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Author Biography (approx. 25 words)

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The impact of a teacher education culture-based project on identity as a mathematically thinking teacher

Identity as a mathematics teacher is enhanced when a teacher explores the cultural setting of their mathematics. 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. The reports were written by preservice and inservice, mainly secondary, teachers at the University of Goroka, Papua New Guinea. While all 239 reports were read and considered in terms of the thesis of this article, 60 (25%) were analysed in detail developing the argument. The results indicate the strengths of such projects to take account of cultural knowledge when colonised education systems are further modified through reforms that emphasise culture. The significance for teacher education is the role that an activity which links culture and school mathematics plays in building values and identities.

Keywords: ethnomathematics; mathematical identity; ecocultural pedagogy; Papua New Guinea; secondary teacher education

Introduction

Cultural-historical activity theory suggests that activity results in change in identity and thought at the point of the observable outside activity meeting the inside mental activity. Thus involvement in activity that challenges current belief systems can result in changes to identity (Roth, 2012). The deconstructing of thoughts as a result of a dialogue between two cultural experiences can modify identity (Ferreira, 2010). The cultural-historical identity associated with home and community background is challenged when confronted by difference. Given a culture-based activity, a teacher deconstructs the experiences of the past whether they are experiences from the home or from earlier schooling in order to establish new meaning and identity as a teacher. Cultural differences associated at both the macro-level of curriculum or at the micro-level of the classroom and local community impact on the teacher’s identity when they deconstruct the mathematical activities of the community and the school (Strutchens et al., 2012).

Mathematical activities involve mathematical thinking processes such as explaining, measuring, designing, locating, problem solving, and enumerating (Bishop, 1988). A teacher has a number of individual and interacting identities resulting from activities in which the teacher participates. Thus a teacher has a cultural identity developed through cultural activities and dialogue. A mathematics teacher will also develop an identity as a mathematical thinker through activities. In the sense that mathematical identity is developed through interactions in cultural contexts, there is no universality of mathematical ideals or referents resulting from activities (Radford, 2006). The activities may be in-school or out-of-school but they are primarily in school or in other educational institutions. Involvement in out-of-school activities may or may not be seen as involving mathematics (Wager, 2012) or the mathematical processes may be intuitive, tacit, nonverbal knowledge that are not explicated (Frade & Falcão, 2008). In cultural terms, mathematics may not be expounded within the culture although that is changing with an increase in recognition of ethnomathematics and cultural change (Clements, 2008; D'Ambrosio, 2006; González, Moll, & Amanti, 2005; Teasdale, 1992). Schooling provides tools for students and teachers to deconstruct their thinking about cultural activities so they incorporate mathematical thinking when identifying with their cultural activities. The research study reported in this article explored whether a culture-based project impacts on a teacher's mathematical identity so it incorporates both ecocultural[i] mathematical thinking and school mathematical thinking.

Nevertheless, valorisations or values held by the community occur when new processes of thinking are accepted by many of the community and used in the community for communication and activities (de Abreu, 2002). Competing valorisations and identities in cultural and school activities require mediating. The mediating tool may be physical or in the mind such as numeracy systems (Lerman, 2001). While the external contexts and activities are observable, there are internal activities that may be manifested externally. Furthermore, identity itself is internal and an individually constructed concept.

Identity is partially determined by cultural background, community practices and valorisations which are constantly changing. Individual motivations and thought interact in a two-way fashion between sociocultural contexts and the developing mind (Roth, 2012). In fact, a teacher or student participates in multiple activities and identities that impact on motivations and other affective aspects of learning as well as goal-setting and cognitive thinking (Ferreira, 2010). Reaching consonance between one knowledge and another is no easy task but knowledges are mediated by experiences (Bishop, 2002). Meaning-making is dependent on the ecocultural background of a teacher mediating those experiences (Gruenewald & Smith, 2007), no matter how colonised that background might be (Chinn, 2007). A teacher may value one knowledge more than another in general or in a specific situation. During transitions from the culturally mediated tools to school mathematics, the gap is bridged by explaining practices (de Abreu, 2002).

The literature on identity tends to emerge from either a sociological perspective or a psychological perspective. The sociological perspective relates to identification with the values, knowledges, beliefs and attitudes of a social group. On the other hand, the psychological literature considers identity from the point of view of individual personal beliefs about oneself emphasising the cognitive and affective personal aspects in establishing identity (Owens, 2007/2008). Malmivuori (2006), from a psychological perspective, notes that self-regulation is systemic and often not articulated in consciousness, a self-system with stable internal structures including:

- content-based mathematical knowledge, but also
- learned socio-cultural beliefs about mathematics, its learning and problem solving
- beliefs about the self in mathematics
- affective schemata
- habitual behavioural patterns in mathematical situations. (p. 151)

Thus sociocultural aspects are recognised as part of the self-system of self-regulation, including self-appraisal and self-confidence, embedded in reflective direct activity and self-awareness that has “high personal agency with effective and creative self-system processes” (p. 153). In a previous study in Papua New Guinea (PNG), architecture students faced with solving a design problem had pride in their cultural heritage that led them to consider they were good architectural designers and in one case a good mathematician (Owens, 1999). Their self-system regulation (Malmivuori, 2006), self-confidence and cultural responsiveness (Owens, 2007/2008) resulted in perseverance with the problem and unique, beautiful, and balanced paper sculptures that reflected cultural artefacts.

Davis (1999) argues that identity is an enactive, dynamic, interactive ever-changing state of being. It is a becoming within a social context. The social identity interacts with the self-regulation of the learner in developing the mathematical identity (Macmillan, 2009). Owens (2007/2008) elaborated this idea and presented it diagrammatically as shown in Figure 1. The interaction between social context and self is two way and does not occur in a linear fashion but flows back and forth over time and in different aspects of being. Context influences social identity which affects participation in learning.

Figure 1 on Owens’ identity model about here

Owens’ model provides details about each aspect and has similar approaches to another integrated model of identity by Keck-Staley (2010) who associated this integrated approach with particular well-known theories. She explains how mathematical identity is formed from human resource capital consisting of sociocultural capital (Vygotsky’s theory), human capital (Bandura’s social learning theory), and personal capital (Erikson’s identity theory) through a mathematics community of practice (Lave and Wenger’s theory).

> Mathematics identity consists of the dispositions and deeply held beliefs that individuals develop about their ability to participate and perform effectively in mathematical contexts and

> to use mathematics to change the conditions of their lives. Further, … (mathematics) identity encompasses a person's self understandings (Keck-Staley, 2010, p. 6).

In the current study, mathematical identity has processes of cognitive and affective self-regulation but also a sociocultural identity different to the wider dominant cultural group's identity, values and beliefs about mathematics but similar to the University class's sociocultural identity and values about ethnomathematics. Hence this dynamic situation is worth investigating to expand on how sociocultural contexts and self-regulation are impacting on mathematical identity.

Mathematics Education

An enculturation perspective of mathematics education suggests that the teacher is responsible for enculturating the students into Mathematics[ii] as interpreted through educational institutions. Bishop (1988) noted that mathematics teacher education "should develop a broad understanding of Mathematics as a cultural phenomenon,… the values of Mathematical culture, …symbolic technology, … and a strong metaconcept of the Mathematical enculturation process" (p. 175). Bishop drew on his experiences in PNG where he realised how culturally-based concepts, concept development, and values could be quite different to mainstream school education (Clements, 2008).

This sociocultural dimension of education implies that learning is more than a simple cognitive process. Concepts are developed through interactions with other people, through reflection on ideas that at first seem unrelated. For example, out-of-school and in-school experiences result in self-negotiation mediated through practice of activities (Radford, 2006). In the current study the practice is manifest in a defined ethnomathematics project which entailed interaction with other people. The writing of the report on that practice represented the conceptual ideas, meanings and values established through the teacher's project. It required reflection on what seemed like unrelated activities: school mathematics and village practices.

Similar projects had occurred for other communities. For example, variations of spatial concepts as portrayed by sentences and the overall worldview of the Navajo (USA) indicated three basic concepts (a) the essence of movement and the viewing of objects as a slice in time, (b) the sense of volumeness/flatness, and (c) the notion of dimension (but not as an orthogonal grid) (Pinxten, van Dooren, & Harvey, 1983). Based on this deconstruction and reconstruction of cultural thinking, mathematics in Navajo curriculum and schools developed these basic concepts within the Navajo context before expanding on them and incorporating some school mathematics, namely topology.

We might ask whether in PNG, with more than 850 language groups, it is possible for each teacher of mathematics to provide a curriculum for each community based on their ecology and culture given their unique qualities and the significant difference of the contexts to that of a curriculum developed largely from a western perspective. The logical systems, the languages, and the purposes for mathematical thinking differ. The question is whether teachers develop values and identities from an ethnomathematics course that might impact on their future teaching.

However, the recognition of mathematics within the culture requires teachers to make the connections deliberately. In some cases, this is within the curriculum documents such as those from the Alaskan communities USA (Barnhardt, 2007; Lipka & Adams, 2004) and those prepared for elementary teachers in PNG. The PNG education reform included a recognition that education was best developed from the home culture and community of the students (Dawson, 2005; Litteral, 2001). This reform policy was a valuing of their many cultures, their languages and their community relationships. Nevertheless the teacher must identify with such perspectives and be empowered by an identity as an ethnomathematical thinker to implement these reforms.

In terms of Figure 1, we note that the identity as an ethnomathematical thinker influences the interactions with the sociocultural context. This is manifest in the socio-political situations developed from an ethnomathematics perspective in the work of Pinxten and his colleagues (Pinxten & François, 2012; Pinxten, et al., 1983), Gutstein (2007) in a USA barrio school, Lipka and Adams in Alaska (Lipka, Mohatt, & The Giulistet Group, 1998), in the establishment of Maori education and mathematical language in New Zealand (Meaney, Trinick, & Fairhall, 2012), and in establishing Sámi mathematics and teachers' cultural competence in Sweden (Jannok Nutti, 2008).

A critical pedagogy that takes account of the learners' sociocultural background and interrelated ecology of the place associated with the learners and their community is an ecocultural pedagogy. Such a pedagogy values holistic, integrated knowledge that has changed and accumulated over time and consists of interrelated constructs that continue to develop with thinking, problem solving and experience (Crotty, 1993; Morrison, 2007). The ways of representing cultural resources and maintaining wellbeing are mediated by teachers to reduce the complexity of everyday experiences, respectfully and "without losing site of the rich and dynamic totality of their lives" (González, et al., 2005, p. 21). In this USA Latino/a study, mathematics included basket-weaving patterns reducing the complexity of the everyday situation but still being associated with the use of baskets, the reasons for variations, and the creation of variations. Teachers took over certain procedures, artefacts, discourses and reasoning from the students' families. They were inquirers with questions, and they accepted that these funds of knowledge are fluid and negotiated through discussions among participants. These same processes became the metalanguage and processes of their own teaching with the students actively involved in developing their knowledge. Teachers became risk-takers, supportive, and non-judgemental. A hybridity of this fund of knowledge developed as two-ways or both-ways education (Stanton, 1994) in which there was negotiation of meaning, respecting both cultural and school mathematics (Ovington, 1994). By recognising the ecological and sociocultural context and its impact on learning, an ecocultural pedagogy becomes a part of a teacher's identity as a mathematical thinker.

The Study

The University of Goroka (PNG) has a large collection of 239 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) or primary (Grades 3 to 8) school curriculum by making links between cultural knowledge and school topics, and by providing lesson plans and examples for school students that illustrated this connection.

This research study explored whether an ecocultural project impacts on a teacher's interactive changing state of being which is self-regulating and identifying 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 would indicate how their identities as mathematical thinkers incorporated aspects of cultural identity and their preparation of lessons would express this ethnomathematical identity.

Methodology

All 239 reports were read and a note made of the category of mathematics involved (Bishop, 1988), the syllabus topics used, the quality of the reported mathematics, the depth of cultural knowledge, and how the connections between culture and school mathematics were made (e.g, poorly, superficially, embedded in cultural thinking, synergistically or two-way). Sixty reports that provided good detail of culture and school mathematics were analysed in depth to see how the teachers identified with their cultural knowledge and with school mathematical knowledge and how these knowledges were related. Figure 1 guided my thinking when reading the reports. I was interested in how sociocultural contexts (their language group, the University class, the National curriculum and educational reform) were influencing the students as reported by them. Social identity was marked by the students' emotive words when referring to their culture or family, reference to themselves as part of the cultural community of practice, and the depth of knowledge of the cultural practices. Identity as a mathematical thinker was evident through the sense of ownership of the mathematics (both cultural and school) expressed by affective terms, knowledge depth, goal focus and reasoning in problem solving through the project, and making connections between school and cultural mathematical thinking. Students' self-regulation was clear in the goals they set, the quality of their reports, and their efforts to carry out the project as they described them. The impact of change in identity to incorporate cultural mathematical thinking into school mathematics was depicted by the materials they prepared for their students and in the value they placed on using ethnomathematics when teaching.

The document analysis was part of a larger research project with ethics approval from my Australian University and the host PNG University. This research project focussed particularly on measurement activities and associated spatial and numerical knowledge with data gathered from as many of the 850 language groups as possible. The relevant Department of the latter University had requested the document analysis and supplied the documents. My 30 year association with Papua New Guineans, firstly during a 15 year period when I lived and worked in PNG and then during research with my PNG colleagues, has influenced my interpretation of data. I had friends from many different village areas, I stayed in villages in most provinces of the country for one or two nights to weeks; I went by rough-road vehicles, small planes, boats, and canoes and then walked to many places to see and discuss village activities first hand; and I have been privileged to participate in or read countless conversations, interviews, questionnaires and reports sharing village ways and cultural thinking. These activities and dialogues in ethnomathematics have impacted on my identity as a mathematical thinker and teacher.

Results and Discussion

Pepeta (2001), one of the teachers, provided an overall purpose for his project and a philosophical statement about why ethnomathematics should be a basis for school mathematics (Figure 2).

Figure 2 on Pepeta about here

Over 90% of teachers presented a similar rationale for their projects. They were strongly motivated and had a clear goal that encouraged their self-regulation in solving the problem of understanding their cultural activities as mathematics and relating them to school mathematics. Pepeta, as indicated in Figure 2, deconstructed the issues of school mathematics and in his research made use of shapes with local names rather than using school terms. The mathematics was culturally situated.

Figures 2, 3 and 4 provide examples of what was pervasive throughout the reports. The ecocultural context and its influence back and forth on the teachers' cognition and affect were recognisable in their expressed valuing of cultural mathematics. Every student, despite distance from ancestral land or non-use of their group's language because of parental marriage or workplace, stated their language and provided details of artefacts or cultural activities that involved mathematical thinking. Cultural identity was expressed through their acknowledgements, descriptions of cultural activities, and stories that they told to contextualise their examples and exercises for their students; the affective language that showed pride in the achievements of their culture, relatives and ancestors; and the emotive expression of their relationships with their families and those who helped them with the project.

Dingi (2007), a teacher from Gumine District, Simbu Province illustrates how the ecocultural context supports the development of identity (Figure 3). “They reflect the social patterns, climate and resources, which exist in a particular area, … an outward sign of community self-reliance and cultural pride” he says. He gives details of the mathematical and scientific thinking of the community, “The basis of the structures of the buildings come as a result of trial-and-error, intuition and from astute observation of structures found in nature ” illustrating that the project was engaging him and he was able to identify with the cultural mathematics and scientific thinking (Kahan, 2004).

Figure 3 on Dingi about here

The school curriculum was also a context for Dingi. By bringing together his cultural and school mathematics Dingi provided examples about shapes and measurements related to village houses that were sound mathematically and connected to the syllabus. In doing this, he showed how he made the connections between community activity and the content of school mathematics. The project was a tool to assist students to appreciate the syllabus and school textbooks (Lerman, 2001; Roth, 2012). Dingi’s comment illustrates how the project was a tool for him: “Working on this project gives me greatest insight to see into many ordinary activities that I do and people at home do (that) involve a lot of mathematics that I learn in the classroom.” The project fulfilled Lebow’s (1993) suggestions for quality teaching: (a) it provided a context for learning that results in both autonomy and relatedness, (b) the reasons for learning were embedded in the learning itself, and (c) it supported self-regulated learning by providing skills and attitudes that enabled the learner to take increasing responsibility for the restructuring process.

Dingi’s identity as a mathematical thinker was applied back into society (Figure 1). Dingi’s rich emotive language and close connection to family activities (“that I do and the family do”) was linked to increasing self-esteem, even for school dropouts, reducing societal problems, a socio-political impact (Mellin-Olsen, 1987).

Like Dingi, Bire (2007) from Lufa in the Eastern Highlands Province (Figure 4) also noted that learning mathematics in culture will reduce the lack of cultural identity for school dropouts and hence reduce crimes in society as well as valuing his family and culture. He dedicated his project to an Elder, and acknowledged God, his parents and the man who demonstrated the trap, using powerful words in valuing his people’s thinking and skills. He used his Nega language as well as the metric system. The teachers generally valued the help of their family and the assistance of the University class and department as part of their communities of practice.

Figure 4 Bire about here

Bire showed his strong identity with his culture and he expressed his belief in the role that culture plays in learning mathematics, not only cultural mathematical thinking but also school mathematical thinking. His belief about mathematics was encapsulated in his statement: “application of mathematical concept in everyday activity is very vital for better understanding and hence makes life much easier in daily activities” seeing it as a foundation for school mathematics. He lamented the use of purchased traps that reduced the trap-making activity in his culture, reducing opportunities for mathematical thinking. A similar comment is made by John (2007, p. 3) in describing the making of clay heads for Asaro mud-men dancers: “Through the process of this cultural activity some mathematical ideas are derived but are not relevant to the cultural context until it is understood”. About 95% of teachers identified themselves as mathematics teachers with similar beliefs about mathematics being based in cultural ways of thinking and doing but explained by school mathematics. They expressed an identity within culture and a role in restoring culture and making mathematics more meaningful to their own students. The valorisation of promoting culture was supported by National policy, an outer context for their developing identities.

Most teachers adequately presented the school mathematics that they related to the cultural activities as illustrated by the Figures 5, 6, and 7. When using the making and painting of a door board for a large community building (e.g. a *haus tambaran* for men or a family long house) by the Telefol, Sandaun Province, Onggi (2005) used questions on proportion and ratio structured like school mathematics with the cultural background as context. Each question on ratio related to the mixing of colours and grease using his language for colours and typical containers for measurement. However, the cultural activity is discussed as if the cultural mathematics was the basis for understanding ratio, a school mathematics topic. He also had geometry topics (e.g. symmetry) linked to both cultural design and school mathematics. The two-way synergy of school and cultural mathematics was noticeable.

About 20% of the students provided the steps and ways of thinking required for creating an artefact whether a garden or an object like a wig as shown by Piru (2005) (Figure 5). He too marvelled at the mathematics of his ancient cultural group, and at the explanation that he was given linked to school mathematics with drawings and symmetries. He enhanced school mathematics adequately with the customary explanation of wig making. He himself was cognitively and affectively engaged in the project and his cultural mathematics. His self-regulation and cultural mathematical identity are evident in his goal of connecting both school and cultural mathematics, his self-evaluation of his language and representations (explaining the size of *ki),* his use of a diagram strategy, and his strong sense of ownership and valuing of cultural activity as mathematics. He was identifying as a mathematical thinker in both school and cultural mathematics and hence providing quality relational mathematics for his future students. It should however be noted that he is code-switching and using the Tok Pisin term *centimeter* as "the small unit".

Figure 5 Piru about here

Piru, nevertheless, superimposed some calculus questions onto the final wig:

> "Find the gradient by differentiating from the first principle.
>
> $y = -x^2 - 10$ is the equation of curve B" (Piru, 2005, p. 7)

The connection to cultural mathematics is not clear.

Rather than use cultural ways of mathematical thinking, many teachers situated the school mathematics examples in their cultural background but they did not always make a link between the mathematical thinking of the community and school mathematics. Most teachers used the cultural artefact as a contextual problem for engaging school students and providing a context for school mathematics rather than providing the ethnomathematical thinking required in creating the artefact. This is similar to western school students considering the mathematics found in environmental objects when participating in mathematics trails or scavenger hunts in a park or a zoo (Owens, Pattison, & Lewis, 2003; Smart & Marshall, 2007). Similarly, Julius (2001, p.2) from Tabare, Sinasina, Simbu Province engaged students with cultural designs and language. She noted that the weaving of pitpit blinds[iii] with designs "*kewah*, *egleh*, *gamlageh*, *bongeh*, for starry, pentagonal, hexagonal and octagonal shapes" could be used for developing the rules about the angle sum of interior angles of polygons by adding auxiliary lines (diagonals) to form triangles inside the shapes, tabulating the results and summarising the pattern (Figure 6). Strong mathematical knowledge in the use of patterns and inductive reasoning was noticeable throughout her project. Her identity as a mathematical thinker was strong. Men generally do the weaving of blinds and some male teachers used the patterns related to the actual weaving or the areas of the concentric squares (*diamonds* in Tok Pisin) or other shapes. In the pattern discussions, these teachers were beginning to report cultural mathematical thinking that occurred in the activity.

Figure 6 Julius about here

Self-regulation and a strengthening of identity as a mathematical thinker were also manifest in another well-constructed report by Yambi (2004), a Kewabi speaker, Kagua, Southern Highlands Province. She recognised the extraordinary thinking and ability of those who build bridges but she imposed school mathematics onto the activity and artefact. The report contained beautiful sketches about the building of cane bridges that span the canyons above fast flowing rivers of PNG (Figure 7). Based on the picture, there were problems expressed as stories involving village people building the bridge but involving trigonometry, something that would not have been used although the recognition of lengths, angles, and how these vary relationally (ratios are embedded in trigonometry) would have been significant thinking in the bridge-building activity. Similarly, the wave formed by the side vines of the bridge was used as an analogy for a sine wave about which some exercises were provided (the “flattening” of the curves is reminiscent of the flattening of the double helix diagrams of the Yolngu (Thornton & Watson-Verran, 1996). The story problems and valuing of cultural practices indicated identity with culture but the quality of the report showed engagement, self-regulation, and identity with mathematical thinking.

Figure 7 Yambi about here

Ownership and valorisation were commonly evident in the mathematical examples that were set in cultural context with appropriate names and activities of place. Galligali

(2001), Western Province, expressed not only school mathematics terms but language words and cultural mathematical analysis behind the classification of Gogodala canoes by size, speed and clan-related colours. The information was sourced from a book as well as home background. The report gave details about preparation, and practice of paddling and singing that accompanied the canoe races, together with explanations and examples on ratios of number and size, speed and rates as well as calculus questions on velocity and acceleration.

Cultural elements incorporated into the mathematics classes in about 30% of the analysed reports involved language words for the names of objects used in the activities and/or the counting systems. However, around 10% gave action words or measurement words and covered the processes of thinking mathematically. Bire (2007) called the steps of bandicoot trapping *Klge'vu* and used words for objects (Figure 4).

The analysis of the reports indicated a valorisation of ethnomathematics in the multicultural University class as a community of practice (Wenger, 1998). Many students thanked their fellow students as well as their community Elders or family in their acknowledgements. The teachers' reports expressed the belief that their people used mathematics but did not think or call it mathematics. Interviews with the classes' three University lecturers (who came from three different Provinces of PNG) suggested that this valorisation was reflecting the lecturers' perspectives. Most teachers considered school mathematics as more exact than village mathematics which only had to meet the needs of the village but several reports show this perspective was contested. For example, ropes or sticks or steps or small units were used to measure and ensure the house was sturdy or a wig or mud-head mask fitted the wearer properly.

The teachers considered the intuitive, experiential mathematics gained from observation or activity in the village as building blocks or fundamental analogies for school mathematics. Bafimu (2007) from Teptep, Raikos, Madang Province said:

> The basis of fundamental ideas or the building blocks of the mathematics that we usually learn in schools … is comparing the size of the "toms" [long sticks] dividing the bigger cleared areas into smaller areas to speed up cultivation, … equal share of the land for participants, …to plant different species of yam and to make it easy for gardeners to weed and harvest (pp. 3, 6, 7)

While this is a long-term cultural approach for planting it can be compared to the valorisation of the introduced use of two equal length sticks for tree planting (cf, de Abreu, 2002). The equilateral triangles form units of area that were visualised but not necessarily noted as area units (Owens & Kaleva, 2008a). Another example that provided a sound basis for understanding both coordinates and area embedded in the culture was provided by Manue (2004) of Soli, Yangoru, East Sepik Province, who drew a garden grid, with vertical and then horizontal lines explaining the purpose of both. Again there was a strong analogy from culture for school mathematical concepts. Similarly, Yalura (2004), Southern Highlands Province, related area to the rectangular *mumu* cooking pit[iv] with a school-style perspective drawing. He compared areas and volumes of this pit with the truncated cone pit and the deep cylindrical pit used for a whole village feast. Pepeta (2001), from Wapenamanda, Enga Province, described a connection between the children's game *bras flaua* (matching cards in the same family) and the collection of like terms in algebra.

As a result of the synergy between culture and school mathematics, an important finding from the study was the resultant quality of the school mathematics and pedagogical content knowledge presented in the reports as illustrated in the Figures. In an interview as part of the larger study, Kerapi (2007), Southern Highland, noted her ethnomathematics project strengthened her valuing of cultural mathematics and the two-way relationship between home and school understandings. She also noted "my family uses an area unit to measure the area of the gardens unlike most families", a fact that was borne out by Owens and Kaleva (2008a).

However, a small number (5%) of reports showed a discrepancy between the derived construction of school mathematics from the cultural artefact and the generally accepted school mathematics (cf, Owens & Kaleva, 2008b). The ecocultural context did not always ensure development of school knowledge despite having school textbooks and the impetus to link it to cultural mathematics. For example, after studying some symmetry of different weaving and bag designs, one teacher (whom I have selected not to name) discussed the angle sums of interior angles of polygons.

> "Since there are six equilateral triangles to the hexagon, the sum of the total interior angles would be;
>
> 180^0 x 6 triangles = 1080^0"

without noting that this also included the angles at the centre of the hexagon (compare to the correct mathematics presented in Figure 6). The teacher used words such as "subtended" and "interior" without appreciating their meaning. Despite the use of a diagram, the teacher was unable to recognise the error. This suggests that this teacher, perhaps because of language difficulties, was struggling to review her own work (self-regulate), a critical aspect of identity (Owens, 2007/2008). Nevertheless, these few teachers still provided a clear record of their mathematical journeys in their reports.

Conclusion

The social contexts for the teachers included an ecocultural background consisting of a village place and language. The context included a former colonial school system that changed over the 30 years as an Independent nation to reflect their cultures and their needs for professional mathematics [v]. The ethnomathematics project engaged the teachers and provided them with an opportunity to inquire about their cultural mathematics. It was an important tool in the process of change of perspectives on mathematics, and as a means of self-regulation that results in a developing identity. Their ownership of the knowledge that they constructed from their personal cultural backgrounds showed their purpose and participation in bringing about change in pedagogy. They had a strong sense of identity with their culture and their projects encouraged them to reflect upon their cultural heritage and recognise that it was valuable and relevant to school mathematics education. Construction of knowledge arose from resolving the differences between mathematical knowledge perceived as part of the curriculum and the ethnomathematical knowledge embedded in cultural practices, rather than any dissonance of knowledges associated with a negative shattering of valuing themselves as agents who can affect their own lives and society's development (Gutstein, 2007; Presmeg, 2002). This point was recognised by teachers who were concerned about the dropouts from school. In terms of the diagram on identity (Figure 1), there is a strong link back to the community context expected from the teacher's mathematical identity.

Knowledge of cultural practices may be shared by experts but the younger teacher/researcher may not have access to all relevant knowledge to connect to the curriculum and may not have been involved in the creative activity that resulted in the cultural artefact (Owens, 2006). Furthermore, languages do not necessarily translate directly into school mathematical terms adding difficulties to these projects. Teachers also noted people used intuitive knowledge in cultural practices (also mentioned in González, et al., 2005). The connections between school and community mathematics were not straightforward. Pinxten et al. (1983), Chinn (2007) and others experienced similar difficulties in connecting cultural perspectives to schooling. Nevertheless, the teachers valued their cultures as funds of mathematical knowledge in process and product (González, et al., 2005), as analogies, for motivation and as story contexts for problems. In 5% of cases only (see the example above on interior angles of a hexagon), the school language of mathematics was not strong, suggesting that these few teachers had limited self-regulation in reviewing and seeking information restricting development of their identities as mathematical thinkers.

It is expected in the power relationship between student teachers and lecturer that the teachers would follow the lecturer's perspective on ethnomathematics in an assessment task. Nevertheless, cultural identity and recognition of mathematical knowledge as having a basis in culture were effective drivers in producing quality mathematics. Much of this can be credited to self-regulation for the following reasons (Figure 1; Owens, 2007/2008; Wilson, 1997):

- the projects were on topics they selected themselves,
- they applied their own goals,
- they explained the mathematics,
- they solved the problems of sourcing the details of the activities and connecting them to school mathematics,
- they structured learning environments for their school students, and
- they evaluated their successes in their conclusions.

Affective aspects were revealed by the degree of engagement with the task, portrayal of ownership of the mathematics in the culture, their imagination to prepare examples, resilience in problem solving, and the quality of their reporting.

There was a synergy between ecocultural mathematics and representations of school mathematics. Teachers valued the abilities or mathematical processes of their ancestors and Elders but their understanding was enhanced by school mathematics. The teachers recognised the importance that an ecocultural pedagogy had in terms of learning and developing their students' sense of worth, and hence ethnomathematics was a sociopolitical force in society. The powerful nature of the state in terms of the defined curriculum and available materials dominated the teachers' perceptions of mathematics as expected in an education curriculum that focuses on concepts rather than processes. Too few teachers expressed an ecocultural way of thinking that was systematic but different to their school mathematics systems.

Nevertheless, the teachers were supported by the government's reform for education that placed culture as a foundation and they expounded the power of using ethnomathematics. Bire (2007) noted that "recognition of the value of culture and teaching culture in schools would reduce the drift to towns and the associated criminal activity". To him, "mathematics was a powerful force if cultural activities were used as analogies (physical models) in schools". These teachers used their ecocultural backgrounds to engage school students in mathematics, valuing culture and ethnomathematics to link cultural mathematics to topics in school mathematics and to prepare lesson plans and examples for school students.

Acknowledgements

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Figure 1. Developing identity as a mathematical thinker (Owens, 2007/2008).

Figure 2. Philosophy for the project (Excerpts from Pepeta, 2001).

Figure 3. Valuing the relationships of people in the learning of ecocultural mathematics, Simbu Province, PNG (Excerpts from Dingi, 2007).

Figure 4. Preserving culture through mathematics of the bandicoot trap, Eastern Highlands Province, PNG (Excerpts from Bire, 2007).

Figure 5. Shapes in weaving, Tabare, Simbu Province, PNG (Excerpts from Julius, 2001).

Figure 6. Measurement by Huli in wigmaking, Southern Highlands Province, PNG (Excerpts from Piru, 2005).

Figure 7. Mathematics in bridge building, Southern Highlands Province, PNG (Excerpts from Yambi, 2004).

Figure 1 – Identity

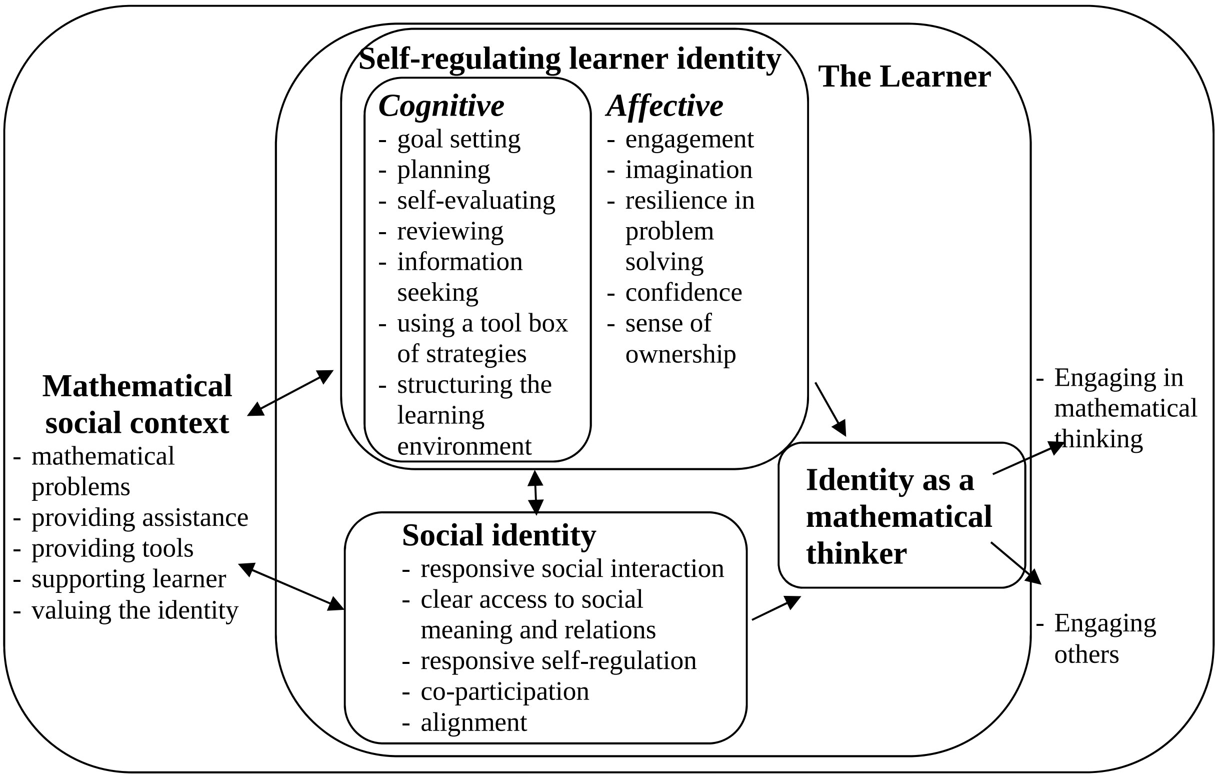


Figure 2

Why do students find it hard to solve mathematics problem? Why couldn't they interpret what is asked as the writer wants? Why is mathematics too hard to comprehend? Is it because mathematics is written using the second language? Or is it that it is not part of the Papua New Guinea (PNG) culture? These are serious questions parents, teachers, students and even the elites ask. These projects will mainly figure out some missing aspects in the mathematics curriculum. To impart what is in the text books to the students is hard for it is not part of their life especially in the society which they come from. The missing part in the school mathematics curriculum is what they (students) normally do as part of their everyday activity. The above questions will only be minimized when mathematics learned in the culture is included in the current mathematics. … (By using) traditional mathematics which is in them which they thought was not mathematics … only then will the students be able to understand the current mathematics.

Figure 3

I am dedicating this work to my brother B and my loving and concerned mother T. B, … I have never had a chance to thank you for all that you have done for me. Words like love, care, support and encouragement will be just another word to me if I had not felt them from you … This work shows my love for you. …

… The conditions that people are in determine the type of houses they build. In Papua New Guinea, the housing traditions vary from place to place. They reflect the social patterns, climate and resources, which exist in a particular area … an outward sign of community self-reliance and cultural pride. …

The people have been very practical with their knowledge … but the system of education does not help our students to acknowledge and relate those knowledges to the Western brought school knowledge. However, Ethno mathematics tries to change this perspective. This project looks at investigating the Mathematics that are found in the everyday activities…

The people have precise knowledge and understanding of the behavior and characteristics of the materials they use to build their houses. The materials that they use are in consideration with the climatic factors and its durability,… available locally. … The people know that the life span of the wood is reduced if they come into contact with water. Therefore, they make drainage surrounding the house…Given the limited range of available building materials, the people exhibit skillful response to the spanning of space ---- the collection of gravitational forces and their transmission to the ground ---- and the need for stability against lateral loads. The basis of the structures of the buildings come as a result of trial-and-error, intuition and from astute observation of structures found in nature (e.g. trees) …

All buildings in my area are constructed by their inhabitants with assistance from close kin who would expect the favor returned. …

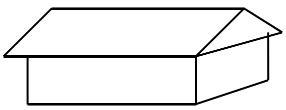
Though my ancestors and some of my elderly people did not go to school, they are indeed great mathematicians. In their everyday life, they use mathematics that is taught in the classrooms. In almost all the activities that they do, they unconsciously use mathematics. …

OUTCOME: By the end of the lesson, students should be able to identify triangles in the rectangular coastal house and find the angles. In addition, they should be able to identify the Sine, Cosine and Tangent Ratios by cutting the triangles into half.

LESSON PLAN CONTENT

Introduction: **(5mins)**

Drawing rectangular coastal house.



Body:

Identifying triangles-*triangles have 3 sides and their angles add up to 180 degrees….*

Divide triangles and find angles …

(examples, explanations, and lesson plan details are included) …

(He concludes) Working on this project gives me greatest insight to see into many ordinary activities that I do and people at home do (that) involve a lot of mathematics that I learn in the classroom. Nowadays people in the village are thinking that people who go to an institution have a better set of mind …. This affects them psychologically and drops their self-esteem. …Therefore, I think we use many activities from our local environment in our teaching … this would at least help the students to realize that in whatever they do they are putting their intelligence into practice… and this would help maintain their self-esteem. At the end, we can expect fewer problems in our society.

Figure 4

Please see attached document

Figure 5

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Figure 6

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Figure 7

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[i] Papua New Guinea has 850 languages and associated cultures, and a diversity of environments and ecologies which all impact on mathematical thinking. The term ecocultural refers to ecology and culture in terms of context of education.

[ii] Mathematics beginning with a capital letter was used by Bishop to refer to the body of mathematical knowledge taught in schools and further educational institutions.

[iii] *Blind* is the Tok Pisin word for woven walls from leaves or bark of specific trees or split bamboo or cane

[iv] A *mumu* is a method of cooking in which stones in a ground pit are heated by fire before covering with food and then leaves and soil to seal in the heat. Water is often poured onto the stones through a hole in the covering soil creating steam for cooking.

[v] Changes were by PNGians often with overseas advisers who brought a global perspective such as using investigations, educating in the vernacular for the first three years, and outcomes-based education