Culture at the Forefront of Mathematics Research at the University of Goroka: The Glen Lean Ethnomathematics Centre
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Abstract
Ethnomathematics is fundamental to the development of mathematics. People in different societies have developed mathematics and so a record of what has and is being developed and used in Papua New Guinea societies is essential part of the University of Goroka’s mathematics. The University established the Glen Lean Ethnomathematics Centre as it houses the first contact and later material gathered by Glen Lean to establish his extensive thesis with appendices of the counting systems of 1200 languages in Papua New Guinea and Oceania. This was a massive undertaking. The Centre was set up initially in 2000, moving to the historic house in 2001 as a result of the vision of the then Vice Chancellor, Head of Mathematics and its early Directors, Wilfred Kaleva and Rex Matang. A USA National Science Foundation Award assisted with setting up a database and website of the material. A copy of Glen’s thesis, Rex’s Masters thesis and others are housed in the Centre. In recent years, the Centre has promoted other research such as a large study of measurement in Papua New Guinea, Rex’s investigation of the role of counting in Tok Ples for enabling early school arithmetic, Pickles’ study of gambling in Goroka, and most recently a study of Improving the teaching of mathematics in elementary schools by using local languages and cultural activities: Technology enhanced teacher professional learning funded by Australian Development Research Award and involving the staff of the Division of Mathematics and Computing.

Keywords: Counting systems of Papua New Guinea and Oceania; measurement in Papua New Guinea; Elementary school mathematics; Glen Lean Ethnomathematics Centre, website and database; gambling in the Highlands of Papua New Guinea; ethnomathematics

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Introduction
Ethnomathematics is a study of mathematics from a cultural perspective. It exists as an important area of mathematics as cultures have provided the systems and purposes that become mathematics. Ethnomathematics acknowledges cultural systems and frameworks that have existed since the beginning of the community and language. Thus ethnomathematics is important for Papua New Guinea and other countries that have long lasting Indigenous cultures that predate Middle Eastern and European mathematics. For this reason, Figure 1 represents the position of ethnomathematics argued also by Barton (2008) and Pinxten and François (2012). Academic mathematics is another lens or branch of ethnomathematics.
Ethnomathematics encourages investigation and adaptation of historical, sociocultural practices within and outside of the classroom at all levels of learning. Ethnomathematics helps educators discover pathways that foster student engagement through conceptualizing and supporting new approaches to learning mathematics by connecting to student’s culture (Furuto, 2012). The teacher and the learner are both learning. The teacher takes account of the funds of knowledge of community by probing deeper into the knowledge of the community (González, Moll, & Amanti, 2005). This can be a mutual interrogation and two-way development of mathematical knowledge (Adam, 2010). The learner has an active role bringing in their creative background rather than being a blank sheet of paper on which foreign ideas are written, often with little understanding and relevance.

History of Ethnomathematics in Papua New Guinea

One of the main stimulus for ethnomathematics in PNG was the setting up of the Mathematics Education Centre at PNG University of Technology (Unitech) where materials and research were undertaken to assist PNG students from a far different cultural background than that present in colonising countries like England, Germany and Australia. The Centre attracted mathematicians with an interest in education from around the world (supported by Nuffield Foundation and Monash University). At the same time a focus on educational psychology was emanating from the Educational Research Unit at the University of Papua New Guinea (UPNG). Other long-standing institutes and anthropologists have also contributed to ethnomathematics such as the Melanesian Institute, on-going anthropology especially at UPNG (e.g., Strathern) and from Australia, Europe and USA (e.g., Saxe, Dasen, Wassen, Keck) and the language (linguistic and educational) work of SIL. The Indigenous Mathematics Project (1979) brought together important studies on mathematics from a PNG Indigenous perspective. Important researchers such as Alan Bishop and Ken Clements spent several months to a year at Unitech, mostly carrying out research with Glen Lean whom Alan supervised for his PhD from Unitech. Philip Clarkson, one of the Directors of the Mathematics Education Centre researched the impact of Tok Pisin on mathematics education. However, there has been important influences from overseas (e.g., Britt Roberts), the University of Goroka staff, and National Research Institute researchers such as Patricia Paraide as a constant influence in curriculum writing. Alan Bishop supervised PhDs by Wilfred Kaleva and Frances Kari on attitudes of teachers and students on ethnomathematics showing that it was an important consideration for teaching mathematics within this country. Subsequent to his visit to PNG and other countries, Alan Bishop wrote a ground-breaking book called Mathematical Enculturation (Bishop, 1988). It was some 14 years later working with a student from South America and others interested in

However, the most significant work has been the PhD study of Glendon Angove Lean while he worked at Unitech and subsequently at Deakin University: The Counting Systems of Papua New Guinea and Oceania (Lean, 1992). This was a mammoth task collating data from first SIL, governments and other records and questionnaires of counting given to all entering Unitech students, many teachers and field work. He collected data on 560 languages from PNG as well as all the Oceanic languages. He systematically analysed the systems presenting them in terms of frame words, operational systems and cycles e.g. (2, 5, 20). For this work, he built on the important work of Geoff Smith, a language lecturer at Unitech, who analysed all the Morobe Counting Systems (Smith, 1984). This work actually countered other researchers’ work. Lean also provided an extensive range of body part tally systems as well as the more common digit tally systems (5, 20) or (2, 5, 20) cycles. Figure 2 provides one example of the body tally systems.

![Figure 2. Fasu body-part tally system, Southern Highlands (May & Loeweke, 1981)](image)

He mapped areas of different cycles (see Figure 3 for an example). He established an alternative perspective on the development and spread of number by considering how counting systems might have developed. He particularly noted the influences of neighbouring languages, cultural purposes, and words linked to body parts. Lean’s thesis was that number counting did not spread from the Middle East in waves of 2s then 5s and then 10s. Rather counting systems could spontaneously development or occur as a result of negotiations with neighbouring languages or specific purposes. It took Glen Lean 22 years to collate and report his findings in his thesis. For more details, see the GLEC website (GLEC, 2008) and summaries (Owens, 2000, 2001). His work will form a substantial section of a new book to be published next year on the history of number from a PNG perspective (Owens, Lean, with Paraide, & Muke, 2016).
When Glen Lean died, his academic executor, Alan Bishop, sent his collection of papers and the raw data taken from his old Apple computer disks to Wilfred Kaleva and Francis Kari. Although some papers were damaged before they could find a home, the boxes sent to Wilfred at the University of Goroka were unpacked, the articles filed both as a bibliography and in alphabetical files in 2000. This was not such an easy task as the mid 18th century German papers often had the journal editor as dominant. However, all was completed. The then Vice-Chancellor Dr Mark Solon felt it was important that there be a proper Centre and not just two filing cabinets so with the then Head of Department Dr Musawe Sinebare, the Centre opened with Dr Wilfred Kaleva as Director. So the small historic house on campus was selected and furnished as a comfortable office. Soon Wilfred became Head of Department and Mr Rex Matang became the Director. The Centre was officially opened in 2001 by Professor Geoffrey Saxe from Berkeley University.

In that year, I received a phone call from Nancy Lane, then Director of Pacific Research in Education and Learning. As part of a large grant to digitise materials in the Pacific, the University of Western Sydney and GLEC received a large grant from the USA National Science Foundation to document and digitise the Centre’s materials. With the aid of the Japanese JICA volunteer, Kiyu and subsequent volunteers, Martin Imong and several other assistants we developed a website which could be linked to a dedicated server for a Filemaker Pro database of the counting systems. It could be searched on line. This remained until power destroyed the server but the remainder of the materials remained on the University website. Given this was the time of simple scanning, each old paper was scanned as separate jpegs that were cleaned using Photoshop and then combined into html files. The various theses were added. This is a large resource. We also made a hard copy of Glen’s thesis by combining various sources. This again was not easy as we had to scan from original copies.

![Figure 3. Distribution of 2-cycle variant counting systems in New Guinea (Lean, 1992).](image-url)
in Lae until the ink ran out in all the Unitech printers. For some papers that were lost, new hard copies were sourced through UWS.

Rex Matang began to think about his doctoral study. He already had a Master of Education in ethnomathematics from Queensland University of Technology (his papers are on the GLEC website). He wanted to do a decent examination of the effect of Tok Ples on the learning of arithmetic strategies. He found support through Southern Cross University, Dr Bob Wright. While Rex completed most of his data collection except for lack of funds and time for Milne Bay, he was able to show that children in elementary school who had access to Tok Ples while learning arithmetic did significantly better than those who did not have access except for the small select sample from Goroka who had school in English only. The group that did not succeed well were learning mostly in Tok Pisin or Tok Ples and Tok Pisin. The children could answer in any language and then Rex would answer in Tok Ples (he had taught in these areas so could speak enough of the languages to ask the arithmetic questions) or Tok Pisin (Matang, 2008; Matang & Owens, 2014). Unfortunately, Rex died suddenly before he was able to submit his thesis but an early draft was used for the 2014 paper. This work is supported by the well-researched work of Patricia Paraide on bilingual education (Paraide, 2003, 2009, 2014).

Measurement Study

With the assistance of funds from CSU, Wilfred and I were able to begin a study of measurement practices in PNG. We collected data from several villages with special thanks to Charly Muke, Serongke Sondo, and Zuzai Zhizoke. However, we had more than 10 interviews also at UoG with staff and students, hundreds completed questionnaires, and some assisted with focus groups or longer reports. In addition, many of the UoG student reports on ethnomathematics involved measurement practices and these were often well explained and illustrated along with links to the curriculum. Linguistic sources were also used. In total, we have data on more than 350 language groups. The main findings from this research were that PNG had a rich collection of mathematical activities and ways of thinking about length, area, mass, volume, and time together with various ways of describing the position of places. In general the ways of thinking mathematically are incredibly linked to cultural practices and relationships. While informal length units are the main tool for measuring length, area and volume, it is apparent that practice results in a virtual ready-reckoner with the proportional relationships involved in length and overall size (area or volume) are visually imaged, discussed and issues such as land sharing, garden size to plant, pigs to exchange, or houses to be built are resolved (Owens, 2007, 2012, 2015; Owens & Kaleva, 2008a, 2008b).

Like the counting study, this work is closely associated with the work of Patricia Paraide (2010) on the mathematics of Tolai culture. In her study, Patricia details the ways in which groups and sizes were recognised especially in distribution. In particular, the use of the hanging lengths for fathoms and the parts of a fathom were evident. However, other aspects of measurement were tacitly known such as the use of weights when fishing.

Space and Geometry Study

As part of the work on measurement, further literature was analysed to develop some sense of how space and geometry learning occurs in PNG. The ecology and the culture of places had a significant effect on the way in which people identify places and use spaces, develop and create art, material objects, and design. This study particularly highlights the ways in which visuospatial reasoning is closely related to culture (Owens, 2015; Owens & Kaleva, 2008a, 2008b).
Gambling Study
Anthony Pickles spent a year with those playing cards and other forms of gambling found in and around Goroka. This unique town with residences from many parts of Eastern Highlands together with people mainly from other highlands areas has developed not only their own card games on which people gamble but certain roles and ways of adding monies to the collected amounts. In this way, certain patterns of relationships between people are established and the role of the cards themselves is defined (Pickles, 2013). Similarly, those who are ‘big men’ and play the pokies distribute to and require support from others.

Elementary School Teacher Professional Learning
Based on the years of research on ethnomathematics, this large research project involving the staff of UoG in the Division of Mathematics and Computing together with an early childhood lecturer and others, has researched a design of principles to guide the professional learning of elementary teachers. Importantly in this study, it has been found that teachers were assisted to recognise the rich and different cultural ways of thinking for mathematics and also how to achieve a good transition from home to school through an inquiry method of learning. The challenge has been to provide information to teachers in a way that was meaningful especially when they have little opportunity to read and speak in English. We have made use of video materials and are increasing this medium to illustrate how cultural practices have mathematical processes and how young children learn to count and do arithmetic. We are also simplifying the language and extending the length of the workshops. We have encouraged trainers to play a role in the workshops. We have provided the materials in electronic form to many of the trainers and teachers so they can inservice their teachers as well as supplying a manual and six early reading books on mathematics.

Figure 4 illustrates the principles while Figures 5 to 8 provide further details of what is considered in the materials.

*Figure 4. The three strands of principles for teaching mathematics from a cultural perspective.*
Mathematical ways of thinking

• Culture and school mathematics
• Mathematics is thinking
• Problem solving
• Explaining and Reasoning
• Understanding mathematical ideas
• Fluently applying concepts and procedures
• Asking questions
• Investigating by trying ideas
• Understanding through patterns and generalising relations
• Communicating in mathematics

Figure 5. Workshop participants communicating to solve the open-ended problem.

Thinking mathematically involves processes as listed in Figure 5. Groups discuss open-ended problems in workshops and develop their own teaching questions for similar purpose. Thus they experience these mathematical ways of thinking.

Cultural practices are seen to have these mathematical thinking processes. However, often the teachers need to learn more from Elders and others to realise the important capacity to think mathematically in cultural ways. Figure 6 illustrates how students developed and practiced a lesson based on weaving and shapes in which the participants then looked at making shapes with their bodies as had been illustrated on a video.

Cultural activities
Recognise and Value cultural mathematics
Extend cultural mathematics
• patterns,
• groupings,
• constructing & designing,
• building relationship,

Cultural capacity & partnership
• Values - need to preserve culture & languages of people
• Elders roles for community cohesion

Figure 6. Group link cultural practice to a class activity of making shapes with their bodies during peer teaching practice of their developed inquiry plans.

Language
• Language and learning
• Strengthening school maths with language
• Counting word patterns
• Language and measurement
• Language and locating
• Cultural shapes
• Cultural representations
• Two languages & bilingual education
• Dictionary

Figure 7. Working on a mathematics dictionary in Tok Ples.
Figure 8 illustrates how the language can assist in establishing basic arithmetic facts.

<table>
<thead>
<tr>
<th>Tok Ples Pattern</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>2+1</td>
<td>3</td>
</tr>
<tr>
<td>5+1</td>
<td>6</td>
</tr>
<tr>
<td>5+2</td>
<td>7</td>
</tr>
<tr>
<td>10-3</td>
<td>7</td>
</tr>
<tr>
<td>10-2</td>
<td>8</td>
</tr>
<tr>
<td>2x5+1</td>
<td>11</td>
</tr>
<tr>
<td>5+5+5+5+1</td>
<td>16</td>
</tr>
<tr>
<td>2x3</td>
<td>6</td>
</tr>
<tr>
<td>2x4</td>
<td>8</td>
</tr>
<tr>
<td>2x4+1</td>
<td>9</td>
</tr>
</tbody>
</table>

Figure 8. Some language patterns in Tok Ples relevant to learning English arithmetic.

The data on measurement and counting systems for many languages are also provided to teachers.

The early childhood principles are linked with early mathematical thinking in terms of basic skills like ordering and one-to-one matching. These are incorporated into game-like activities as illustrated in Figure 9. Many games are used in the workshops as we discuss how best for children to learn and understand basic mathematics.

**Early mathematical thinking**
- Patterning
- Noticing features of groups and shapes
- Sorting
- Comparing
- Ordering
- One-to-one matching
- Recognising equality
- Symmetry
- Locating and travel
- Time patterns
- Representing

Figure 9. Early mathematical thinking and an activity for groups to do after playing a find your pair game with the numeral cards and 10-frame cards.

One aspect of teaching arithmetic is to establish efficient strategies and in particular to learn the addition facts with meaning and with ways to remember that is not just rote learnt. The addition by splitting and regrouping to make 10 is one of these methods as shown in Figure 10. These strategies assist students to overcome counting by ones when they are ready.

**Early childhood education**
- Strengthen identity
- Transition from home to school
- Learning experiences "in but outside" school
- ECE, play and inquiry

**Learning experiences**
Number
- Counting
• See and know numbers
• Visualising
• Arithmetic in language
• Recognising pairs & groups
• **Using number relationships**
  - Splits and regroup
• Group counting

Space and geometry
  - Visualising & investigating
  - Describing & classifying

Measuring
• What is measured
• Comparing & Measuring
• Informal ratio comparisons
• Units for different attributes
e.g. length different to area

Figure 10. Important early knowledge development illustrated by splits and group to 10 and adding in jumps along the empty number line.

Many game-like activities are used to involve children in their learning. Some of these are shown in Figure 11.

![Figure 11](image)

Figure 11. Three of the games used to encourage understanding of number size or to be used on any topic.
Sources. a. K. Owens *Creating Space*

Key to linking culture and mathematics has been the use of a weekly planning method to encourage inquiry and investigation which are natural ways of learning along with play. Figure 12 shows this with teachers ‘having a go’ (one of our slogans) and preparing their weekly plan.
Planning for inquiry
• Tuning in
• Finding out
• Sorting out
• Going further
• Making connections
• Taking action
• Reflecting

Figure 12. Groups of participants work together to prepare inquiry learning plans.

Books on mathematical concepts for early readers have been another tool for teaching as shown in Figure 13. These teachers learn how to hold the book, ask questions about the book, and do activities related to the book.

Assessing and reporting
• Standards
• Observing and questioning
  Informal ratio comparisons
  Units for different attributes
  e.g. length different to area
• Games for fun and fluency
  • Learning stories
  • Questionnaires

Rex Matang assessing a child at Binimap Primary School inspiring the Elementary School Project.

Figure 13. Assessing and reporting
Examples of observing and listening to responses to questions and other discussions are provided in association with example problems and children’s answers. Assessing and reporting can be achieved by using a learning story in which an activity is described (may be with a picture) and the children’s responses and discussions are recorded to provide evidence of learning. Participants also watched a demonstration of asking a child a series of questions and how to record possible answers. An example of a child responding to one of the questions is seen in Figure 13.

Evaluations have been very positive in terms of supporting the basic approach with the principles indicating this is a meaningful and enriching approach. In addition, in each workshop, teachers have increased their understanding of not only their own cultural mathematics but concepts in school mathematics. For example, we discuss and do activities about area because many people only know about measuring area by strides along the garden. We discuss that they have a good image of the overall size by knowing the number of strides but strides are not area units. We also cover areas with area units that need to be like tiles without gaps. We discuss the area spaces in gardens whether they are squares, rectangles or triangles. There are two books about area with activities. Attendance is very high as the teachers are very involved in the activities and discussions of the workshop and they are really pleased to be learning so much that they often had not learnt in previous training. In other cases, some of the material was perhaps a little too involved for the teacher to follow in the future, especially if the workshop was too short for them to practice, for example, the child’s numeracy questionnaire. In some cases, discussions about the treasures and issues in Tok Ples were only just being realised at the end of the workshop. It is expected that teachers would continue to discuss these with their communities. In some instances, this was due to the teacher’s own lack of knowledge of the Tok Ples or the school was in a town with multiple languages. However, in most cases, the teachers were fluent speakers of Tok Ples.

Mathematics, Culture and Language

One of the electives for the undergraduate program at the University of Goroka offered by the Division of Mathematics and Computing and a popular topic for research projects in the end-on teaching degree and Masters, has been to carry out a project on their own, or some times another group’s, knowledge and sometimes to make comparisons between two groups. In many cases, the teacher education student needed to ask information of a knowledge keeper or Elder. They were appreciative of the knowledge that was shared by Elders and knowledge holders and they were writing with strong emotions as they made links to the school syllabus and provided activities or exercises for their students to do. An analysis indicated that their cultural identity and the engagement with the project resulted in students being responsive and identifying with both cultural and school mathematics as a mathematical thinker (Owens, 2014). These projects have also informed the measurement and space project. An example of the material that has been produced is given in Figure 14.
Mambu Anda was sitting on the cross bars at the top of the posts tightening the supporting ropes of the cane bridge. While he was there, his “small uncle” Wapi Yamo, was waiting for him on the other side of the fast flowing Yalo River. The distance from the cross bars of the posts, where Mambu sits to the base of the posts is 15 meters and the distance from the base of those same posts to where his small uncle sits is 40 meters.

Identify which is the angle of depression?

What is the angle of depression that Mambu sees his uncle?

What is the angle of depression if his uncle just moved inwards towards the bank of the river 5 meters?


Figure 14. Example of an ethnomathematics project by UoG student.

One aspect of these projects is that they often looked at the products but a few looked at the mathematical thinking processes in creating the product. In many cases, there were diagrams and other forms of visuospatial reasoning together with examples of metaphors that could be used in teaching about a concept. For example the hand rail curve was used as a metaphor for the sine curve.

Conclusion

Academic mathematics relies on symbolic proof but there are other reasons for accepting things that work as mathematically sound. First there are other kinds of proofs such as visual proofs that make a conjecture durable over time. However, it is crucial to ensure that in deciding on appropriate cultural processes, consideration is given to what is needed in a particular situation. For example, why might all variables need to be considered and measured in a gas pipeline production? Why might a rule of thumb work best in practice? When is taken-as-shared visuospatial reasoning used? Strong mathematical processes such as

- estimation,
- mental calculation and judgement,
- visual reasoning, and
- communication for decision-making

can develop from mathematics embedded in activities of the community. School mathematics is relevant to more applications but only if seen as relevant to the learner.

Given the extraordinary diversity of PNG cultures and the beauty and depth of relationships embedded in the culture including the material culture, there is much mathematical reasoning in the many mathematical activities of each culture. These need to be not only recorded but also shared with younger generations and explored for richer mathematical meanings.

More importantly, there needs to be ways of drawing the knowledge into the school learning in a meaningful and enriching way. Mathematics at school and academic level should draw on the richness of these mathematical ways of thinking.

Further analyses should be undertaken to reach higher order mathematical studies and systematic, possibly new approaches to mathematics.
References


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