CREATING YOUR OWN SYMBOLS: BEGINNING ALGEBRAIC THINKING WITH INDIGENOUS STUDENTS[1]

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Because mathematics education devalues Indigenous culture, Indigenous students continue to be the most mathematically disadvantaged group in Australia. Conventional wisdom with regard to Indigenous mathematics education is to utilise practical and visual teaching methods, yet the power of mathematics and the opportunities it brings for advancement lie in symbolic understanding. This paper reports on a Maths as Story Telling (MAST) teaching approach to assist Indigenous students understand algebra through creating and manipulating their own symbols for equations. It discusses effective Indigenous mathematics teaching, describes the MAST approach, analyses it in terms of Ernest's (2005) semiotic processes, discusses its applications, and draws implications for Indigenous mathematics learning.

For the last few years, we have been researching ways to reverse Indigenous mathematics underperformance. Because mathematics teaching in Australia is Eurocentric (Rothbaum, Weisz, Pott, Miyake, & Morelli, 2000) and does not take into account the models of the world Indigenous people have created to inform their knowledge, many Indigenous students perceive mathematics as a subject for which they must become 'white' to succeed (Matthews, Watego, Cooper, & Baturo, 2005) and which can challenge their Indigenous identity (Howard, 1998; Pearce, 2001). Teachers tend to have low mathematics expectations of Indigenous students, blaming underperformance on absenteeism, social background and culture rather than themselves and the education system (Bourke, Rigby, & Burden, 2000; Sarra, 2003). As a result, few Indigenous students complete advanced post-compulsory mathematics subjects that lead to tertiary study in disciplines with a mathematics basis (Queensland Studies Authority, 2006) and only one Indigenous person, the lead author, has graduated with a mathematics doctorate.

We have endeavoured to *contextualise* mathematics pedagogy with Indigenous culture and perspectives (Matthews et al., 2005) because this overcomes systemic issues of Indigenous marginalisation with respect to mathematics learning (Cronin, Sarra & Yelland 2002; NSW Board of Studies, 2000) and instils a strong sense of pride in students' Indigenous identity and culture (Sarra, 2003), both are prerequisites for mathematics improvement. However, although we can contextualise algebraic applications through modelling (Matthews, 2006), contextualisation is not so apparent for the teaching and learning of formal algebraic structure and symbol manipulation.

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IMPROVING INDIGENOUS PERFORMANCE

We are aware that effective mathematics teaching is crucial for Indigenous students' futures as mathematics performance can determine employment and life chances (Louden et al., 2000). However, there is some ambivalence in the literature regarding the nature of effective Indigenous mathematics teaching. Indigenous students appear to learn best through contextualised concrete "hands-on" tasks (e.g., Day, 1996; Gool & Patton, 1998), "have greater sensitivity and success in dealing with visual and spatial information compared to verbal" (Barnes, 2000, p. 10), and "learn by observation and non-verbal communication" (South Australia DETE, 1999, p. 10). However, these findings may be an artefact of Indigenous students being taught in Standard English with which they may not have the words to describe many mathematical ideas (Roberts, 1998) and the words they have may be ambiguous (Durkin & Shire, 1991).

We are aware that school programs can dramatically improve Indigenous learning outcomes if they reinforce pride in Indigenous identity and culture, encourage attendance, highlight the capacity of Indigenous students to succeed in mathematics, challenge and expect students to perform, and provide a relevant educational context in which there is Indigenous leadership (Sarra, 2003). We recognise that non-Indigenous teachers with little understanding of Indigenous culture can have difficulties with contextualisation and reject it in favour of familiar Eurocentric approaches (Connelly, 2002; NSW Board of Studies, 2000). Thus, we believe in building productive partnerships between these teachers and the Indigenous teacher assistants (ITAs) employed from the community to assist them (Warren, Baturo & Cooper, 2004). We have also had success with educating ITAs by focusing on structural learning of mathematics (Baturo & Cooper, 2004) and we are aware that Indigenous students tend to be holistic, learners, a learning style that appreciates overviews of subjects and conscious linking of ideas (Christie, 1995, Grant, 1997) and should appreciate algebraic structure.

In our early Indigenous mathematics-education research, we focused on elementary mathematics and at-risk students. Our more recent projects have focused on assisting secondary school Indigenous students to use mathematics as a way of gaining high status employment. This has stimulated an interest on algebra for three reasons: (1) algebra is the basis of many high status professions; (2) algebra is based on generalising pattern and structure, skills with which Indigenous students may have an affinity because their culture contains components (e.g., kinship systems) that are pattern-based and which may lead to strong abilities to see pattern and structure (Grant, 1997; Jones, Kershaw, & Sparrow, 1996); and (3) algebra was the vehicle whereby the first author mastered mathematics. As he reminisced:

> When reflecting back on my education, my interest in mathematics started when I began to learn about algebra in my first year of high school. ⋯ For me, algebra made mathematics simple because I could see the pattern and structure or the generalisation of algebra much clearer than the detail of arithmetic.

SYMBOLS AND SEMIOTICS

Our answer to the dilemma of contextualisng the teaching and learning of algebra was to focus on representing mathematical equations as stories which leads to contextualising of mathematical symbols. Thus, we developed an approach to symbolisation based on students creating and using their own symbols, drawn from their socio-cultural background, to describe these stories as a precursor to working with the accepted mathematics symbols. We now describe the Maths as story telling (MAST) approach and analyse it in terms of Ernest's (2005) semiotic processes.

Maths as Story Telling (MAST). The approach utilises Indigenous knowledge of symbols within domains such as sport, driving, art and dance as a starting point for building understanding of arithmetic symbolism in a way that can be easily extended to algebraic symbolism. The approach has five steps.

Step 1. Students explore the meaning of *symbols* and how symbols can be assembled to tell and create a story. This is initially done by looking at symbols in Indigenous situations (e.g., exploring and understanding symbols in paintings) and then creating and interpreting symbols for simple actions (e.g. walking to and sitting in a desk).

Step 2. Students explore *simple addition story* by acting it out as a story (e.g. two groups of people joining each other). A discussion is then generated to identify the story elements such as the different groups of people and the action (the joining of the two groups) and the consequences of the action (the result of the joining).

Step 3. Students *create their own symbols* to represent the story. This step could be done in a freestyle manner; however, we have opted to take a more structured approach by using concrete materials (which are familiar to the students) to represent the objects (or people) in the story. The story is then created by allowing the students to construct the two groups of people with the concrete materials and construct their own symbol for "joining two groups" and lay this out to represent the action (or history) of the story. In a similar fashion, the students then construct their own symbol for "resulting in" or "same as" to tell the story of what happens after this action has taken place. Figure 1 gives an example of an addition story that was constructed by a student in Year 2.

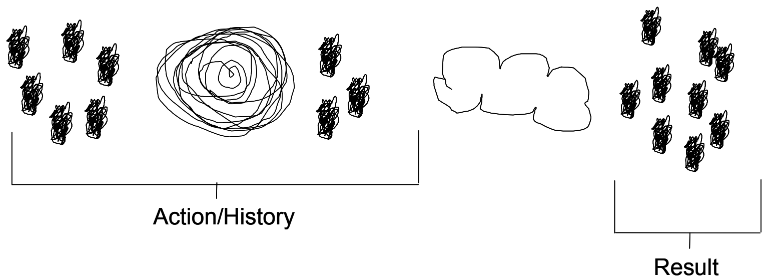

Figure 1. A Year 2 student's representation of the addition story 6 + 3 = 9.

Step 4. Students share their symbol systems with the group and any addition meanings their symbols may have. For example, in Figure 1, the student's "joining" symbol was a vortex that sucked the two groups together. The teacher then selects one of the symbol systems for all the students to use to represent a new addition story. This step is important to accustom students to writing within different symbol systems and to develop a standard classroom symbol system.

Step 5. Students *modify the story* (a key step in introducing algebraic ideas) under direction of the teacher. For example, the teacher takes an object from the action part of the story (see Figure 1), asks whether the story still makes sense (normally elicits a resounding "No"), and then challenges the students by asking them to find different strategies for the story to make sense again. There are four possibilities: (1) putting the object back in its original group, (2) putting the object in the other group on the action side, (3) adding another action (plus 1) to the action side, and (4) taking an object away from the result side. The first three strategies introduce the notion of compensation and equivalence of expression, while the fourth strategy introduces the balance rule (equivalence of equations). At this step, students should be encouraged to play with the story, guided by the teacher, to reinforce these algebraic notions.

Analysis in terms of Ernest's (2005) semiotic processes. Because the students create their own symbol system, the MAST experience bypasses the first process of Ernest's (2005) representation of Harre's (1983) semiotic model of "Vygotskian space", namely, *appropriation*. The MAST experience minimises the effect of the Ernest's fourth process (*conventionalisation)* so that students can freely express their creations and the meaning behind their symbol systems. The approach is designed to allow students to engage with Ernest's second and third processes (*transformation* and *publication* respectively*)* for symbols they create before being required to undertake the full four processes for the universally-accepted mathematical symbol system. Thus, the MAST steps could be considered as "twisting the Vygotskian space" to refocus on creativity and the expression of this creativity.

MAST Steps 3 and 4 are the essential steps that focus on transformation and publication. They enable students to: (1) create their symbols with personal meaning, by working backwards from meaning to symbol (and not forward from symbol to personal meeting as usually happens when learning the normal symbols); and (2) reinforce these personal meanings through sharing them with other students and sharing in the other students' symbols, to see the personal in relation to the collective (and not in the collective). As such, the steps are a powerful semiotic method for teaching and learning mathematics (in Ernest's, 2005, terms) because they are "driven by a primary focus on signs and sign use" (p. 23) and focused on how the students individually create, appropriate and openly express these symbol systems to a collective. Transformation and publication are important processes for MAST to encompass because they allow students to see: (1) beyond the "well-known pathological outcome of education in which learners only appropriate surface characteristics without managing to transform then into part of a larger system of personal meanings" (p. 25); and (2) a little of how a collective actively regulates and standardises symbols and their use. The variety of symbols experienced in the publication process in MAST Step 4 offers an opportunity for students to investigate commonalities across symbols systems, that is, to abstract at a high level. This develops the essence of the semiotic approach (i.e., the meaning of symbols, the relationships between symbols, and their underlying rules and applications).

MAST Steps 4 and 5 involve students discussing and critiquing each others' symbol systems (being proponents and critics for each other in Ernest's, 2005, terms) and, therefore, have the potential to develop high learning. As such, MAST introduces, very early on in the learning of symbols, the capacity to be creative and generate new expressions and possibly new meanings and structures within symbol systems.

APPLICATIONS OF MAST

MAST is the first product of the Minjerribah Maths Project which was set up to answer the following questions. *Can we improve achievement and retention in Indigenous mathematics by refocusing mathematics teaching onto the pattern and structure that underlies algebra? In doing this, are there Indigenous perspectives and knowledges we can use? Can we at the same time provide a positive self-image of Indigenous students?* MAST is our attempt to work from the story-telling world of the Indigenous student through to the formal world of algebra by experiences with the creation of symbols that have personal meaning. The story telling starts with simple arithmetic but moves quickly to algebraic thinking. It brings enables Indigenous students to bring their everyday world of symbols into mathematics.

The Minjerribah mathematics project. The project's focus is to put Indigenous contexts into mathematics teaching and learning (making Indigenous peoples and culture visible in mathematics instruction) and to integrate the teaching of arithmetic and algebra (developing the reasoning behind the rules of arithmetic while teaching arithmetic so that these can be extended to the rules of algebra). The overall aim is to improve Indigenous students' mathematics education so they can achieve in formal abstract algebra and move into high status mathematics subjects. This project is being undertaken through an action-research collaboration with teachers at a rural Indigenous Years P-10 school by putting into practice processes to improve and sustain these enhanced Indigenous mathematics outcomes. The research is qualitative and interpretive and adopts the "empowering outcomes" form of Smith's (1999) decolonising methodology which aims to address Indigenous questions in ways that give sustained beneficial outcomes for Indigenous people.

MAST in the classroom. MAST has been presented at professional development (PD) sessions for teachers within eight Queensland schools and has been used within Year 2 and Year 8 classrooms. Although results are preliminary, they appear to validate the potential we believe the approach has. Responses from teachers to the PD sessions have been overwhelmingly positive; no teacher has rejected the approach and most have been highly engaged in the activities. In particular, secondary teachers' responses to the PD activities have led us to add extra steps to the approach to introduce and solve for an unknown group of objects, thus reinforcing the balance rule. Interestingly, MAST experiences appear to provide teachers with a deeper understanding of algebra. Three teachers who were not mathematically trained jointly said: *This was the first* *time we understood algebra*. An English teacher said: *For the first time, I can see that mathematics is creative like poetry.*

The Year 2 trial was a revelation. The Year 2 students enthusiastically worked with the teacher to construct symbols to tell the story of one of their number walking into their classroom and sitting at her desk. They equally eagerly constructed symbols for three of their number joining another two. They were able to do all the work and all the MAST experiences were successfully completed. Some of their symbols were particularly creative and they were able to discuss and solve the equivalence activities. In fact, they were the first group that suggested the third strategy of adding another action; we had not thought of it. Interestingly, the teacher did not stipulate the use of materials to represent numbers and half the Year 2 students' first symbols were not linear (see Figure 1). For example, one student drew 2 circles and then drew 3 students in one circle, 2 students in the other and 5 where the circles overlapped, making the 5 <u>between</u> the 2 and the 3. Students who did non-linear drawings like this were able to change to linear, as in Figure 1, when the teacher stipulated this in the second part of the lesson.

For the Year 8 students, the MAST experiences provided a method for understanding more complicated equations as well as an introduction to symbols. This was shown later when a student asked why equation $2x = 8$ was divided by 2 to find x. The teacher directed the student to represent the equation in a quasi creative manner with two x's on one side of a line and 8 circles on the other. The student was then able to see that dividing both sides by 2 will give the value of x. The teacher argued that this could not have been done without the students' having previously experienced the MAST steps and created novel representations of equations.

IMPLICATIONS

The five MAST steps are an illustration of how the MAST approach could be used to introduce students to algebraic ideas, while the semiotic analysis indicates the implications of the approach for bridging the gap between arithmetic and algebra.

Creating one's own symbol system appears to be an effective way to introduce algebraic thinking to Indigenous students. In Ernest's (2005) semiotic terms, it meets all the requirements for relational and high level understanding. With Step 1, MAST contextualised algebraic symbolisation (Matthews et al., 2005), an experience for both teachers and students as they explore symbols in the Indigenous world view. Such contextualisation could be difficult for non-Indigenous teachers (Bourke, Rigby & Burden, 2000; Connelly, 2002; NSW Board of Studies, 2000) but it would certainly make learning two-way strong, from teacher to students and students to teacher, a positive outcome for Indigenous learning (Howard, 1998; Pearce, 2001). Seeing Indigenous knowledge underlying the most abstract of mathematics could well lead to growth in self confidence and development of positive self image for Indigenous students that, in turn, may well assist to reverse Indigenous mathematics underperformance (Sarra, 2003).

We believe that MAST has implications for all learners (Indigenous and non-Indigenous). It appears to be a powerful way to assist all students move from arithmetic to algebra. By taking emphasis away from foreign systems, it shifts the emphasis to algebraic pattern and structure within something that is familiar. Step 4 is designed so that, conversation "can be fluid and shifting in its actualisation" with "near spontaneous verbal responses as well as other modes of response ··· sought and encouraged" (Ernest, 2005, p. 30). This, along with each student creating their own symbolism, should provide a feeling of freedom within the MAST activity. In any case, MAST is a worthwhile activity for the way in which it utilises agency in initiating action.

However, it would be remiss of us not to mention an uncertainty in the approach; which is the process of translating from developed personal symbols to the conventionalised symbol system. This is a research question for this year: *Are there disadvantages of moving away from appropriation in the Vygotskian space?*

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