MATHEMATISING AND CONTEXTUALISING – CONNECTING MATHEMATICS AND NUMERACY TO IMPROVE LEARNING FOR ABORIGINAL STUDENTS (MAKE IT COUNT)

STEVE THORNTON

Charles Darwin University
stephen.thornton@cdu.edu.au

JO STATTON

Alberton Primary School
joanne.statton@albertonps.sa.edu.au

As part of the *Make it Count* project teachers in the Alberton cluster of schools in SA are focusing on the connection between mathematics and numeracy, and particularly on the impact of learning in context. We suggest that the connection between mathematics and numeracy can be understood using the ideas of mathematising, which involves moving from the everyday to the mathematical, and contextualising, which involves moving from the mathematical to the everyday. We report on the project as it has unfolded at the schools in the Alberton cluster, and on the development of a focused research question that will guide the final two years of the project.

Introduction

> Much of the present teaching of mathematics, particularly in the primary years, has Aboriginal students doing mathematics that is not related to their world and their everyday experiences. As a result, by the time many Aboriginal students have reached the latter years of primary school they have been alienated from mathematics. (Matthews, Howard & Perry, 2003, pp. 12, 13)

Make it Count is an Australian Government funded project conducted by the Australian Association of Mathematics Teachers (AAMT) Inc. Its aim is to develop an evidence base of practices that improve Indigenous students' learning in mathematics and numeracy. Over the course of four years schools in eight urban and regional clusters throughout Australia are developing projects that are relevant and targeted to their particular situation. With support from AAMT, consultants and critical friends, each cluster is creating a professional learning community in which teachers share ideas, trial activities and programs and document results.

Specifically *Make it Count* aims to:

- document and share effective models of teacher professional development, whole school change and community engagement in relation to mathematics and numeracy;
- develop whole school approaches to mathematics and numeracy that result in markedly improved achievement by Indigenous students;
- build and participate in networks and professional learning communities; and
- act as catalyst and support for action by others.

In the Alberton cluster of schools in SA teachers are focusing on the connection between mathematics and numeracy, and particularly on the value of context in the learning of mathematics. In this paper we discuss the theoretical framework for mathematics and numeracy that has guided the planning undertaken by teachers in the schools, and particularly on the role of mathematisation and contextualisation in planning effective mathematics learning for Aboriginal students. We then report on the project as it has unfolded at the schools in the Alberton cluster of schools, and on the development of a focused research question that will guide the final two years of the project.

The Alberton cluster of schools

The Alberton cluster of schools consists of three schools, Alberton Primary School, Northfield Primary School and Ocean View Birth to 12 College, each of which has a significant proportion of Aboriginal students. The cluster is located to the North and West of Adelaide in suburbs that were typically populated by blue-collar workers with a high proportion of migrants and Indigenous people. Like many dockyard and near-city suburbs they are undergoing rejuvenation, with a growing sense of community pride and identity. This sense of pride is reflected in the schools, where students and teachers are generally engaged and enthusiastic.

At each school staff have developed a project that is focused on students in the middle years of primary school learning mathematics through interesting and relevant contexts. While the projects are classroom-based and hence inclusive of all students, in developing the projects staff have been particularly mindful of the needs of Aboriginal students. At Alberton Primary School and Ocean View College students in years 3, 4 and 5 have been grouped for literacy and numeracy, and given the opportunity to choose to learn through contexts such as art, design, technology, sport or enterprise. At Northfield Primary School teachers have focused on structuring lessons through a brain-based learning model (Sousa, 2008), which includes the use of contexts to create meaning.

Theoretical framework

Although the focus of the project was to make mathematics learning for children come alive through mathematics that was learnt in context, we were also mindful that context alone may not promote deeper learning or greater engagement (Lubienski, 2000). Hence we developed a model of learning in context that would be more nuanced and powerful than merely suggesting that teachers should use real-life examples to teach mathematics.

Our initial model used a two dimensional model based on Dowling's (1998) domains of practice. We were aware that this was a gross oversimplification of Dowling's work, however hoped that it would provide a framework for thinking about our work in the project. We termed the quadrant represented by content and expression that was clearly mathematical *mathematics*, and the quadrant that represented everyday content and expression *numeracy*. The remaining two quadrants we termed mathematisation[1] to describe real-world context expressed mathematically, and contextualisation to describe mathematical content expressed in everyday language (Figure 1).

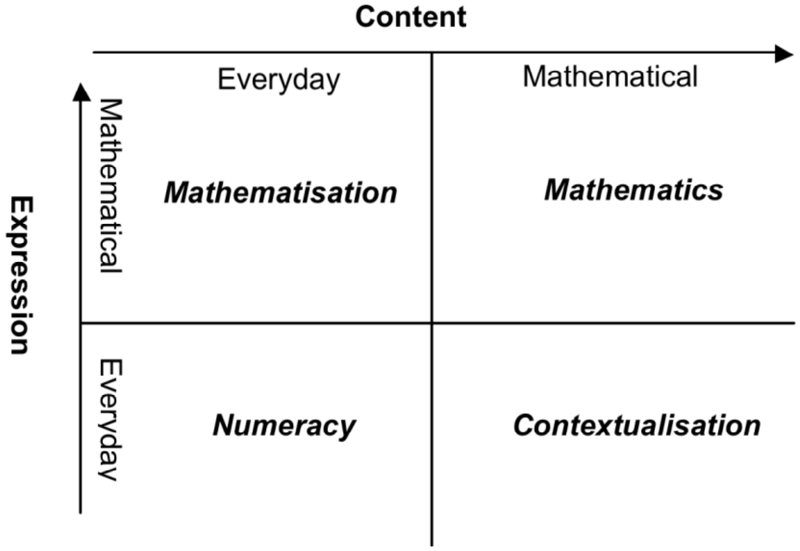

Figure 1: The Alberton Cluster model for mathematics and numeracy

In making use of this model we described contextualisation as the shift from mathematics to numeracy, a process in which mathematical ideas are deliberately embedded in everyday contexts. These contexts then provide a springboard for the learning of mathematical ideas. Contextualisation thus provides a strong sense of purpose, in that it has a meaningful learning outcome for students in terms of the mathematical understanding developed (Ainley, Pratt & Hansen, 2006). Mathematisation is then the reverse process in which everyday contexts are expressed mathematically, and mathematics becomes the vehicle for solving real problems. This process shows the utility of mathematics, in that it is used to make sense of and solve a meaningful task (Ainley, Pratt & Hansen, 2006).

The deliberate acts of mathematisation and contextualisation described above also address the oft-criticised use of pseudo-contexts in mathematics (Olive, Makar, Hoyos, Kor, Kosheleva, & Sträßer, 2010). Rather than presenting students with artificial and contrived problems typically found in school textbooks, the deliberate acts of contextualisation and mathematisation enable teachers to ensure that students solve rich mathematical problems with an authentic purpose. In this way they closely align with the principles espoused by the Dutch *Realistic Mathematics Education* program, in which students are guided through the process of constructing mathematical tools and principles in meaningful contexts (Van den Heuvel-Panhuizen, 2003).

[1] Treffers and Goffree (1985) term this horizontal mathematisation, the act of making connections between mathematics and the real world. They also use the term vertical mathematisation to refer to connections between mathematical ideas. As this project was explicitly about learning mathematics in context we used the single term mathematisation to capture the idea of expressing everyday ideas using mathematical language and concepts.

Two vignettes

One teacher, Aaron, was initially challenged by the school principal to teach literacy and numeracy through art. While he felt comfortable as a teacher of literacy, Aaron had always expressed a personal dislike for mathematics, and could not see the connection between mathematics and art. However through exploring ideas such as the golden ratio, Aaron was able to overcome many of his misapprehensions and find meaningful situations for the processes of mathematisation and contextualisation. In one lesson he worked with a mixed group of year 3, 4 and 5 students to mathematise the process of drawing a face. The students took measurements in real contexts of the position of various facial features, and calculated key proportions. They also looked at the overall shape of faces, noting the variation from a circle or ellipse. The students then drew an outline of a face, and used rulers to measure and calculate the required positions and size for the eyes, ears and nose for their own outline.

Sarah worked with a mixed group of year 3, 4 and 5 students learning literacy and numeracy through design. One of the projects was to design a school garden, including measuring the pH of soil to determine the suitability for particular plants. While the students could not be expected to understand the science of pH, the activity involved reading a scale or comparing indicators with a colour chart to obtain a reading accurate to ½. This prompted Sarah to explore the concept of a fraction with children. She extended their understanding by asking them to find and explain other examples of fractions in their environment, such as time or sharing food. In this way Sarah and the students contextualised the concept of a fraction, giving a strong sense of purpose to the activity and richer meaning to the mathematics.

Through the deliberate embedding of literacy and numeracy within art or design, coupled with the intentional use of the processes of mathematisation and contextualisation, mathematics came alive for Aaron and Sarah's students, and equally importantly for the teachers themselves. Students saw mathematics as a rich area of learning as they extended their own understanding of measurements, proportions and fractions, and as being useful in authentic situations such as drawing more realistic faces or as being important in making sense of fractional scales. The benefits of such an approach were equally evident through the observations and reports of other teachers who used science, sport or enterprise as learning areas in which to embed literacy and numeracy. Anecdotal reports suggest that the benefits of this embedded approach were particularly significant for the Indigenous students in the school[2].

Development of a research focus

The framework described above gave teachers in the Alberton Cluster of schools a common language through which to discuss the use of context in learning mathematics. They were able to express ideas in a deeper and more nuanced way than simply saying that context seems to improve learning. In particular they became sensitive to the opportunities for mathematisation and contextualisation, and were able to talk about their classroom planning and activity in those terms. Informal observations and

[2] The collection of more focused evidence relating to the cognitive and affective benefits of this approach for indigenous students is a major goal of the project in the ensuing two years.

reflections from the teachers involved suggested that this approach provided both affective and cognitive benefits for students. However this was what we termed “feel-good” data, rather than being based on systematic observations or measurements. We were thus challenged to develop a clear, concise and measurable research focus for 2011 and 2012, the final two years of the project.

A purposeful approach to mathematisation and contextualisation

There is a considerable body of literature that suggests that the use of meaningful and relevant contexts may be important for Aboriginal students learning mathematics. Frigo (1999) suggests that “(c)ontextualising mathematics … means finding ways of providing experiences and strategies in which students can gain meaning and develop the appropriate language that enables them to extend their skills in Western mathematics.” (p.13) Although recognising that contextualising mathematics for Indigenous students is not straightforward and involves the overturning of power relations and tacitly held beliefs about Indigenous students, Matthews, Watego, Cooper and Baturo (2005) suggest that it “has the potential to change the educational environment so that Indigenous cultures and their way of knowing are valued rather than devalued and that Indigenous students have pride in their culture and believe that they can perform well in the education system.” (p.519)

However Brown (2008) suggests that context alone may not be enough.

> 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. (Brown, 2008, p.93)

This caution is echoed by Sullivan, Zevenbergen and Mousley (2003) who suggest that contexts, both mathematical and pedagogical, may exclude some children. They argue that the mathematical context is often artificial, alienating, or excluding and always requires recontextualisation to draw out the mathematics, and that the pedagogical context must be made explicit to enable children to understand the purpose and make sense of the mathematics. It seems that elements such as social justice, empowerment, engagement, reconciliation, self-determination, connectedness and relevance (Matthews, Howard & Perry, 2003) need to work together to ensure that learning mathematics in context is meaningful for Indigenous students.

The Alberton cluster question

In discussing the benefits of the approach to teaching and learning described in the vignettes above, teachers particularly highlighted students’ increased engagement, and their enhanced understanding of the nature of mathematics. One teacher related how an indigenous student who had previously been negative about mathematics had become much more confident, actively looking forward to learning mathematics. On entering the classroom he now asked questions about what he might be learning, rather than expressing his dislike for learning. Another reported that a student was able to articulate what she saw as the distinction between mathematics and numeracy in terms of using mathematical ideas to solve everyday problems. All teachers reported on the sense of pride students took in their work and on their capacity to articulate the concepts they had learnt. The project teachers highlighted two particular aspects of students' learning that they felt had been enhanced by their approach to mathematisation and contextualisation and that they considered important for improving outcomes for Aboriginal students: resilience and transfer of knowledge.

Mathematical Resilience

The project team identified mathematical resilience (Johnstone-Wilder & Lee, 2010), the capacity to continue learning despite setbacks and mistakes, as being crucial to improved outcomes in mathematics. We felt that the use of mathematisation and contextualisation had the potential to show students the value of mathematics and to increase their motivation to succeed. As suggested by Sullivan, Tobias & McDonough (2006) the learning orientation of some students may lead to a lack of success. However a performance orientation may enable students to persevere on tasks they find difficult and see success as desirable.

We identified five key aspects of mathematical resilience: having a growth mindset shown through behaviours such as learning from mistakes; meta-cognition shown through a willingness to reflect on answers and problem solving processes; adaptability shown through a willingness to try new strategies or start again; inter-personal aspects of learning such as seeing asking questions as clever rather than an admission of lack of knowledge; and a sense of purpose shown by a student's desire to seek meaning in his or her learning. The teachers were able to identify many of these characteristics in their writing about the first two years of the *Make it Count* project, and felt that this would be a productive area on which to focus in the more formal data gathering stage. As Johnstone-Wilder and Lee (2010) state "if it (mathematical resilience) is important, why are we not measuring it?" (p.41).[3]

Transfer

While the project team believed that mathematical resilience was highly likely to have a positive impact on student outcomes, we were conscious that the construct focused on affective rather than cognitive outcomes. We believed that the pedagogical focus on mathematisation and contextualisation in the project also ought to enable students to be able to use their mathematical knowledge in new situations, and hence decided to focus on identifying the impact of the project on students' ability to transfer knowledge.

The literature surrounding transfer is extremely problematic, ranging from a relatively simplistic belief that transfer will happen whenever students learn mathematics in context to a belief that all learning is contextual and hence transfer is unlikely. Boaler (1993) addresses this polarisation of beliefs, suggesting that transfer is likely to occur when students are encouraged to seek meaning in contexts and to explicitly identify underlying mathematical principles. We suggest that this implies the use of mathematisation and contextualisation.

[3] We have developed an observational tool for resilience, which will be trialled and used during the final two years of the project. This will be combined with analysis of video records of Aboriginal students engaged in problem solving tasks to obtain comprehensive data on the impact of the project on students' mathematical resilience.

More recently a controversial study by Kaminski, Sloutsky and Heckler (2008) claimed that contextual learning actually inhibited transfer. In their experimental study with university students, Kaminski and colleagues provided two different computer-based learning environments, one of which was highly symbolic and the other practical. Students were then asked to apply what they had learned to a new situation, which involved using chains of symbols to determine an outcome. They found that those students who had learned through an abstract representation of mathematics were able to transfer and generalise that knowledge more effectively than those who had learned through more concrete examples. Not surprisingly this created some dissent among the mathematics education community, as it appeared to contradict many unquestioned beliefs about the use of concrete representations.

The Kaminski et. al. study was replicated and extended by De Bock, Deprez, Van Dooren, Roelens and Verschaffel, L. (2011), who added a second component to the evaluation – the application of learning to a concrete instantiation of the mathematics. Like Kaminski and colleagues, they found that students learning in an abstract way were better able to transfer learning to another abstract situation involving chains of symbols, however those who had learned in a concrete way were better able to transfer their knowledge to an applied situation.

While these recent studies of transfer were conducted in experimental settings with university students, they provide an insight into the model of learning described above as the Alberton Cluster model. In this model students do not learn in either an exclusively concrete or abstract way. Neither are they asked to transfer knowledge to one situation. Rather our model involves an intentional act of linking mathematics and context in an ongoing cyclic process of mathematisation and contextualisation. We suggest that this process is likely to promote transfer of learning to both mathematical and real world settings, and hence to improve cognitive outcomes for Aboriginal students[4].

Conclusion

Consistent with the above discussion the Alberton Cluster's research question has now become "What is the role of mathematisation and contextualisation in developing mathematical resilience and promoting transfer of learning among indigenous students?" This question is captured in Figure 2, which is the model that will guide both the design of teaching and learning activities and the collection of focused data during 2011 and 2012.

[4] The development of instruments and tasks to empirically measure students' capacity to transfer knowledge is a key aspect of the work of the project in 2011 and 2012.

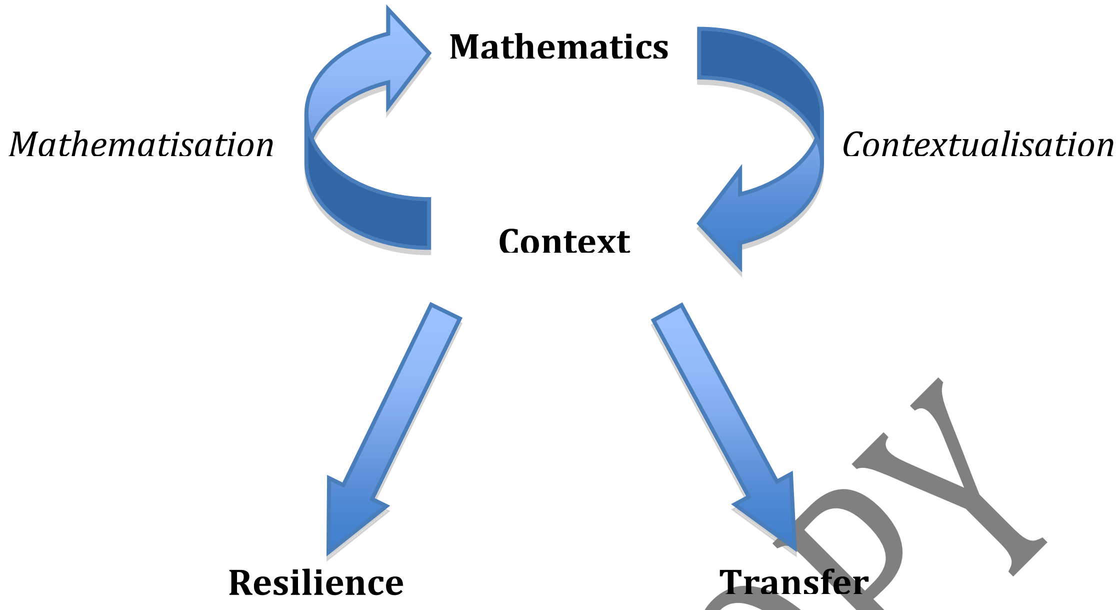

Figure 2: The Alberton Cluster research model

The question addresses the problematic issues surrounding the use of contexts in teaching mathematics to Aboriginal students by providing a systematic approach to pedagogy through the intentional use of mathematisation and contextualisation. Furthermore it provides a focus for evaluating affective and cognitive outcomes that are specific and measurable.

References

Ainley, J., Pratt, D. & Hansen, A. (2006). Connecting engagement and focus in pedagogic task design. *British Educational Research Journal, 32*(1), 23–38.

Boaler, J. (1993). The role of contexts in the mathematics classroom: Do they make mathematics more "real"? *For the Learning of Mathematics 13* (2), 12-17

Brown, K. (2008). Employing mathematical modelling to respond to Indigenous students' needs for contextualised mathematics experiences. In M. Goos, R. Brown, & K. Makar (Eds.), *Navigating currents and charting directions (Proceedings of the 31st annual conference of the Mathematics Education Research Group of Australasia).* Brisbane: MERGA. pp. 93-99

De Bock, D., Deprez, J., Van Dooren, W., Roelens, M. & Verschaffel, L. (2011). Abstract or Concrete Examples in Learning Mathematics? A Replication and Elaboration of Kaminski, Sloutsky, and Heckler's Study. *Journal for Research in Mathematics Education 42* (2), 109 - 126

Dowling, P. (1998). *The Sociology of Mathematics Education: Mathematical Myths/Pedagogic Texts*. London: Routledge Falmer.

Frigo, T. (1999). *Resources and Teaching Strategies to Support Aboriginal Children's Numeracy Learning: A Review of the Literature.* Sydney: NSW Board of Studies

Johnston-Wilder, S. & Lee, C. (2010). Mathematical Resilience. *Mathematics Teaching 218,* 38-41

Kaminski, J. A., Sloutsky, V. M., & Heckler, A. F. (2008). The advantage of abstract examples in learning math. *Science, 320*, 454–455.

Lubienski, S. T. (2000). Problem solving as a means toward mathematics for all: An exploratory look through a class lens. *Journal for Research in Mathematics Education, 31*(4), 454–482.

Matthews, S., Howard, P. & Perry, B. (2003). Working together to enhance Australian Aboriginal students' mathematics learning. In L. Bragg, C. Campbell, G. Herbert & J. Mousley (Eds.), *Mathematics education research: Innovation, networking opportunity. Proceedings of the 26th annual conference of the Mathematics Education Research Group of Australasia* (pp. 9-28). Sydney: MERGA.

Matthews, C., Watego, L., Cooper, T. & Baturo, A. (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 connections: Theory, research and practice. Proceedings of the 28th Annual Conference of the Mathematics Education Research Group of Australasia* (pp. 513-520). Melbourne: MERGA.

Olive, J., Makar, K., Hoyos, V., Kor, L. K., Kosheleva, O. & Sträßer, R. (2010). Mathematical Knowledge and Practices Resulting from Access to Digital Technologies. In C. Hoyles & J-B. Lagrange (Eds) *Mathematics Education and Technology-Rethinking the Terrain. New ICMI Study Series Vol 13 Part 2* (pp. 133-177). US: Springer

Sousa, D. (2008). *How the Brain Learns Mathematics*. Thousand Oaks CA: Corwin Press.

Sullivan, P., Zevenbergen, R. & Mousley, J. (2003). The contexts of mathematics tasks and the context of the classroom: Are we including all students? *Mathematics Education Research Journal 15* (2), 107-121

Sullivan, P., Tobias, S. & McDonough, A. (2006) Perhaps the decision of some students not to engage in learning mathematics in school is deliberate. *Educational Studies in Mathematics 62*, 81–99

Treffers, A. and Goffree, F. (1985). Rational analysis of realistic mathematics education – the Wiskobas program. In L. Streefland (Ed.). *Proceedings of the Ninth International Conference for the Psychology of Mathematics Education* (Vol II pp. 97-121). OW&OC, Utrecht University, Utrecht, The Netherlands: IGPME

Van den Heuvel-Panhuizen, M. (2003). The didactical use of models in Realistic Mathematics Education: An example from a longitudinal trajectory on percentage. *Educational Studies in Mathematics 54*, 9–35.