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Abstract: Design research or experiment is a relatively new research methodology in education and other areas. A design for professional learning for elementary teachers to recognise and use cultural mathematics in schools has been developed and will be tested through three phases. In addition, a design for technology delivery has also been developed and will be assessed. Evaluation at each phase will lead to improvements in the designs. The design takes account of three ecological areas of Papua New Guin...

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PROFESSIONAL LEARNING ENHANCED BY TECHNOLOGY FOR ELEMENTARY SCHOOL TEACHERS FOR CULTURE AND MATHEMATICS: A DESIGN RESEARCH PROJECT

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Introduction

PNG has a good Reform education policy but implementation at elementary remote schools in mathematics needs strengthening to provide a strong foundation for children both in their identity which avoids dysfunction in society and hence crime but also strong mathematical proficiencies for future development. Current curriculum support has Australian influence although adapted to PNG but a stronger community-based two-way education would enhance languages, cultural identity and strong mathematical conceptualisation. All children need this opportunity, no matter how remote so a feasible elementary teacher professional learning process is also required assisted by technological advances in terms of computer facilitation.

The research builds capacity for elementary teachers, Provincial Education Officers and Trainers, Curriculum Development and Assessment Officers, and preservice teacher educators. The technology enhancement provides a model for further professional learning and development of standards among teachers through a community of practice that is connected by technology. The research also involves researchers in the global community of researchers in ethnomathematics for whom PNG can be a major contributor. This research approach has not been attempted in such a multilingual society so it is ground-breaking. The project will result in a design that will be useful for other Indigenous communities.

While training teachers in literacy has reasonable support, eg. from SIL and other linguists, in the values and processes of learning to read and write in the vernacular, the same has not been the case for mathematics. Research across the world has shown how important it is for there to be continuity...
between home and school mathematics (González, Moll, & Amanti, 2005). Any discontinuity can lead to poor understanding of concepts and to loss of cultural identity and knowledges (de Abreu, Bishop, & Presmeg, 2002). The Reform in PNG wished to strengthen education and Indigenous identity and to improve the transitions. Thus it is important to find ways to do this well for mathematics (Owens et al., 2011).

Through the Glen Lean Ethnomathematics Centre (GLEC), University of Goroka (UoG), and other researchers, eg. Paraide (2012) at National Research Institute, Smith (1984), Lean (1992), & Owens (2001), there is a growing body of research about different 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.

The ways of thinking about counting and the counting words have been reasonably well disseminated, but there is still work to be done on building on the vernacular words and arithmetic strategies (Owens, 2000) and for other number concepts. Further, the ideas on space and measurement have been less well disseminated. Through GLEC, UoG in recent years, eg. Owens & Kaleva, with the assistance of numerous participant researchers especially Muke and Matang, have gathered data and analysed the data for a range of different cultural groups across Provinces (Owens, 2010, 2012b; 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 their own lived experiences in their own homes and by over 60 village stays (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 addition, without conversations between Elders and teachers in a language group, there will be a colonisation of thinking (Tuhiwai Smith, 2005; Owens et al., 2012) 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, who have had a council to decide on a mathematical dictionary, grammar and mathematics education approaches, the issue for PNG is that there are many language groups and so a system that facilitates quality educational continuities is required. Thus the current research considers whether there can be a generic approach to teacher professional learning for Cultural Mathematics, the Elementary School mathematics subject.

**Research Questions**

Focus 1: What are appropriate guidelines for elementary teachers to recognise & 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?

Research Design and Methodology

Design or design-based research is a relatively new research method (Bell, 2004; Collins, Joseph, & Bielaczyc, 2004). A model based on theory and research is designed, improved and validated. The methodology for this study is deliberately developmental to research the designs both of the training guidelines and the implementation of the guidelines through remote teacher professional learning. Design research is based on but also develops the theoretical position. The first design will be the principles for assisting vernacular teachers to appreciate their cultural mathematical proficiencies especially building on measurement knowledge and how teachers can connect these to mathematics in school, especially in elementary schools. The design will be modified in a similar way that Lean’s categorisation of counting systems was a beginning for connecting vernacular and school mathematics but extended by Paraide (2012) and Owens (2000). The guidelines will involve consideration of language usage for ideas that are important in school curriculum. A small number of case study conversations with communities and teachers will be undertaken. Each case study will be evaluated and inform later ones for a validated design.

The second design is about principles and practicalities for elementary teacher development. The course will be prepared, implemented and evaluated leading to improvements and trials, and then to implementation in other regions and modes. The implementation scheme will pursue the use of e- and mobile learning possibilities once a sound face-to-face training approach has been established.

Our previous research into cultural mathematics provides a beginning theoretical position around recognising and using cultural mathematical proficiencies. The four expected prongs are mathematical processes, language support, community involvement, and linking to school mathematics. This theoretical design is developed by evaluating the implementation of the professional learning during each phase of the research. Phase 1: initial development; phase 2: implementation with schools; Phase 3: by Provincial Education Trainers with groups of schools; Phase 4: by distance with group of schools.

Analysis

The principles developed from previous research are used to evaluate the guidelines and implementations in a constant-comparative analysis of data. There will be triangulation of data from sources (teachers, researchers, community and children) and through types of data (observations, teachers’ written documents, field notes and reflective journals, conversations, and interviews). Children’s participation during lessons, their emotional responses to classroom learning, and concept develop as indicated during interviews and classroom behaviour will be quantified. Linguistic analysis will consist of the number and length of occurrences in which cultural practices and language phrases are used to develop concepts. This numerical data will support the analysis related to linguistic conceptualisation of mathematical skills, knowledge and processes.

Design Principles

The design of principles has developed into the diagram shown in Figure 1.
The design for the technology enhancement includes the principles of:

- 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

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

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

- 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

- What they learn?
  Assess, report, plan

Figure 1. Design of key principles for teacher professional development in Cultural Mathematics.
• Sustainability,
• Ease of use,
• Engaging the teachers to both read the professional learning materials and engage in preparing and implementing mathematics lessons by using local languages and cultural practices,
• Build a community of practice of teachers implementing this approach.

Implementation
The workshops are provided currently with a printed manual providing extensive details on how to teach an inquiry method. This is presented as follows:

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,

**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 book, 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.

**The Inquiry Model**

This is a summary about an inquiry learning approach (Murdoch, 1998) to teaching. It is appropriate for building on outside community experiences to assist integrated learning. These notes emphasise its value in teaching mathematics. It helps children develop understanding about the world in all areas of the curriculum. It encourages:

- Cooperating and interacting with other children
- Reasoning and reflecting
- Imagining and inquiring
- Assessing and evaluating

Children learn to perceive (see) different things and express themselves in different ways including in language, English, mathematics, visual and performing arts and movement. They will also learn about their culture, living skills, and the environment.

In mathematics, they will estimate, measure, subtract, understand and use mathematical concepts, reason, problem solve, and communicate mathematics orally, with gestures, in writing and in symbols.

By following the tuning in, finding out, sorting out, going further, making conclusions, taking action, sharing and reflection, you will be helping children to investigate and develop mathematical thinking and concepts. That is, (called the 6Es model):

- **Engaging** - make a list of ideas for engaging children in mathematical activities.
- **Exploring** - what is the role of the teacher to assist children to explore? Ask questions, accept a variety of ideas, make their activity and expressions clearer in terms of mathematical thinking processes,
- **Examining** – trying things out, systematically keeping track of tries, thinking about possibilities
- **Expressing and Explaining** – children explain. Why is this stage important? How would you help children to do this? Give them tools for explaining (e.g. discuss key words, play with them to assist their knowledge development,
- **Extending and Enriching** - how would you plan to do this? Provide additional resources to extend their thinking and help them to link the ideas to others,
- **Evaluating and Enabling** - what might you wish to evaluate? How could you go about this?

Teachers’ role is to:

- arrange the environment so that it helps children to initiate investigations, talk about experiences and manipulate materials in a variety of ways.
- pose questions, make comments, and offer resources that move the children to problem solve and predict potential outcomes.
• identify what it is we want children to learn before setting out the resources, including facts, ideas, mathematical thinking (questioning, problem solving, reasoning, communicating) and skills.

The presentation of the workshop is through activities and small group discussions. It develops from an introductory ice-breaker to get to know participants, a look at mathematics and then at those mathematical processes in culture through small group discussion of a cultural activity. After sharing, we take a closer look at early mathematics and appropriate early mathematical activities, illustrated by videos. The inquiry method provides a means for participants to plan using all this research-based knowledge. We also look at language, bilingual education, dictionaries, and cultural capacity development for the school involving the community especially Elders. Assessment is incorporated and particularly helping teachers to carry out an appropriate individual interview with children to really appreciate the details of the workshop ideas.

Conclusion
This paper provides an overview of the research to improve the teaching of mathematics at the elementary schools of Papua New Guinea. Initial workshops have been showing that the design is strong and bringing about change in teachers’ knowledge and practice. The program meets the essence of the Reform in maintaining and strengthening culture and the identity of the children as well as assisting them to learn mathematics well at elementary school. Classroom practices are also beginning to change.

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