.g. kaukau). For Prep, the rectangle needs one row of two squares. Use the back for the child’s drawing of shapes and writing down the numbers for the pattern – write child’s name on it.
- Dot cards: 5, and 4 with 3 together; and numeral cards 4, 7, 10, 15
- Record sheet for each child – write child’s name on it.

Instructions for you are given in plain print and questions you ask the child are in *italics print*.

You should practice before asking the children. Read the instruction sheet and record sheet together to know what variety of responses are likely from the child.

**Start by saying:** I am going to ask you questions, I want you to say aloud what you are thinking as you do the questions.

<table>
<thead>
<tr>
<th>Task Number</th>
<th>Tasks</th>
</tr>
</thead>
</table>
| 1 | **Patterns**  
Take the stones and make a pattern in a row e.g. 2 black, 1 white, 2 black, 1 white  
*Show me how you continue this pattern.*  
*Describe this pattern.*  
*If black stone is replaced by hand clap and white stone by knee clap, clap the same pattern.*  
*What number pattern is this? Give the total group number and the part group numbers? Write this down in numbers.* |
| 2 | **Tell me about a local pattern of numbers** in one of our activities. |
| 3 | **Length**  
Place down two strings, but not straight.  
*Which rope is longer?*  
*What did you do to compare them?* |
| 4a | **Put out 6 stones**  
*How many stones are there?*  
*Can you count them another way?* |
| 4b | **Put out 6 stones**  
*How many stones are there?*  
*Can you count them another way?* |
| 5 | Leave that pile and put out a pile of stones.  
*Get me 4 stones* |
| 6 | Check by looking that there are 6 stones and 4 stones.  
*How many stones altogether?* |
| 7 | I want you to tell me how many dots on these cards. I will show them quickly. Show briefly when the child is watching. [Image of dots] |
| 8 | Say the numbers as I show you the cards.  
Display each card one by one: 4, 7, 10, 15 |
| 9 | Without counting, put out 6 stones and cover. *Here are 6 six stones*  
Briefly display, then cover again. Put out 2 stones.  
*Here are 2 two more stones. How many stones are there altogether?*  
Accept the answer and if correct or reasonable ask “how did you work that out?” |
| 10 | Put the stones away and say:  
*I have 5 ripe bananas and I get another 3 more. How many ripe bananas do I have altogether?* |
| 11 | Put out 5 stones.  
*I have 5 stones. (Briefly display, then cover).*  
*I’m taking away 3 stones. (Remove 3 without raising the cover) How many stones are left?* |
| 12 | Put out 8 stones.  
*I have 8 stones. (Briefly display, then cover)*  
*I’m taking away some stones and there are 3 left. (Remove 5 stones without lifting the cover but don’t show them to count.) How many did I take away?* |
| 13 | Put the stones away and say:  
*I have 9 bananas and I eat 4 of them. How many bananas do I have left?* |
| 14 | What are two numbers that add to 5?  
What are another two numbers that add to 5?  
What are two numbers that add to 8?  
Can you give me another two numbers that add to 8? |
| 15a | Present a pile of stones, more than 8, to the student. (Randomly spaced, not in a line. Do not count them out.) Use these stones to make groups. Each group has 2 stones. Make 4 groups. How many stones are there altogether? |
| 15b |  |
| 16 | **Fractions**  
Put out 8 stones  
*Show me half.* |
| 17 | Give the child the longer string.  
Here is a string. *Show me half.* |
| 18 | **Recognising partly covered shapes**  
Take the shape and screen the shape except one corner.  
*This is a game so we want to know what the shape might be and not what it really is.*  
Tell me what shape it might be in Tok Ples, in English.  
With your finger, draw its shape without touching the cover?  
Could it be another shape? *Why?*  
Show a little more of the shape.  
Could it be another shape? *Why?* or why not?  
With your finger, draw its shape?  
Could it be another shape? *Trace it.* |
| 19 | **Area (multiplication)**  
Show the picture of the rectangle  
Here is a picture of a garden for yams planted in rows of two.  
There are 5 rows. How many plants or mounds altogether?  
How do you know?  
Draw the garden area to show the 10 square areas for the 10 yams. One row is drawn. |
| 20 | How do people know when to plant yams? |
| 21 | Explain how people tell you how far to a specific distant garden. |
| 22 | **Direction**  
Without pointing, *tell me the way* to the cemetery. |
| 23 | **Location**  
Show the picture of the table.  
Here is a table with four cups. Which cup is on the left?  
Point to each of the other cups in turn and ask the child  
*How do you say where this cup is compared to the other cups?*  
Point to one on the right.  
Point to one in front.  
Point to one at the back. |
<p>| 25 | Do you like (Would you like ...) <em>learning mathematics in your Tok Ples?</em> |
| 26 | Do you like linking outside activities with maths? <em>Why?</em> |</p>
<table>
<thead>
<tr>
<th>Task Number</th>
<th>Tick response</th>
<th>Comments: working out, languages, actions</th>
</tr>
</thead>
</table>
| 1. pattern, 2, 1, 2, 1 | - Continues the pattern  
- Says 2, 1, 2, 1, 2, 1  
- Gives group number as 3 and part group number as 2 and 1  
- Writes down 2, 1 and brackets as three or 2+1 = 3; or 3, 6, 9, 12 |  |
| 2 + 1 = 3; (3, 6, 9, 12) | - Continues the pattern  
- Says 2, 1, 2, 1, 2, 1  
- Gives group number as 3 and part group number as 2 and 1  
- Writes down 2, 1 and brackets as three or 2+1 = 3; or 3, 6, 9, 12 |  |
| 2. Local pattern | - e.g., dance; or one up, one down weaving pattern |  |
| 3. longer, compares | - Just points  
- Gets ends carefully together and straightens string |  |
|  4a. counts 6 | - Uses some numbers and tries to match  
- One-to-one matching of stone with number tag pointing or moving each stone; order correct; finishes at 6  
- Counts in head only, may nod or move eyes as each is counted showing 1-to-1 matching, says 6 |  |
| 4b. groups, counts | - Counts in reverse order or starting with a different stone  
- Groups to help count e.g. in pairs |  |
| 5. counts 4 | - Begins counting correctly but does not finish correctly  
- Counts correctly |  |
| 6. 6+4 | - Says a number but can’t explain, or counts but makes a mistake  
- Counts from 1, takes a long time, stops at 10  
- Counts from 6 or 4 on to 10  
- Says 10  
- Quickly says 10 and explains they are a pair for 10 or similar |  |
| 7. see and say  
5  
4+3 | - Says 4 or 6 (incorrect but close)  
- Says 5  
- Says 4 and 3  
- Says 7  
- Says 7 and explains it is 4 and 3 |  |
| 8. 4, 7, 10, 15 | - Recognises 4  
- Recognises 7  
- Recognises 10  
- Recognises 15 |  |
| 9. 6+2 | - Says a number 4 or more  
- Uses fingers from 1 to 8  
- Counts from 2 to 8 in their heads, takes a long time  
- Count 6 to 8 in their head, or similar explanation  
- Quickly gives the correct answer 8 and explains |  |
<p>| 10. 5+3 | - Uses fingers to count from 1 to 8 |  |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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<tbody>
<tr>
<td>11.</td>
<td>5 - 3</td>
</tr>
<tr>
<td></td>
<td>Uses fingers to count from 5 to 8</td>
</tr>
<tr>
<td></td>
<td>Counts 5 to 8 or 3 to 8 in their head, takes a long time</td>
</tr>
<tr>
<td></td>
<td>Uses another correct combination like 6 and 2 is 8</td>
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<tr>
<td></td>
<td>Quickly gives the correct answer 8 and explains</td>
</tr>
<tr>
<td></td>
<td>Uses fingers &amp; toes or other body parts for 5 and tries to count backwards but gives incorrect answer</td>
</tr>
<tr>
<td></td>
<td>Counts backwards from 5 or counts up from 3 but incorrect answer</td>
</tr>
<tr>
<td></td>
<td>Counts with fingers or body parts backwards from 5 correctly to 2 or counts up from 3 to 5 and says 2</td>
</tr>
<tr>
<td></td>
<td>Counts in his/her head backwards from 5 correctly to 2 or counts up from 3 to 5</td>
</tr>
<tr>
<td></td>
<td>Quickly gives the correct answer 2 and explains (may be one of the above or says 3+2=5 so 5-3=2)</td>
</tr>
<tr>
<td>12.</td>
<td>8 - ... = 3</td>
</tr>
<tr>
<td></td>
<td>Uses fingers or other body parts for 8 but gives incorrect answer</td>
</tr>
<tr>
<td></td>
<td>Counts backwards from 8 or counts up from 3 but incorrect answer</td>
</tr>
<tr>
<td></td>
<td>Counts backwards from 8 correctly to 5 or keeps track to 3 &amp; says 5</td>
</tr>
<tr>
<td></td>
<td>Counts up from 3 keeping track of numbers to 8, answers 5</td>
</tr>
<tr>
<td></td>
<td>Breaks 8 into 5 and 3, so take away 5, leaves 3 or similar explanation</td>
</tr>
<tr>
<td></td>
<td>Quickly gives the correct answer, 5 and explains using one of the above or says 3+5=8 so 8 – 5=3 so 5 was taken away</td>
</tr>
<tr>
<td>13.</td>
<td>9 - 4</td>
</tr>
<tr>
<td></td>
<td>Gives answer between 3 and 6 but can’t explain or uses fingers or other body parts for 9 and tries to take away 4 but gives incorrect answer</td>
</tr>
<tr>
<td></td>
<td>Counts backwards from 9 or counts up from 4 keeping track of numbers to 9, answers 5 but incorrect answer</td>
</tr>
<tr>
<td></td>
<td>Counts backwards from 9 correctly to 5 or counts up from 4 keeping track of numbers to 9, answers 5</td>
</tr>
<tr>
<td></td>
<td>Quickly gives the correct answer 5 and explains using one of the above strategies or 4+5=9 so 9-5=4 or 10-4 = 6 so 9-4=5</td>
</tr>
<tr>
<td>14.</td>
<td>Additions = 5</td>
</tr>
<tr>
<td></td>
<td>Gives two numbers less than 5 but not correct</td>
</tr>
<tr>
<td></td>
<td>Gives 2 and 3 or 1 and 4 or other possible combination</td>
</tr>
<tr>
<td></td>
<td>Gives another possible combination</td>
</tr>
<tr>
<td></td>
<td>Gives two numbers less than 8 but not correct</td>
</tr>
<tr>
<td></td>
<td>Gives 4 and 4, 5 and 3 or other possible combination</td>
</tr>
<tr>
<td></td>
<td>Gives another possible combination</td>
</tr>
<tr>
<td></td>
<td>Follows a pattern to provide answers</td>
</tr>
<tr>
<td>15a.</td>
<td>4 groups of 2</td>
</tr>
<tr>
<td></td>
<td>Tries to make a group of stones</td>
</tr>
<tr>
<td></td>
<td>Makes one group of 2 stones. May make another group but incorrect.</td>
</tr>
<tr>
<td></td>
<td>Makes two groups with 4 stones and does not self – correct when question repeated</td>
</tr>
<tr>
<td></td>
<td>Makes four groups with 2 stones correctly</td>
</tr>
<tr>
<td>15b.</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Count from 1 to 8</td>
</tr>
<tr>
<td></td>
<td>Group counts 2, 4, for some of the groups, but then counts on by one</td>
</tr>
<tr>
<td></td>
<td>Group counts all the groups, 2, 4, 6, 8</td>
</tr>
<tr>
<td></td>
<td>Quickly answer 8. Explains by group counting.</td>
</tr>
<tr>
<td>16.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Makes 1 or 2 unequal groups</td>
</tr>
<tr>
<td></td>
<td>Makes two equal groups of 4 and indicates one group is half.</td>
</tr>
<tr>
<td>17.</td>
<td>a. String half</td>
</tr>
<tr>
<td></td>
<td>Folds into two unequal parts or tries to.</td>
</tr>
<tr>
<td></td>
<td>Folds into two equal parts, checks, show one part as half.</td>
</tr>
<tr>
<td>18.</td>
<td>shape named visualises</td>
</tr>
<tr>
<td></td>
<td>Possible shape, visualises</td>
</tr>
<tr>
<td></td>
<td>a.</td>
</tr>
<tr>
<td></td>
<td>b. reasonable outline e.g. correct number of straight sides.</td>
</tr>
<tr>
<td></td>
<td>c.</td>
</tr>
<tr>
<td></td>
<td>d. reasonable outline e.g. correct number of straight sides, good explanations</td>
</tr>
<tr>
<td>19.</td>
<td>area 3 rows of 2</td>
</tr>
<tr>
<td></td>
<td>separated squares, small squares, too many or too few squares</td>
</tr>
<tr>
<td></td>
<td>draws reasonable sized squares one by one, 10 or 8 or 12</td>
</tr>
<tr>
<td></td>
<td>draws line down middle and draws 4 lines across to form 10 squares of roughly same size</td>
</tr>
<tr>
<td>20.</td>
<td>local calendar</td>
</tr>
<tr>
<td></td>
<td>explains any form of season used by villagers eg: rainy season, new moon etc</td>
</tr>
<tr>
<td></td>
<td>uses more than one natural event</td>
</tr>
<tr>
<td>21.</td>
<td>local distance</td>
</tr>
<tr>
<td></td>
<td>Explains any form of measurement used by villagers eg: pass one mountain, two rivers or whatever methods villagers use to explain distances.</td>
</tr>
</tbody>
</table>
22. local direction
- Uses landmarks e.g. a church or tree
- Uses left, right or east, west
- Uses distances and more precise directions

24. location of cups
- Points to right cup (incorrect response but understandable)
- a. Points to left cup at first; b. says ‘right’ when you point to the right cup
- Gives the directions in terms of north, south, east or west
- Describes position of the other two cups in terms of Tok Ples or as in front or closest to self, at the back or behind (note the words in the comment column)

25. maths in Tok Ples
- No and gives a reason
- Yes
- Yes and gives a reason

26. transitions between local and school
- Says yes
- Gives a reason

Note. The main difference between this and the Grade 1 and 2 interview schedules are the size of numbers and the multiples used. Grade 1 has mostly numbers in the early teens and covers multiples of 4 and 5 while Grade 2 has numbers up to 20 and covers multiples of 3.

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