Managing the Ongoing Impact of Colonialism on Mathematics Education

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This paper is a brief summary of a large historic research project in Papua New Guinea (PNG). The project aimed to document and analyse the nature of mathematics education from tens of thousands of years ago to the present. Data sources varied from first contact and later records, archaeology, oral histories, language analyses, lived experiences, memoirs, government documents, field studies, and previous research especially doctoral studies. The impacts of colonisation, post-colonial aid and globalisation on mathematics education have been analysed and an understanding of the current status of mathematics education established as neocolonial. Managing neocolonial education policies may minimise the loss of cultural ways of thinking.

Papua New Guinean societies existed from at least 40 000 years ago with several migrations from the north or west. Around 5 000 years ago, a major new wave of migration occurred and the Austronesian Oceanic languages developed in East New Britain before spreading around the coast and to Island Melanesia as far as Fiji (Addison & Matisoo-Smith, 2010). Groups were relatively autonomous, managing with trade arrangements and intermarrying relationships to meet their needs. There was no central government. The 850 PNG cultures and languages remained with no influence from Europe or the Middle East until the 1800s. Not only was Australia a colony for which this study has some relevance but it also colonised Papua New Guinea (PNG).

Research Aims and Methodology

The purpose of this research was to document and analyse the development of aspects of mathematics and mathematics education in Papua New Guinea from the past to the present. There were a couple of available bibliographies of education up until the mid-1970s (Cleverley & Wescombe, 1979; Smith, 1987) but no focus on mathematics education from the time before European contact and, despite on-going research within the country, there was little in the post colonial period on the development of mathematics education per se. The research involved an extensive use of first contact and later documents and memoirs, archaeological and linguistic research from a diversity of areas and language groups, oral histories, lived experiences, field visits to villages, large research studies on number systems, measurement practices, and mathematical words from different cultures across the country, research studies on mathematics education and teacher education, government documents especially major reports and plans recommending changes to education, syllabuses, and studies on the language of instruction.

Themes that emerged from these sources included the languages of mathematics in villages and in schools, the use of visuospatial reasoning in mathematical thinking, the valuing of both traditional mathematics for everyday life (once identified) and school mathematics for the dream of a job, and the dissonance of mathematics at home and at school. However, the key findings were (a) the depth and diversity of foundational/traditional mathematics, (b) the growth and sources of neocolonialism, (c) the limitations of neocolonialism, and (d) examples for overcoming neocolonialism.

Historical Developments

In the late 1800s, a few anthropologists visited (e.g., Miklоucho-Maclay, 1975), European sailors navigated its waters, and a few German business men began plantations or recruiting for other plantations in the Pacific region (D'Entrecasteaux, 2001). Missionaries soon followed sharing the gospel of Jesus in the vernacular languages, often in a religious format but also in assisting villagers especially with health issues and education (Jinks et al., 1973).

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Governments felt the need to set up administration and controls. The German government in the northern mainland and islands soon set up administrative centres laying claim to it as a colony in 1884. This prompted the British to lay claim to the southern side close to Australia, leaving the colony of Queensland and later Australia to administer. One issue of the early administrators was the exploitation of 'the natives' as they were called. This encouraged them to provide a basic education. Mostly it was through supporting the mission schools but then they began requesting that schooling be in English so that the administrators could converse with the natives. Money was attached. However, overall, little money was available to support the colonial administration. Interestingly, in early administrative reports, basic word lists of the local languages were recorded as new centres were set up.

In Port Moresby, Lawes (1890) and colleagues had written down the Motuan language and used it in the large schools for the local people (Owens et al., 2018). Other village languages were also used especially Dobu in the Papuan islands, Tolai in East New Britain, Bel in Madang area, and Kôte and Yambim in Morobe for church and school. Students completing Grade 6 would then be recruited as teacher assistants in schools. South Sea islanders also came as pastors and teachers. After World War I, the League of Nations passed the northern section to Australia as a Trust Territory. Gold mining was added to exploitation already occurring through plantations. This provoked many foot patrols into the virtually unknown, unpacified highland areas which were then opened up since aircraft were able to fly in. Not only the locals but also the Germans were required to have schools in English for government funding (Smith, 1987).

During and after World War II there was one administration. In the 1960s, the Prime Minister started to talk about autonomy for the Territories since more colonies became independent. However, education was very limited. Hurriedly, high schools were set up (Cleverley & Wescombe, 1979). By now many Australians, often quite young, were recruited as kiaps and teachers to remote areas as well as the towns and coastal centres. Teachers' colleges trained both Papua New Guineans and Australians. By 1966, the University of PNG was set up in Port Moresby and then PNG University of Technology in Lae. There were graduates by self-government in 1973. Research into education, particularly mathematics education, was strong and began influencing worldwide research (Owens et al., 2019; e.g. Bishop, 1988).

Foundational/Traditional Mathematics Learning

Papua New Guinean societies were using mathematics in technology, trade, social relationships, and understanding natural sciences tens of thousands of years ago. Much of this knowledge is still passed on between generations today using Indigenous ways of learning and teaching (Paraide et al., 2022). Most foundational mathematics is learnt from older men or women who gather under relational connections to share knowledge in groups during everyday or special traditional activities (Paraide et al., 2022).

A few remarks might indicate the extent and depth of this knowledge. Seafarers had fishing and navigation skills, travelling over the horizon to distant places (Lewis, 1973). There were trading routes and reciprocity to negotiate with items often passed on to far distant places crossing many language groups (Swadling, 2010). Kinship patterns were extensive and again reciprocity was significant (Shaw, 1974). There were tools and processes for carrying, collecting, fishing, agriculture, food and materials preparation, creating, building, playing and celebrating (Paraide et al., 2022). There were designs of cultural significance, replication of objects like the curves and lines of canoes (Campbell, 2002), pots, drums, baskets, string figures (cats's cradles), shields, bows and arrows, axes, or house walls and roofs (Owens, 1999, 2012). There was extensive knowledge related to medicines (Kopi, 1997), spatial knowledge in recognising the place and the plant for gathering and then in knowing how and what malaise to treat with different medicines and processes.

Classification and sets in designs were sophisticated and related to culture (Owens, 2022). These are evident for the shapes on the various parts of canoe boards, house boards, shields, other carvings, leadership symbols (Were, 2010), food containers, and pots (Owens, 2015; Paraide et al., 2022). Actions, their order and links have been studied in string figures (Vandendriessche, 2015) but also in making other items like bilums. They are remembered but also reorganised to create new designs. Patterns occur in gambling practices (Pickles, 2013), weaving, and string bag making. Numeral systems are varied, some unique, and some shared with neighbours. Some are linked to collecting, measuring, trading or classifying (Owens, et al., 2018; Owens, 2020a).

Colonial Impact on Education and Languages

Administration in colonising countries focussed on law and order, taxes, and keeping records of businesses and other groups such as churches (Megarrity, 2005). Initially in the early and mid-1900s, funds went to government schools and to missions if English was the language of instruction and proportional to achievement in English and mathematics examinations. The missions or churches have dominated education training so that all but one of the primary teachers' colleges are run by churches with the Institute of Education mostly concerned with early childhood education. The University of Goroka also provides Certificates and Degrees in Early Childhood Education and degrees (including Master's) in education for all sectors.

Before and after Independence, there were committees to advise on curricula for primary and secondary education and teacher education. The college staff were able to be in touch and share their ideas and strengths. Some overseas mission staff were in the country for many years while others came for short terms (Paraide et al., 2022; Quartermaine, 2001). Before self-government, Australia instigated a 6-month training program in Rabaul, mainly for Australians and then ASOPA in Sydney, assisting with some understanding of cultural diversity and respect for students undertaking school education, certificates and degrees (Paraide et al. 2022).

There have been schools using local languages for teaching, e.g. Tolai in East New Britain, Tok Ples or local church language in remote Morobe. School students from 1960 to 1985 reported they were punished for speaking languages other than English in both government and mission schools. Since the education system meant that students often left their village for a small centre, they were already beginning to use a non-home language. The children then went to high school, Senior High School, teachers' or another college or University where English and later Tok Pisin were the main languages between students. After years of education away from their village, teachers might or might not go back to their village area to teach. Many students struggled to keep their culture and vernacular language and to learn their village or family foundational knowledge. Despite this they still had strong connections and pride in their family and their family's foundational technological and mathematical knowledge (Owens, 1999; Owens & Kaleva, 2008). Was the loss irrevocable?

An Indigenous Voice

Before Independence, a committee of educated Papua New Guineans chaired by Alkan Tololo prepared a report for education (Department of Education Papua New Guinea, 1974; Tololo, 1976). They recognised the importance of students valuing their culture, knowing how to live in their villages, and connecting village knowledge and school knowledge. However, there was still an Australian responsible for the Territories and he could not see how this report could be implemented so he went to the expatriate Dean of Education at the University who hurriedly prepared another education plan (Cleverley, 1976; Weeks, 1993). The opportunity to hear and develop the Indigenous voice was lost at this stage and indeed for 10 years until 1986 when another Indigenous committee, this time chaired by Paulius Matane wrote a report to which plans were made (National Department of Education Papua New Guinea, 1986). Importantly, with the support of a World Bank report,

cultures and languages were to be recognised and used in education together with the unachieved goal of universal primary education (Weeks, 1993).

Attempts to Educate Following the Indigenous Voice

The Reform period began. They were not just following externally dominated ideas. The desire for universal education meant elementary schools in villages would use the home language of the children (Paraide, 2002). Now there were more PNG educators with higher degrees and curriculum advisory committees had strong national representation from practicing fields, universities and schools. However, they were not necessarily meeting regularly as before 1990. In addition, funding was an issue. It was taken away from higher education but it did not reach the school sector. It was decided that villagers would provide the schools and teachers' houses while the government would provide salaries. Teachers first trained under the head teacher and were accredited upon inspection if they knew the local language, had a Grade 10 education and undertaken training Then they would be paid. However, for years training was often not available and inspectors found it difficult to visit. Many teachers received no or inadequate salary.

An Australian advisory team, whom it was said had too much say, was involved in teacher education for elementary schools (Weeks, 1993). The teacher education courses were set up as Self-Instruction Units with a short introductory workshop, often given as lectures to a large number of teachers in a village area. At first teacher education was by the travelling Institute staff and then by Provincial Education Officers of varying skills, training, and experiences. There was no full unit on teaching bilingually from vernacular language bridging to English language and there was no mathematics unit developed by the Institute using cultural mathematics. One book on Patterns incorporated many cultural materials. Later a research team did develop a Self-Instruction Unit that was given to the Institute of Education (Owens et al., 2015). Teachers who joined in remote workshops valued what they learnt but they were only 3 to 5 days. This was too little, too late. SIL was beginning to make good inroads into teaching teachers how to teach bilingually and to recognise cultural mathematics, at least their counting systems. However, the delay meant that after years of English (or Tok Pisin) education with limited understanding and loss of language, it was now difficult to arrest the language loss or valuing of language. The lack of teacher education meant that students were not adequately learning to read in Tok Ples or English and mathematics was just as poor. The Advisory team from Australian Aid (Curriculum Reform Implementation Project) introduced Outcomes-Based Education (OBE), then common around the world, with inadequate syllabuses for teachers to use and no initial or strong Indigenous voice. The Teachers' Guides and expensive books soon disappeared. OBE too was seen as a problem by the elite and others. The country was in a dilemma with its lack of funding and a new neocolonial curriculum. Like many of the reforms in mathematics education, even going back to the introduction of Dienes blocks, it was inadequately supported by teacher education or inservicing (Paraide et al., 2022).

The End of Learning Cultural Mathematics in Home Language

In 2012, O'Neill was elected as Prime Minister with the promise that English would be the language of instruction from the start. This was despite so much research stating that learning mathematical and other concepts in one's home language and bridging later to English had so much strong support as the best educational approach although students were not doing well on Pacific standardised tests (Paraide et al., 2022). The elementary schools disappeared and were replaced by early childhood education centres for two years (having a play-based first year and picking up the pre-elementary syllabuses from the elementary schools) and then the students had to go to primary school for Grades 1 to 6. Mathematics was no longer called Cultural Mathematics. There were restructures yet again of the education school system (National Department of Education Papua New Guinea, 2016). In fact, instead of Australian colonialism, Japanese approaches to mathematics began. The English version of a Japanese textbook, was now available for teachers to buy if they

did not receive it from the Department of Education. Standards-based assessment, following world trends again, was introduced. The initial syllabus supposedly had PNG Curriculum Advisors involved but there is some evidence there was little understanding of the Japanese approach (Paraide et al., 2022).

A Possible Way Forward

In 2022, at the International Conference on Ethnomathematics 7, a plenary speaker from Papua New Guinea, Charly Muke, said that teachers and administrators now need to do something differently because they were stuck with English. If English is decreed the language of instruction from early childhood onwards, then there needs to be alternative ways forward. Voices like Charly's and Patricia Paraide's were being drowned out. Charly noted how he sat in primary school not understanding a word but for mathematics with concrete materials he figured out what was going on in his own language in his head. Patricia also from village parents had the good fortune of learning in her vernacular Tolai but was exceptionally good when she started school in English. Racial slurs on her background did not help her (Paraide et al., 2022). Notably, there was little work done on local language for mathematics outside of the counting words and systems. How this could be done would be costly and many skilled persons would be needed. Could the Teo Māori experience be repeated even in a small way? A list of mathematical terms for primary school were translated into local language in workshops by teachers and Elders in discussions but this was not ongoing and often only a few terms were explored in the short time available (Edmonds-Wathen et al., 2019). Perhaps, said Charly, we need to consider how Papua New Guineans think mathematically when they are doing cultural activities that often involve science, technology, engineering, and mathematics. Firstly, we know they think visuospatially in these contexts. They often call it 'in my head' or 'by eye'. How do they do this?

Charly also recommends the use of traditional games like their betting game with stones, cat's cradles, their counting systems and the links to cultural practices (see above). Work on the many 850 languages' orthographies, the involvement of Elders in the school curriculum and appropriate materials for schools needs funding. A generation had passed with poor local language or English education so rectifying this situation will not be easy. Teacher education for multilingual classes and cultural mathematics needs to be compulsory.

Ethnomathematics and School Mathematics

There are sophisticated classification systems for counting, design, art (on cultural artifacts), gambling, and kinship (see above and cf. Almeida, 2022; Watson-Verran, 1992). Classification in school geometry is simplified by not having a spatial and cultural component. Knowledge of places and a mental map of large areas is held in people's heads as they traverse the forests or seas (Lewis, 1973). This knowledge involves position but also visuospatial knowledge of trees, soils, water movement, winds, reefs, fish, sharks, dugongs, shell fish and other creatures that inhabit the different areas. The interconnectivity of the mathematical aspects such as position, shape and vectors has purpose and purpose is a main driver for learning and remembering and making connectivity of mathematical ideas (Owens, 2015).

Knowledge of complex trade, intercultural relationships, and reciprocal agreements (Strathern, 1977) involves complex accounting systems covering many goods and money (PNG kinas or traditional money, e.g. shell *tabu*). Pairs, matching, equality and inequality, increase and decrease are central to these systems (Owens et al., 2018). All these are mathematics. Some mathematical knowledge is recorded, often on the body in some way or by objects and displays. Representations include tattoos, body parts, displays, *bilas* (body decorations), demarcation of land, and house size and design (Owens, 2015, 2020a, 2020b; Paraide et al., 2022). All cultures have mathematical thinking for activities—counting, measuring, designing, locating, playing and explaining

(Bishop,1988), understanding, interpreting, inventing, and reasoning (D'Ambrosio, 1985). There are techniques and modelling of cultural ways of thinking mathematically (Orey & Rosa, 2021; Vandendriessche & Pinxten, 2022).

Implementing Ethnomathematics in Schools

Listening and working with Elders is essential. Money is needed for this. First the range of mathematical activities needs to be discussed, the mathematics teased out and represented as in mathematical modelling. The mathematics might not easily fit into the school curriculum but they can be used for patterns and relations. For example, string figures show algorithms and inventions, canoe boards show classifications and patterns. Designs e.g. *kapa* (round leadership symbols from hard shell and tortoise shell) have diverse symmetries, patterns, and angles. Ways of counting have systems, many can easily be coded (Kari, personal communication, 2003), others indicate intricacies related to cultural practices. Each basic counting system can be classified using the frame words (basic words from which others are made), and cycles (this indicates the systems of making high numbers and in most cases in PNG this is a more appropriate approach than using the term base. Most are digit-tally systems with (2, 5, 20) cycles (Owens, et al., 2018). Appropriate teacher education is essential (Tapo, 2004).

Besides the work on foundational/traditional mathematics given in the two chapters of Paraide et al. (2022), Owens (2022) discusses cultural implications for discussing large numbers, groupings, time and work patterns, transactions, classifications, art and design and Bino (2023) indicated mathematical thinking on model canoe building and sailing. In cultural practices, people discuss problems and situations that need resolving. They share their conceptual understandings which are generally associated with visuospatial reasoning which is a holistic way of presenting the problem. Concept, comparison, memories of the past related to the problem or object, patterns, parts, size and shape are all considered visuospatially and ecoculturally. The environmental supports and constraints are discussed including patterns of activities and diversity of responses. These sophisticated mental ways of thinking need to be expounded more by teachers, villagers, researchers, and curriculum writers. This idea of mental mathematical thinking which generally includes visuospatial reasoning (Owens, 2015, 2016) needs to be captured in mathematics and these thinking skills brought to the fore in school mathematics in PNG if neocolonial loss is to be overcome.

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