Employing Mathematical Modelling to Respond to Indigenous Students' Needs for Contextualised Mathematics Experiences

Kelli Brown
Queensland University of Technology
<kelli.brown@qut.edu.au>

This discussion paper highlights some of the issues related to mathematics underachievement experienced by Indigenous students. Mathematical modelling can be implemented as a rich way to provide contextualised mathematics learning experiences able to be couched in significant contexts that Indigenous students can relate to and enjoy. This paper proposes that mathematical modelling will enhance Indigenous students' motivation to engage in Western concepts of mathematics, hence improving cognition and achievements in this Key Learning Area.

A Chronic National Problem

Underperformance in mathematics directly influences Indigenous students' access to successful social, fiscal and educational futures, for example, it obstructs their ability to meet minimal Vocational Education Training (VET) mathematics requirements for apprenticeships and traineeships. The Queensland Studies Authority's (QSA, 2006) Queensland State wide numeracy tests are administered to all schools in Queensland and have indicated annually, since their initial implementation in 1998, that Indigenous students in Years 5 and 7 lag behind non-Indigenous students by up to two years in their understandings of numeracy.

Previous literature and research has mainly focused on Indigenous students' learning environments and preferred learning styles, literacy and general mathematics learning. Further research is required that specifically targets three things: Indigenous students' perceived value of mathematics, their conceptualisations of the usefulness of their school mathematics beyond the classroom, and the ways in which their underachievement can be improved. Insufficient research has been performed to reveal new or alternative mathematics teaching strategies that can contextualise mathematics for Indigenous students. Contextualising the mathematics curriculum would be an effective means to significantly improve both Indigenous and non-Indigenous students' understandings of mathematics. In particular the utilitarian aspects of mathematics that will augment their future learning and achievement in this Key Learning Area (KLA), thus promoting greater employment prospects, could be made clear for students through the implementation of real world mathematics applications in mathematical modelling.

Examining This National Concern: A Historical Perspective

Historically, colonists judged the intellectual capacity, civility and worthiness of Australian Indigenous cultures and societies by the degree to which they could be compared to European modes of thinking, norms and customs (National Health and Medical Research Council, 2003). Perceived as competent in concrete thought yet incapable of making abstractions and generalisations or performing analytic thought, these cultures were perceived by proponents of Scientific Racism to be of lesser intelligence and not capable of formal logic or reasoning (Ascher & Ascher, 1986; Eckermann, Dowd, Chong, Nixon, Gray, & Johnson, 2006; Nakata, 2002). Ascher and Ascher (1986) state that "in any context these descriptions are heavily judgmental; in the context of mathematics they are condemning" (p. 128). Hence, in terms of owning mathematics, history perceived Indigenous cultures as being incapable of developing or using mathematics and indeed were viewed as having little or no real use for mathematics in their inferior societies (Nakata, 2002). In the past, Indigenous students have been taught no more than basic numeracy skills; Bin-Salik (1990) and Morgan and Slade (1998) propose that the purpose of this was to disallow intellectual integration into Australia society.

Ascher and Ascher (1986) clearly state that there are no studies or studies that have been repeated that support the myth of the childlike primitive. Walkerdine (1997) claims that it is usual for mainstream teachers to reflect the dominant culture's views via the curriculum and some, albeit unwittingly, promote the idea that Indigenous students are childlike and simplistic in their thinking. It is important to note here that cultural differences can be thought to reside more in the circumstances to which particular cognitive processes are applied, rather than

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in the existence of a mental process in one cultural group and its absence in another (Ascher & Ascher, 1986). Negative attitudes, values and misconceptions formed about Aboriginal and Torres Strait Islander people are shaped around the concept of scientific thought. These stereotypes persist in contemporary society and continue to marginalise Indigenous people (Eckermann et al., 2006).

What is Happening for Indigenous Education in Contemporary Society?

In recent times, Australia has witnessed the creation of new Acts and policies to improve educational outcomes for Indigenous students, committing resources to improve Indigenous students' numeracy. The literature provides a plethora of reasons as to why Indigenous students do not succeed at school compared to their non-Indigenous peers. However, what the literature does not explain is why, when armed with new and informed syllabus documents, research knowledge and government allocated funding, Indigenous children continue to experience difficulties in becoming numerate citizens. An example is the Australian Commonwealth Government's recent National Indigenous English Literacy and Numeracy Strategy (2000-2004), endorsed by all Commonwealth, State and Territory Ministers, that states all Indigenous students should achieve English literacy and numeracy at the same level as other Australian youth (DEETYA, 2005). To achieve this, it is necessary for students to have appropriate educational resources in their home environments as this has been positively correlated with student performance (De Bortoli & Creswell, 2004). The availability of a dictionary, a space conducive to study that has a desk, necessary textbooks and calculators are necessary to ensure that Indigenous students do not continue to fall behind their non-Indigenous peers in numeracy (De Bortoli & Creswell, 2004). Other factors, such as parents' education and employment histories, travel time to school, availability and usage of computers in out-of-school settings, homework skills and support all impact significantly on students' underperformance in mathematics (De Bortoli & Creswell, 2004).

Nationally, the gap between Indigenous and non-Indigenous students in mathematics, and particularly in numeracy, is alarmingly high and persistent (Schwab & Sutherland, 2001). In their attempt to cure the problems in mathematics education, recent syllabus documents support the contemporary learning theories that emphasise the importance of acknowledging the students' social and cultural contexts and teacher and student relationships and challenge educators to implement a mathematics curriculum that is meaningful, relevant and culturally appropriate for Indigenous students (Coleman-Dimon, 2000; Frigo & Simpson, 2000). Yet the problem escalates and Indigenous students' low mathematics performance is of major concern for Australia, particularly as it relates to low retention rates in secondary school and an inability for Indigenous students to meet the minimal Vocational Education Training (VET) mathematics requirements for apprenticeships and traineeships and entry to university studies.

Many Indigenous students accept as personal failure their inability to achieve acceptable academic outcomes in literacy and mathematics in urban, rural and remote schools, thus limiting their access to the benefits that education provides (Jude, 1998). Low performance and motivation to engage in Western mathematics' practices appears to begin in the primary school years (Tripcony, 2002). A multilevel assessment program conducted by Tripcony (2002) identified that Indigenous students in rural and remote schools perform 3 to 7 years behind urban Indigenous students of the same age in numeracy tests. Tripcony (2002) states that the urban Indigenous student is roughly 2 times more likely than their non-Indigenous peer to be identified in the Queensland Studies Authority's (QSA) Year 2 Net, a ratio that increases to 3 or 4 times for rural and remote Indigenous students.

The QSA (2004) statistics from their statewide tests clearly indicate that Indigenous students continue to fall behind in numeracy in Years 3, 5, and 7. In their findings published in their Overview of Queensland Statewide Student Performance in Aspects of Literacy and Numeracy, the QSA (2004) report that "across all years from 1999 to 2003 the average performances of Indigenous students were generally equivalent to those of non-Indigenous students two year levels lower" (p. iii). This report also found that Indigenous students as a group performed lower than non-Indigenous students where "the mean scale scores for all strands of Numeracy for Indigenous students were appreciably lower than the mean scale scores for the other groups", adding too that these students lag behind the cohort as a whole (QSA, 2004, p. 17). Comparisons were made between 2003 and 2004 Year 3 students' average results and indicated that the 2004 cohort performed slightly lower in all strands of numeracy (QSA, 2004). The report admits that students who perform below the minimum standard deemed acceptable may have difficulty progressing at school. Frigo and Simpson (2000) found similar difficulties for Indigenous students in the New South Wales Basic Skills Test for Years 3 and

5 students, claiming that underachievement of Indigenous students in that State continues, on average, to be significantly lower than for their non-Indigenous peers.

Wright, Martland, and Stafford (2000) agree, noting that their studies revealed that "children who are low-attaining in their early years tend to remain so throughout their schooling, and the knowledge gap between low-attaining children and average or able children tends to increase over the course of their years at school" (p. 2). A recent long term study, conducted by Reynolds, Temple, Robertson, and Mann (2001), indicated that intervention in general cognition in the early years of education for low-income students and students having at risk backgrounds continued to have a positive impact on their educational and social achievements up to the age of 20 years. Intervention programs resulting from the Year 2 Diagnostic Net in Queensland have worked someway towards bridging this gap.

Indigenous culture is still viewed by many as being too primitive to contribute to contemporary society (Howard, 1995; Mathews, 2003). As in the past, Indigenous cultures today are still considered by some as having no valuable mathematics and science knowledge and that any perspectives Indigenous students had on mathematics or science would inevitably be influenced by contact with Western perspectives (Hooley, 2000). The Queensland Mathematics Syllabus (QSA, 2004) states that the concise language of this KLA, both verbal and symbolic, enables communication of shared mathematical understandings within and among communities. It states too that an understanding of mathematical knowledge, procedures and strategies will empower the individual so that they may become effective participants in the interdependent world (QSA, 2004). Mathematics implemented in the Western education system effectively locks out Indigenous students who are unable to speak this concise language of Western mathematics and engage daily in Western education practices that marginalise them.

The Diagnosis

Matthews, Watego, Cooper, and Baturo (2005) claim that one of the significant problems existing in contemporary mathematics education is the lack of relevance. Indigenous students find that their mathematics curriculum undervalues their culture, teaching methods, and worldview. Mathematics as a KLA is viewed as providing students with a futures perspective that involves developing knowledge, practices and dispositions that will enable all students to identify possible, probable and preferred individual and shared futures, leading to insights and understandings about the roles of individuals and groups in visualising and preparing for those preferred futures (QSA, 2004). The QSA (2004) claims that students who hold a futures perspective are empowered as they have an outlook that enables them to take responsibility for their actions and decisions, thus allowing them to participate confidently in the progression of social innovation, recovery and renewal. Indigenous communities often have opposing worldviews to the futures perspectives from the dominant Western culture, which causes disequilibrium for Indigenous students negotiating their educational futures.

Howard and Perry (2007) express it nicely when they pronounce that "all education, including mathematics education, needs to be a place of belonging for Aboriginal students" (p. 402). Unable to perceive its usefulness, Indigenous students require curriculum developers and educators to find a means to instruct Western concepts of in new ways that enable them to make connections between mathematics and various real-life phenomena (Munakata, 2005). Mathematical modelling can be offered to introduce contextualised mathematics experiences for Indigenous students, additional to the necessary, more prescriptive, teacher-led teaching episodes. Today's cognitive learning theories suggest that learning is not linear, rather it develops in various directions at once and at a uneven pace (Lingefjärd, 2002). So, rather than teaching approaches that focus on how to make the learner fit the system, the preferred focus with mathematical modelling would be on how the system can better fit the learners' needs (Frigo & Simpson, 2000).

Working Toward a Cure

The question posed countless times but yet to be satisfactorily answered is how to address the problem of continued underachievement in mathematics for Indigenous students. From their New South Wales study with remote rural Aboriginal students, parents and school staff, Howard and Perry's (2005) results indicated that many Indigenous students believed they attained mathematical knowledge by the teacher depositing it into their heads and also through writing it down. Furthermore, the Aboriginal students believed they acquired mathematical knowledge by redoing incorrect work or through work practised in textbooks; the students were not aware of their own mathematical competencies (Howard & Perry, 2005). Howard and Perry (2005) claimed that although the Indigenous students enjoyed learning new things in maths they found the learning of mathematics concepts difficult, holding negative views about themselves as learners of maths.

It is known that seated bookwork is not conducive to the learning needs of Indigenous students. In fact Hamilton (2007) notes that that there is little evidence to suggest that textbook problem solving will lead to improved mathematical performance beyond the classroom. Mathematics programs that accentuate Aboriginal students' life experiences and contexts bring relevance to their learning, thus providing purpose and in turn increased levels of motivation and engagement. Mathematical modelling and problem solving can inject curiosity into what is sometimes considered by students to be a boring subject: when the two are properly combined, they can improve students' attitudes towards mathematics (Falsetti & Rodríguez, 2005).

Mathematical modelling involves realistic and complex situations where the participant takes on the role of problem solver to work mathematically in ways that move beyond the traditional school experience (Lesh & Zawojewski, 2007). The modelling tasks generate products that often include complex artefacts or conceptual tools required for some purpose to achieve some goal (English, In press, 2009; Lesh & Zawojewski, 2007). Mathematical modelling is dissimilar to customary mathematics instruction as it provides experiences for students to educe their own mathematics (English, In press, 2009). In modelling activities the mathematics is embedded and must be established by the students, thus enabling them to develop mathematisation skills that can become generative resources in life beyond the classroom (English, In press, 2009). Mathematical modelling is much more than merely an inquiry based approach to the teaching and learning of mathematics concepts; mathematical modelling can sustain the integration of key concepts from other KLAs so that mathematics becomes one of the key foci for successful resolution of the task. Modelling provides excellent opportunities for interdisciplinary experiences that require students to not only make full sense of the situation, but to personally mathematise the task in a way that makes meaning for them (English, In press, 2009). Modelling is a cyclic process that includes the interpretation of problem information, the selection of pertinent quantities, the identification of necessary operations that may lead to new quantities, and the creation of significant representations (English, in press, 2009; Lesh & Doerr, 2003). English (In press, 2009) states that "because the children's final products embody the factors, relationships, and operations that they considered important, powerful insights can be gained into the children's mathematical and scientific thinking as they work the problem sequence". It is crucial that Indigenous students be provided with various opportunities to demonstrate what they know and can do (Frigo & Simpson, 2000).

Although mathematical modelling problems require more time for implementation than some other problem activities, the benefits for the students can be outstanding. Mathematical modelling can capture students' imagination and may therefore promote an increased life long interest in mathematics for Indigenous students. Students are often fascinated by things that do not work or fit the correct pattern (Humble, 2005) and educators can provide opportunities for students to think critically through real-life situations where modelling can facilitate the defining and creating of solutions and where often more than one answer can be generated (Lege, 2005). Mathematical modelling allows students to seek solutions, explore patterns and formulate conjectures through culturally appropriate contexts; these activities provide the requisite skills and adequate levels of participation in supported environments necessary for school success (Howard & Perry, 2007). English (In press, 2009) makes clear that this learning approach encourages students to work through complex circumstances collaboratively as a member of a team, developing skills for future-orientated learning. What's more, modelling facilitates the metacognitive skills of planning, monitoring and evaluating all of which are measurable (Tanner & Jones, 2002). Boaler (2001) claims that these mathematical modelling experiences do more than enhance individual understanding; in addition these experiences provide occasions for student involvement in practices that are represented and necessary in everyday living.

An Example of Mathematical Modelling Currently Being Researched

The author of this paper is currently conducting research in an urban Brisbane school with Years 4 to 7 Indigenous and non-Indigenous students. Students work in groups on modelling tasks relating to Australia's cyclones and on the topic of chocolate. The students work with visual and written texts, making connections between the mathematics embedded in the activity and their real world experiences. Students investigate the topic from a historical perspective and in this way it is uncomplicated to integrate the KLA of SOSE with those of Mathematics, Literacy, and Science. In some instances, data are presented on graphs for students to analyse, however much of the mathematics is embedded and students often stated that they didn't realise that they were doing maths.

Negotiation is a key factor featured in modelling tasks. It would have been advantageous to construct modelling tasks for this study that catered for student interest, however, those selected for implementation were done so with student prior knowledge and interest in mind. Students who enjoy taking leadership responsibilities did, and in some groups created roles for themselves and for other group members. Of interest is the ways in which some Indigenous students view the modelling tasks as having a job to do, and compartmentalised the task so that certain members of the groups could accomplish specific parts. Having done that, none of the participants were observed teasing apart the task content so as to specifically identify the maths components of the modelling tasks; considering that most Indigenous students in the study judged themselves as mathematically incompetent when interviewed prior to the implementation of the modelling activity, it was interesting that they did not attempt to avoid the mathematics components of the task when it was recognised. The 'having a job to do' is an interesting concept here, as in the researcher's teaching and research experience Indigenous students often take more pleasure in learning tasks that involve being physically active and are perceived by them to have a genuine utility.

After researching their problem, students responded to the task's assessment by preparing their findings for discussion with their peers. Students are offered a variety of modes to deliver their findings and indeed some students have requested to formulate their own. It is this level of student interest that indicates that mathematical modelling can be perceived by students to be a productive and worthy enterprise.

Recommendations

Educators have long been alert to the fact that our education system is failing Indigenous students. What is required urgently is an integrated and contextualised mathematics curriculum that will engage Indigenous students to actively investigate, analyse, and reflect on real world problems they are interested in. It is argued here that without the development and national implementation of such a curriculum, the low retention rates and low levels of mathematics success for Aboriginal students at secondary school will persist, thus continuing to promote the arrestment of their successful life chances.

This paper recommends that curriculum planners and educators embrace mathematical modelling for the academic and social benefits it can deliver for students. Mathematical modelling could be the step forward in academic change, particularly for Indigenous students. It would be advantageous if curriculum developers were to produce modules, similar to those provided by the Queensland Studies Authority to support the current Queensland syllabus documents, as this would support novice users of mathematical modelling as a pedagogical tool. Development of such modules could foster educator mathematical modelling teaching competence and confidence prior to the teacher constructing specific mathematical modelling tasks for their students.

References

Ascher, M., & Ascher, R. (1986). *Ethnomathematics.* Retrieved January 7, 2007, from http://articles.adsabs.harvard.edu//full/seri/HisSc/0024//0000131.000.html

Bin-Salik, M. A. (1990). *Aboriginal tertiary education in Australia*. Adelaide: Aboriginal Studies Key Centre, University of South Australia.

Boaler, J. (2001). Mathematical modelling and new theories of learning. *Teaching Mathematics and its Applications. 20*(3), 121-127.

Coleman-Dimon, H. (2000). Relationships with the School: Listening to the Voices of a Remote Aboriginal Community. *The Australian Journal of Indigenous Education*, *28*(1), 34-43.

De Bortoli, L., & Creswell, J. (2004). *Australia's Indigenous Students in PISA 2000: Results from an International Study.* Retrieved April 26, 2006, from http://www.acer.edu.au/research/projects/pisa/documents/RM59IndigScreen.pdf

Department of Education, Employment, Training and Youth Affairs (2005). *The National Indigenous English Literacy and Numeracy Strategy*. Canberra: Federal Government of Australia.

Eckermann, A-K., Dowd, T., Chong, E., Nixon, L., Gray, R., & Johnson, S. (2006). *Binan Goonj: Bridging cultures in Aboriginal health.* Sydney: Churchill Livingstone Elsevier.

English, L. D. (In press, 2009). Promoting interdisciplinarity through mathematical modelling. *ZDM: The International Journal on Mathematics Education, 41*(1) (Springer; Europe).

Falsetti, M., & Rodríguez, M. (2005). A proposal for improving students' mathematical attitude based on mathematical modelling. *Mathematics and its Applications. 24*(1), 14-28.

Frigo, T., & Simpson, L. (2000). *Research into the numeracy development of Aboriginal students: Implications for the NSW K-10 Mathematics Syllabus.* Retrieved June 11, 2006, http://www.boardofstudies.nsw.edu.au/aboriginal_research/pdf_doc/aboriginal_num_k10_math.pdf

Hamilton, E. (2007). What changes are needed in the kind of problem solving situations where mathematical thinking is needed beyond school? In R. Lesh, E. Hamilton, & J. Kaput (Eds.), *Foundations for the future in mathematics education* (pp. 1-6). Mahwah, NJ: Lawrence Erlbaum.

Hooley, N. (2000). *Educational research: Towards an optimistic future, reconciling Indigenous and Western knowing*. Retrieved August 9, 2004, from http://www.aare.edu.au/00pap/hoo00103.htm

Howard, P., & Perry, B. (2007). A school-community model for enhancing Aboriginal students' mathematical learning. *Proceedings from the 30th Annual Conference of the Mathematics Education Research Group of Australasia* (Vol 1., pp 402-411) Melbourne, Vic: MERGA 30.

Howard, P., & Perry, B. (2005). Learning mathematics: Perspectives of Australian Aboriginal children and their teachers. *Proceedings from the 29th Annual Conference of the Mathematics Education Research Group of Australasia* (Vol 3., pp 153-160) Melbourne, Vic: MERGA 29.

Howard, P. (1995). Listening to what people have to say about mathematics: Primary mathematics and the thoughts of one Murri student. *The Aboriginal Child at School*, *23*(2), 1-8.

Humble, S. (2005). Section B beware answers with questions. *Teaching Mathematics and its Applications, 24*(1), 37-41.

Jude, S. (1998). Aboriginal education in urban secondary schools: Educating the educators. *The Australian Journal of Indigenous Education*, *26*(2), 13-16.

Lege, J. (2005). Socrates meets the 21st century. *Teaching Mathematics and its Applications. 24*(1), 29-36.

Lingefjärd, T. (2002). Teaching and assessing mathematical modelling. *Teaching Mathematics and its Applications. 21*(2), 75-83.

Lesh, R., & Doerr, H. M. (Eds.). (2003). *Beyond constructivism: Models and modelling perspectives on mathematic problem solving, learning and teaching*. Mahwah, NJ: Lawrence Erlbaum.

Lesh, R., & Zawojewski, J. S. (2007). Problem solving and modeling. In F. Lester (Ed.), *Second Handbook of research on mathematics teaching and learning*. Greenwich, CT: Information Age Publishing.

Matthews, C. (2003). *Notes on teaching Indigenous students mathematics*. Unpublished paper, QUT, Kelvin Grove, Australia, 40-59.

Matthews, C., Watego, L., Cooper, T. J., & Baturo, A. R. (2005). Does mathematics education in Australia devalue Indigenous culture? Indigenous perspectives and non-Indigenous reflections. In P. Clarkson, A. Downton, D. Gronn, M. Horne, A. McDonough, R. Pierce, A. Roche (Eds.), *Building Education* Research Group of Australasia, Vol 2., pp. 513-520), Melbourne. MERGA

Morgan, D., & Slade, M. (1998). A case for incorporating Aboriginal perspectives in education. *The Australian Journal for Indigenous Education*. *26*(2) 6-12.

Munakata, M. (2005). Exploring mathematics outside the classroom through the field trip assignment. *Primus: Problems, Resources, and Issues in Mathematics Undergraduate Studies. 15*(2), 117-123.

Nakata, M. (2002). Indigenous knowledge and the cultural interface: Underlying issues at the intersection of knowledge and information systems. *IFLA Journal*. *28*(5), 281-291.

National Health and Medical Research Council (2003). *Values and ethics: Guidelines for ethical conduct in Aboriginal and Torres Strait Islander health research.* Retrieved November 3, 2006, from http://www.nhmrc.gov.au

Queensland Studies Authority (2006). *Indigenous perspectives*. Retrieved on January 3, 2007 from http://www.qsa.qld.edu.au/yourqsa/policy/indigenous-perspectives.pdf

Queensland Studies Authority (2004). *2003 Overview of statewide student performance in aspects of literacy and numeracy: Report to the minister for education and minister for the arts.* Retrieved on 12th January, 2006 from www/qsa.qld.edu.au/testing/357tests/archive.html#2005

Queensland Studies Authority (2004). *Queensland mathematics syllabus*. Retrieved on March 20, 2007, from http://www.qsa.qld.edu.au/downloads/syllabus/kla_maths_syll.pdf

Reynolds, A., Temple, J., Robertson, D., & Mann. E. (2001). Long term effects of an early childhood intervention on educational achievement and juvenile arrest. *Journal of the American Medical Association,* 18(285).

Schwab, R. G., & Sutherland, D. (2001). Building Indigenous learning communities. Discussion paper No.225/2001. *Centre for Aboriginal Economic Policy Research*, Canberra: The Australian National University.

Tanner, H., & Jones, S. (2002). Assessing children's mathematical thinking in practical modelling situations. *Teaching Mathematics and its Applications. 21*(4), 145-159.

Tripcony, P. (2002). *Challenges and tensions in implementing current directions in Indigenous education*. Paper presented at Australian Association for Research in Education Conference (AARE), Brisbane, Queensland, 2002.

Walkerdine, V. (1997). Difference, cognition, and mathematics education. In A. B. Powell, & M. Frankenstein (Eds.), *Ethnomathematics: Challenging eurocentrism in mathematics education* (pp. 2). Albany: State University of New York Press.

Wright, R., Martland, J., & Stafford, A. (2000). *Early numeracy: Assessment for teaching and intervention* (2nd ed.). London: Paul Chapman Publishing Ltd.