In this paper, I first argue that ethnomathematics is the all-encompassing universal mathematics into which academic mathematics fits. This is particularly important in education which is intended to permit the student to be mathematically literate for their situation. I then give some details on the richness of ethnomathematics in Papua New Guinea resulting from both the diversity of languages but also the diversity of environments in which people live.
The Current Status of Ethnomathematics in Papua New Guinea: Its Importance in Education

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In this paper, I first argue that ethnomathematics is the all-encompassing universal mathematics into which academic mathematics fits. This is particularly important in education which is intended to permit the student to be mathematically literate for their situation. I then give some details on the richness of ethnomathematics in Papua New Guinea resulting from both the diversity of languages but also the diversity of environments in which people live.

Ethnomathematics: The Big Picture of Mathematics
Historically, ethnomathematics was seen as an introduction for children to what was considered ‘real mathematics’ that is school or academic mathematics. At best, it was seen as engaging students or helping them to understand school mathematics. However, there is an alternative perspective. Let us take the statement in the PISA (OECD, 2004) report on mathematical literacy:

Mathematical literacy is an individual’s capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgments and to use and engage with mathematics in ways that meet the needs of that individual’s life as a constructive, concerned and reflective citizen. (p. 37)

This statement takes account of social justice and political issues to say that all children, no matter their situation, are entitled to be mathematically literate for their life in their context. For many children in the world, including in PNG, this means they need to be mathematically literate for where they live in a village or on the streets and not necessarily in a job attained after 12 years of schooling. It also allows for children to appreciate not only mathematics in their context but also the school mathematics and its possible contexts.

What are the differences in these mathematics? First, a strong understanding and processing of mathematics is likely to develop through living in the village and learning mathematics that is necessary for prospering in the village. This mathematics is often embedded in context and activity within that context. It is a way of developing strong mathematical processes such as estimation, mental calculation and judgement, visual reasoning, and communication for decision-making.

On the other hand, academic or school mathematics is likely to be more applicable to a wider range of contexts. However, its application is often limited to particular areas relevant to the person and his career or life.

With this concern for the more encompassing perspective on mathematics, Pinxten and François (2011) state:

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1 Keynote Paper delivered at the International Conference on Pure and Applied Mathematics, Lae, Papua New Guinea, November 2013 as part of the session on Ethnomathematics and Mathematics Education.
Although a good mathematical background will not be a hindrance for creativity in the future, it might become just one out of several sources for powerful knowledge innovation. In the third industrial revolution, we see a large place for creative people who can link good thinking and problem solving to a sort of creativity that is more likely to be found with artists or even businessmen, just as much as with scientists. Academic mathematics, rightly or wrongly, will therefore lose a lot of its argumentation value in the educational field. (p. 268)

To this end, mathematical literacy in context may provide a sound basis for problem solving and creating appropriate solutions to which the content of mathematical literacy in school mathematics may be added. It invites the use of emotional and spiritual intelligences, it invites the cultural mathematics of counting, proportional reasoning, and spatial organisation to be a basis for mathematics education. With diversity and collaboration, people from different societies in PNG can create a new standard in mathematics that goes well beyond the limitations of school mathematics. For example, the mental mapping of place in PNG could be a strong geometry, the sophisticated exchange and negotiations could form a stronger mathematics for economics, and the willing of objects through relationships for achieving goals could be a new form of data analysis based on yet another probabilistic form. While academic mathematics relies on proof, there are other reasons for accepting things that work as mathematically sound. The important point here is what is needed in a particular situation. Why might all variables need to be considered and measured in a gas pipeline production? Why might a rule of thumb work best in a forestry industry (or not – note that English rules of thumb were very poor in predicting and calculating tree volume)? Why does reducing land use to Cartesian coordinate systems of school mathematics limit the decision-making on land use?

To achieve a curriculum that takes account of context, the teacher and the learner are both learning. The teacher takes account of the funds of knowledge that the child brings to school and probes deeper into the knowledge of the community, taking with them their own academic mathematics as another lens or possible branch of the realm of ethnomathematics and which can be associated with the mathematics of the community. The learner has an active role bringing in their creative background. This constructivist theory of learning implies:

(a) people do not discover knowledge, rather they construct it, (b) people create knowledge by connecting it to their previous knowledge and previous experiences, (c) knowledge is an autonomous and subjective construction, (d) the learning process involves active restructuring of how one thinks, (e) people use personal experiences and social interaction to create knowledge, (f) cognitive growth is stimulated when people are confronted with practical, contextual problems or personal problems that present situations that require a new and creative way to think (Pelech & Pieper, 2010, p. 8), cited in (Pinxten & François, 2011, p. 271).

The social aspect of learning is best developed through children talking together, with the teacher and with the community knowledge keepers. In this way, there is a greater transition from home to school learning, social support and a feeling of belonging not only in the group of learners at school but also a feeling of belonging to the community as a respected place of knowledge. Thus the student will develop a stronger recognition of mathematics of culture and community and of school, both equally valued and different as needed for different purposes. Mathematics does not just serve industry and economy. There are other needs that it can serve. The curriculum then may not be the same for all children and yet all children can equally develop as mathematically competent and within their context. For this reason, a study of the ethnomathematics of the different cultures of Papua New Guinea is a beginning to assist teachers and learners in becoming mathematicians for their community and to become a mathematician within the school context. They will know how to problem solve, reason, communicate mathematically and make decisions based on appropriate mathematical thinking. They will be creative in mathematics in familiar and new contexts.

**History of Ethnomathematics in Papua New Guinea**

During the time of the Mathematics Education Centre at PNG University of Technology, Lae, an important study was undertaken called the Indigenous Mathematics Project (IMP) written up in the PNG Journal of Education, 1979. Prior to this, Glen Lean (and others) had begun to collect and
analyse the counting systems of different language groups and Jones (1974) summarised some language data on measurement. However the IMP and many other educational research studies (e.g. from University of Papua New Guinea’s Educational Research Unit, and studies about whether PNG students fitted Piagetian stages of cognitive development) were generally psychology driven and failed to adequately acknowledge the alternative cultural mathematical developments. Nevertheless, many researchers were well aware of culture differences and often considered these in their research.

However, around 1980, Alan Bishop and Ken Clements visited Unitech and subsequently wrote about research influenced by cultural mathematics. This visit challenged Bishop and left an indelible mark on his thinking about mathematics. Thus he wrote a well-known book called *Mathematical Enculturation* (Bishop, 1988) in which he argued that all culture groups participate in activities involving mathematics e.g. counting, measuring, designing, explaining, and playing that could be classified as involving mathematical thinking of various kinds. It took another decade for him to collaborate and write a book about *Transitions between contexts of mathematical practices* (de Abreu, Bishop, & Presmeg, 2002). Kay Owens undertook a small study with Architecture students at Unitech showing how culture had influenced their problem solving when undertaking an introductory design task (Owens, 1999). Two PNG lecturers subsequently completed PhD’s in ethnomathematics, on teachers’ and students’ attitudes towards ethnomathematics at Monash University with Bishop as supervisor. They were Wilfred Kaleva and Frances Kari, the former being the first Director of the Glen Lean Ethnomathematics Centre which began as a resource for documents collected by Glen Lean, and his thesis on *The Counting Systems of PNG and Oceania*, a work that took him 22 years. The Centre developed into a resource on many cultural mathematical activities. Kay and Chris Owens undertook the work of cataloguing and later providing a website of all the materials at the Centre while Rex Matang was the Director with funds from USA’s National Science Foundation. This website includes three theses (Glen Lean, Wilfred Kaleva, and Rex Matang) while the Centre houses hard copies of two other theses (Charly Muke and Anthony Pickles). There are hundreds of other references, papers on ethnomathematics, language and culture related to mathematics, and teaching ideas. It includes many of the Unitech’s Mathematics Education Centre’s Research Reports.

There are several other researchers who have also contributed to research related to ethnomathematics in Papua New Guinea. These include Dasen and Wassman and various colleagues (Wassmann, 1997; Wassmann & Dasen, 1994) and Geoffery Saxe (Saxe, 2012).

**The Wealth of Ethnomathematics in Papua New Guinea Today**

**Glen Lean Ethnomathematics Centre**

GLEC is a world-renowned Centre on Ethnomathematics. Its purposes include:

- Promoting and disseminating data on Indigenous mathematical knowledge through collaborative research projects between researchers from PNG and abroad, and by enhancing research skills of PNG national academics;
- Promoting critical academic discussions across different academic disciplines involving ethnomathematicians, anthropologists, linguists, mathematics educators and mathematicians in developing and designing effective means of teaching mathematics and other academic disciplines in the 21st century and beyond;
- Providing a storage facility for collecting, preserving and cataloguing of all research data on ethnomathematics (both hardcopy & electronic) and enabling accessibility;
- Providing an additional avenue for UOG students to have access to information on ethnomathematics;
• Facilitating and sanctioning all research project proposals on ethnomathematics submitted by overseas researchers for the purposes of approving and recommending in consultation with the National Research Institute (NRI) in Port Moresby for the granting of research visas to conduct research in PNG;
• Designing and conducting relevant research in identifying mathematical practices in the cultural contexts (ethnomathematics) in PNG with the aim to design an Instructional Model that is most appropriate to the PNG situation and educationally beneficial in teaching mathematics;
• Providing an advisory role to different levels of education or other departments or organizations.

The Centre is well-known because of the attendance of Rex Matang and Kay Owens at several international conferences and the respect that has been shown to Rex for his work.

Establishment of Glen Lean’s Repository and Database of Counting Systems and Ethnomathematics Digital Library  http://www.uog.ac.pg/glec/

2002-2004: GLEC established a website with information on:

• the Centre and its researchers,
• both a hardcopy and electronic copy of Glen Lean’s thesis,
• A Filemaker Pro database of over 560 counting system from both hardcopy and electronic files from Glen Lean’s Appendices. The counting systems have many alternatives (e.g., first contact data, SIL wordlists, Counting System Questionnaire) and text provides information on place, language, number frame words, operative system, type of system, cultural context, links to body parts, and relationship with neighbouring systems. In particular, counting systems were classified under cycles, mainly 2, 5, 10, 4 & 6 & 8 & 20, as a digit tally system (2, 5, 20) or (5,20) systems; or body part tally system which varied in terms of the body parts used or other system indicated by cycle or base. Diagrams were given of each of the body tally systems.
• Catalogue of papers: used by Glen and scanned for the website, others used by Glen, other papers held at GLEC and scanned for the website, and others collected but not scanned.
• Key papers by researchers. In particular, this included theses by Wilfred Kaleva, Rex Matang, and a summary of Charly Muke’s thesis. Papers by these researchers and Kay Owens are also included.
• Measurement systems project
• Teaching ideas are included – a few early UoG student projects on Ethnomathematics that linked ethnomathematics to teaching which were put into a booklet by Richard Zepp, ideas generated by Kay Owens based on the counting system classifications, and a few examples categorised under Bishop’s six universal mathematical activities: designing, counting, measuring, playing, explaining, and locating. However, the collection of student projects now mounts to more than 250 from the subject *Language, Mathematics and Culture* taken by Wilfred Kaleva, Rex Matang, Charly Muke, Richard Zepp with Visiting Scholar Kay Owens, and several Research Projects on Ethnomathematics.

Rex Matang’s PhD Thesis on Impact of Language of Instruction on Learning Arithmetic
Rex secured an IAPA to study under Dr Bob Wright at Southern Cross University. In particular, he wanted to investigate whether children learning arithmetic in Tok Ples had an advantage in understanding arithmetic. He developed a test based on Bob Wright’s work. In particular, he categorised children as learning using Tok Ples, Tok Pisin, English or a combination. He selected schools in Morobe (Kâte and Adzera), Madang, West New Britain, Milné Bay, and Goroka where he was familiar with the languages so children were able to answer in their Tok Ples, Tok Pisin or English. A town school in Goroka provided English instruction in Elementary but in some cases, especially in Kâte, there were schools in Tok Ples whereas others used Tok Pisin. Before his untimely death in January 2010, Rex had completed a draft of his thesis. Unfortunately it is not available but he generated many papers which are held at GLEC and final versions of chapter 1 and 2 and some data files are available. Drafts remain on computers at GLEC. It is hoped that a journal paper will soon be published on his work.

Both quantitative and qualitative methods of comparative data analysis were used to analyse the data obtained from task-based interviews of elementary school children on early number assessment and completed teacher questionnaires. Cognitive efficiency theory and the theory of automaticity in mathematics were used as theoretical frameworks to analyse and interpret the data on children’s reaction time (RT) on each numerical task on the early number assessment schedule. An interpretive research approach was used to analyse the data obtained from teacher questionnaires and adult interviews.

The results of the study indicated that the language of formal instruction affected students’ ability to respond correctly to a number of counting and early arithmetic tasks. Although the Tok Pisin-English group did slightly better than other groups by having fewer incorrect responses (mainly numeral recognition and counting), they were not necessarily as efficient in responding suggesting a lower cognitive efficiency level in arithmetic, understanding concepts, and applying concepts. These concepts are embedded in Tok Ples languages and used in the formal languages of instruction. The results obtained indicate that children learning to read and write, and count in their own language Tok Ples performed better than those learning early number knowledge without Tok Ples overall (learning in Tok Pisin or Tok Pisin and English, and to some extent in English only). The results are significant in that they provide further support for use of children’s own language and traditional counting systems in teaching formal school mathematics. Children not only performed better in mathematics early arithmetic tasks when they had some schooling in Tok Ples but they were more cognitively efficient in responding to numeric and arithmetic questions based on their reaction times. The result is contrary to negative views held by parents and critics of the curriculum reform in PNG. This substantial research study supports the view that conceptual and cognitive efficiency in learning mathematics is enhanced by learning in the Tok Ples at the start of schooling. It supports research that confirms that Tok Ples education generally benefits children’s conceptual understanding. Furthermore, it is an important way of making school relevant to children and their home backgrounds and to assist them to transition effectively to English-medium schools in Papua New Guinea.

**Measurement Systems of Papua New Guinea**

This research established a sound conceptualisation of out-of-school knowledge of measurement in Indigenous communities and new concepts for more socially and culturally responsive measurement education applicable in PNG and worldwide. The study illuminated processes that may be implicit and unacknowledged and indicated how education can utilise the linguistic, cultural, and symbolic
capital of the learners. It developed an understanding of the systems and approaches that teachers may take to enhance continuities in learning from home to school. Much of this knowledge is endangered and so there is an urgency to preserve it, value it and build on it for education. This was a collaborative research project with PNG and Australian colleagues especially at the University of Goroka, Madang Teachers College, and Charles Sturt University, Dubbo, NSW, Australia.

The aims and stages of this project

1. identify the different types of cognitive and physical strategies used by a culturally diverse sample of indigenous Papua New Guinean societies in various cultural activities that involve comparing and measuring length (including distance), area, mass, and volume and associated concepts such as ratio within cultural contexts;
2. collect data from as many different languages as possible to confirm the appropriateness of analysis of the systems and strategies and to establish a database of length, area, volume and mass measurements;
3. relate the findings to our current Western understanding of how children develop fundamental concepts of measurement;
4. undertake an evaluation of teaching using this new knowledge to improve students’ learning in elementary school. (See the Elementary Teachers’ project below)

There are two approaches to this research. The first is to provide a record from as many language groups as possible. This data is often provided by more than one person. The method is firstly that of a survey and collation of materials. However, as analyses and issues arise the data collection has been modified. For example the questionnaire was modified to give greater importance to the linguistic aspects of the culture and further sampling has occurred in line with grounded-theory methodologies. This survey data is given meaning by the second more in-depth approach to the research involving an ethnomethodological approach. Observations and interviews are carried out preferably at the village. The study included both Austronesian and Non-Austronesian (Papuan) language groups and different geographical areas such as mountain valleys, coastal mountains, bush and sago gathering communities, areas with kunai and those without, coastal villages that are remote from centres, villages that are closer to towns, and those in large river valleys.

String Designs in Papua New Guinea

This research was carried out by Eric Vandendriessche (Vandendriessche, 2007) from France in the Trobriand Islands. He showed that polynomials could be associated with the designs.

Computerising Designs

Ron Eglash in the United States has a website for bringing ethnomathematics into secondary classrooms. He produced some interactive materials on some designs he was sent by Rex Matang.

Gambling in Papua New Guinea

This research was encouraged by Martin Holbraad and carried out by Anthony Pickles as a doctoral study from the University of St Andrews. His thesis The pattern changes changes: Gambling value in Highland Papua New Guinea, 2012 under his supervisor Adam Reed. This study in the area of social science is significant in presenting a new understanding of a major contemporary cultural activity for which mathematics is important in terms of money exchanges. It is as significant in understanding contemporary culture as the collection of papers in Through a glass darkly” (~1981) which studied how alcohol consumption and use was incorporated into traditional cultural practices. In particular, Anthony illustrates how patterns of behaviour from card playing to poker machine playing and even
the storing and calculating of redistribution of wealth illustrate an incorporation of gambling into the gifting and positioning behaviour of people in Goroka, a city housing many families especially from the Eastern Highlands and Simbu as well as from different villages of the Gahuku-Asaro language group.

**Student Ethnomathematics Projects**

The University of Goroka (PNG) has a large collection of over 250 reports produced by preservice and inservice teachers as a result of an elective course (a single subject) *Mathematics, Language, and Culture*. Prior to preparing their reports, the teachers had received a book of readings and lectures on language and mathematics and on ethnomathematics. They were required to describe some aspects of their cultures and relate these to the secondary (Grades 9 to 12) (most of the student teachers are preparing to teach in the secondary schools) or primary (Grades 3 to 8) school curriculum (mostly by inservice teachers, a program now held at Madang Teachers College) by making links between cultural knowledge and school topics, and by providing lesson plans and examples for school students that illustrated this connection.

One research study (Owens, in press) explored whether an ecocultural project impacts on a teacher’s interactive changing state-of-being supported by self-regulation and identification with both ecocultural mathematical thinking and school mathematical thinking. The question was whether the teachers were aware of cultural mathematical thinking and valued this ecocultural knowledge, and whether they were then able to provide appropriate sound mathematical experiences for their future students. The expectations and values expressed by the teachers indicated how their identities as mathematical thinkers incorporated aspects of cultural identity and their preparation of lessons would express this ethnomathematical identity. The reports of projects that link culture and mathematics were analysed to explore the impact of sociocultural situations together with affective and cognitive aspects of self-regulation on identity as a mathematical thinker. This is represented in Figure 1.
Cultural Practices and Local Languages (PNG): Elementary teacher technology-enhanced professional learning for quality teaching of “Culture and Mathematics”

This project is focussing on how to assist elementary teachers in remote areas through professional learning using a set of key ideas and examples. The intention is to provide the professional learning on a laptop with solar power so that the teacher is motivated to learn. However, the initial implementation will be through face-to-face workshops at a single school or cluster of schools. At each implementation phase, the design of key ideas is evaluated, refined, implemented and re-evaluated. The current design after one workshop is given in Figure 2.
Figure 2. The design of key principles for professional learning for teaching mathematics in Elementary Schools with minor modifications after the first workshop.

With 850 languages in PNG and many ecologies, implementation is undertaken in different language groups across three ecologies: highlands, coastal/island and hinterlands (often mountains in coastal provinces). Similarly, materials are prepared for the different ecologies accessed through hyperlinks in the general materials on the principles. For example, a lesson around mathematics in the garden area is provided from a highland perspective along with an early reader for the children. A lesson and reader on basket weaving is provided from a coastal perspective. There are readers linked to measurement and base 10 counting. In addition, research carried out in culture and mathematics in PNG over the past 45 years is made available. This research particularly covers counting systems and measurement with some material on locating and geometry. The preliminary design above was modified after the first iteration to strengthen aspects of early learning in school of mathematics.

Workshops were delivered incorporating this design. In addition an emphasis on early childhood play and investigation was intertwined with the inquiry model of teaching (Murdoch, 1998) to assist teachers to prepare a plan for a week that enabled them to unpack mathematics within cultural practices and relate it to school mathematics for a strong transition across contexts. It was found that teachers needed to know more about how beginning mathematicians become more efficient in arithmetic so this aspect was incorporated more clearly in the design of key principles (Figure 2).

The second design to be evaluated is related to technology enhancement. Some of the key principles are:

- Sustainability,
- Ease of use,
- Encouraging the teachers to both read the professional learning materials and engage in preparing and implementing mathematics lessons by using local languages and cultural practices.

Besides field and observation notes, teachers are completing a questionnaire that provides comments and a reflection score together with a record of an interview of questions to be asked of four children and another with parents. Data on language usage, ecology, teacher education, and infrastructure associated with distance from town facilities is recorded.

**Papers Developed From the Research Projects**

See also the lists of papers under Key Papers and Papers Held at GLEC on [http://www.uog.ac.pg/glec/](http://www.uog.ac.pg/glec/)

**Rex Matang**


Charly Muke


Wilfred Kaleva


Kay Owens

Matang, R., & Owens, K. (under review). The role of Indigenous traditional counting systems in children’s development of numerical cognition: Results from a study in Papua New Guinea.


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