Maths as storytelling: Maths is beautiful

Precis

After finishing my PhD in applied mathematics, I received a phone call from Professor Tom Cooper and Dr Annette Baturo from Queensland University of Technology (QUT) trying to enlist me into mathematics education projects focusing on Aboriginal and Torres Strait Islander students. The first question they asked me (a bit tongue in cheek) was how can you exist? They qualified by saying that, according to statistics, Aboriginal and Torres Strait Islander students a severely underperforming in mathematics but yet you, an Aboriginal man, has a PhD in applied mathematics. How can that be? I was perceived as an anomaly: a glitch in the system.

My personal experience with education was one of survival. During my education, I was the only Aboriginal student in the class and from an early age had to endure racial taunts from students. During my high school years, these taunts also extended to teachers which gave additional power and justification to the racist attitudes of students. If I defended myself I was only told to sit down and shut up. During this period, I did have a supportive circle of friends but experiences around race and identity were rarely discussed and I was not open to do so. I learnt to be silent; to not make a fuss and to avoid, if possible, any subject that dealt with society particularly history. From these experiences, I was vulnerable with the potential to disengage with education; my future and my place in society as an Aboriginal person was not clear.

I was lucky and lucky on two fronts. First, I started to excel at mathematics during my high school years even though I was an average student in my primary years. Algebra just made sense to me and I could do mathematics better than most of the students in my grade. Second, I had a passion for computers, which was just starting to become part of the education system as well as a household item. I would spend most of my spare time in front of a computer create computer programs for simple games and to solve mathematical problems. These two passions enabled me to hide and become further withdrawn.

In the mathematics classroom, you do not have to deal with notions of race and behind a computer you do not have to deal with people. As a result, I turned my back on my Aboriginal identity; it had no bearing on my abilities with mathematics and computing. This was not an active choice it was just a means to survive. My passion and ability enabled me to go to University and eventually complete a PhD but I would not advocate my journey as a valid educational pathway. I was not a complete person and, over the years, had to deal with what it meant to be an Aboriginal man and mathematician. This desire enabled me to jump at the chance to research in mathematics education and its connection to my people.

About the Author

Dr Chris Matthews is from the Minjerripah (North Stradbroke Island) Community within the Quandamooka Nation (Moreton Bay). In 2003, Chris completed a PhD in Applied Mathematics and was successful in bidding for an ARC Discovery (IRD) Grant to undertake postdoctoral studies within Applied Mathematics. Chris also researches in the area of mathematics education and currently is working with the Yumi Deadly Maths team at Queensland University of Technology (QUT) on an ARC Grant within the Vocational Educational and Training (VET) Sector. Chris is also the patron of the Make It Count Project being carried out by the Australian Association of Mathematics Teacher (AAMT). Chris is currently the Coordinator of the Indigenous Research Network, Griffith University, and the co-chair of the Working Party for the development and implementation of an Indigenised Curriculum using a whole-of-university approach.

Introduction

Being someone qualified in mathematics, I have often been asked the question: How can mathematics be beautiful? This question is usually sparked by popular culture such as the movie A Beautiful Mind and television shows that have popularised mathematics. What the enquirers are really asking is: my experience with mathematics is so divorced from subjective statements like "beautiful" that I can not fathom any connection between them. Isn't mathematics supposed to be objective, which is, transcending our own subjectivity (or bias) to find “true knowledge” or “the truth"? This is a common perception of mathematics and, as will be argued, is informed by our common experience with the teaching and learning of mathematics. This paper will explore such perceptions, question notions such as objectivity and explore how these perceptions have positioned Indigenous people as mathematical learners. In essence, this paper will be exploring the connection between culture and mathematics, putting subjectivity back into mathematics, and looking at how this mind shift can affect the teaching and learning of mathematics for Indigenous students. These new approaches also have implications for mathematics education, in general, by allowing students to connect with mathematics through their own social and cultural background.

What is mathematics?

Personal experiences

Over the years, I have personally conducted many professional development sessions for teachers as well as lectures for up and coming teaching professionals on mathematics education. At each of these sessions, I ask the audience a fundamental question: What is mathematics? The purpose of doing this is to allow people to articulate their perceptions of mathematics, learn how others perceive mathematics and, in turn, how these perceptions affect the teaching and learning of mathematics. Each of these conversations are different but there is a definite pattern that emerges across all of the groups, which is encapsulated in Figure 1.

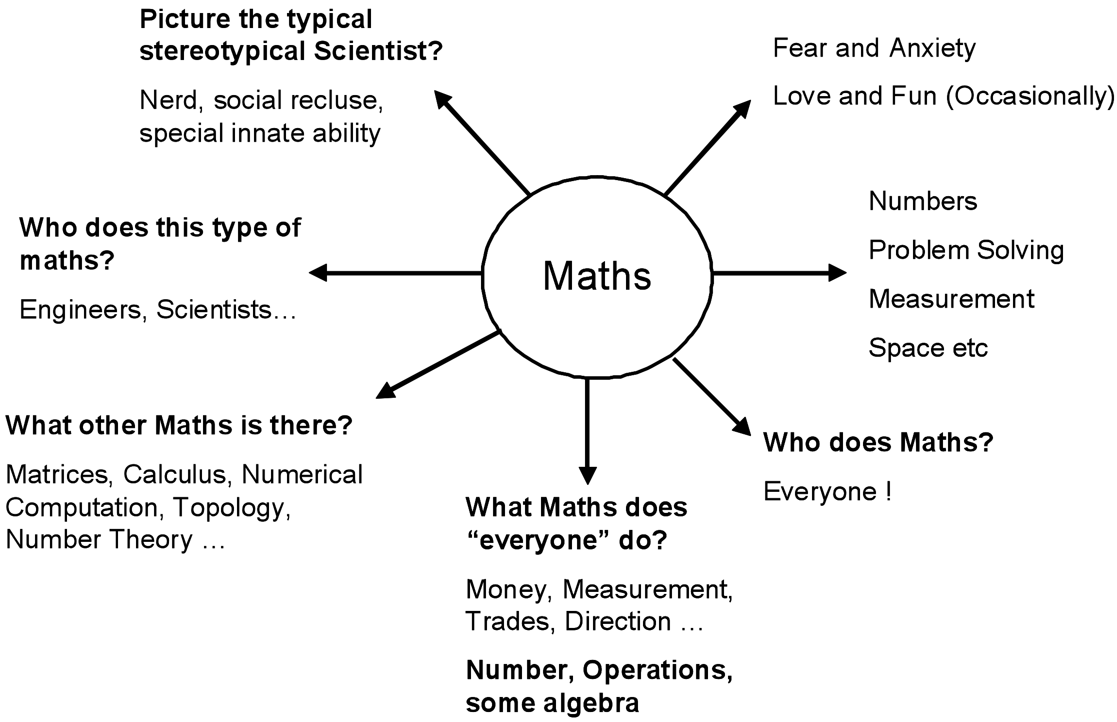

Figure 1: Emerging themes from the question what is mathematics.

As depicted in Figure 1, one of the first themes participants invariable discuss is the "doing of mathematics", for example, mathematics is about number, operation, problem solving and so on. This perception is about mathematics in its abstract form only and is a tool that must be learnt to solve complex problems. Another theme that emerges very quickly in the conversation is the participant's feelings about mathematics. These feelings can be expressed in an intense way (e.g. the first word yelled in one session was vomit) or a reluctant 'yes, I do not like mathematics'. On the other hand, there are also many participants who say they love mathematics and enjoy the challenge of the discipline.

Regardless of whether the participants have a passion for mathematics or not, all participants universally agree that everyone uses mathematics in their everyday life referring to contexts such as shopping, timetables, cooking and trades. These contexts are also commonly used in mathematics education. The group is then challenged to identify the underlying mathematics within the contexts, for example, what mathematics is used when cooking? It becomes apparent that the "everyday" mathematics is limited to number, operation and early algebra associated with other mathematical concepts such as measurement, space and estimation. The group is then posed with the questions: is this all there is to mathematics? What other forms of mathematics do you know? Interestingly, the majority of the groups become silent at this point which indicates that there is very little understanding of what is beyond "everyday" mathematics.

The group is then informed about different mathematical concepts beyond "everyday" mathematics, for example, matrices and calculus. There is an understanding within the groups that this type of mathematics is done by professionals such as engineers and consequently becomes the knowledge of the experts or the elite. At this point, what is also interesting is the discussion around stereotypes of people who engage in this "high level" mathematics. The stereotype that is invariably talked about is the "nerd", which is usually described as a white male who is a social recluse but has an innate ability to comprehend the incomprehensible. In essence, the stereotype labels individuals that succeeds in mathematics as "not being normal" and as part of this abnormality you can understand mathematics. The question is then posed how this stereotype limits student's access to "high level" mathematics. Does our curriculum and pedagogy ensure that this stereotype is perpetuated? At this point, the groups are silent. There is no active acknowledgement nor is their any active refuting of this idea. Instead, I assume that the silence is a recognition that such stereotypes are strongly embedding in the current social fabric of Australian society and throughout the education system.

It is also argued within sessions that the cognitive gap between arithmetic and algebra (Linchevshi and Herscovics, 1996; Warren and Cooper, 2008) is a consequence of these stereotypes, gaps in knowledge and perceptions about mathematics. The cognitive gap does impede student's access and desire to study mathematics and is one of the reasons we have a shortage of students studying in the area, which is at crisis point in Australia. In addition, it will be argued that these perceptions further marginalise Indigenous people from mathematics.

Australian Mathematical Society

The Australian Mathematical Society (AMS) is an association of mathematical professionals, including mathematics educators. The AMS publishes a Gazette where members can express their views regarding mathematics and various issues surrounding the discipline. Interestingly, the AMS posed the question "What is mathematics?" to its members and published the feedback from the members concerning this question in the AMS Gazette (Roberts, 2003). Common perceptions of mathematics expressed in the article are mathematics is:

- an abstract form of knowledge that creates generalizations;
- a study of quantitative "inter-relationships", patterns and structure;
- a language; and
- a powerful tool to solve problems using logical thinking.

In addition to these, members held perceptions such as "a way of looking at the world around us - it is the tint in my glass that colours the way that I see the world", "it is a social construct - the answer to your question varies with people's experience" and "it is a practice like music".

In the AMS Gazette, Praeger (2008) gave a personal reflection on mathematics and how this relates to mathematics education. Her passion for mathematics and its significance comes down to three interconnected essential elements, that is, power, truth and beauty. Praeger (2008) believes the power of mathematics allows practitioners to make sense of the world, transform society and that mathematics and mathematical thinking applies to all facets within society, highlighting the universality of mathematics. In terms of mathematics education, Praeger (2008) states that

> *'In order to help students appreciate how crucial Mathematics will be for their future, it is essential that they learn through their school experience how Mathematics has transformed society over the past century (at least) and how it underpins the society in which they now live.'*

The second essential element of truth emerges from the objectivity of mathematics, which was described by Praeger (2008) as "precision of mathematical language, and the requirement of rigorous logical reasoning, underpinning the unique claim of Mathematics to absolute truth". However, "absolute truth" can only hold while certain assumptions that underpin the mathematical reasoning are satisfied or hold true (Praeger, 2008). Furthermore, Praeger (2008) asserts that if students engage in mathematical proofs, (i.e. the search for truth under guiding assumptions) they will develop critical and logical thinking skills applicable across many disciplines within society.

According to Praeger (2008), the beauty of mathematics stems from its awe inspiring power in being "unreasonably effective" in solving real world problems. Praeger (2008) also sees the beauty of mathematics in mathematical patterns, which is also an extension of real world situations. Praeger (2008) summarises the notion of mathematical beauty with a quote from Bertrand Russell, a mathematician and philosopher, as follows:

> '*Mathematics, rightly viewed, possesses not only truth, but a supreme beauty; a beauty cold and austere, like that of sculpture,..., and capable of a stern perfection such as only the greatest art can show'*

In conclusion, Praeger (2008) offers the following key points that summarise the essential learning outcomes for students of mathematics:

- an awareness of the power of Mathematics to make sense of the world;
- a personal confidence and competence to solve mathematical problems;
- an understanding of the nature of proof in Mathematics;
- an appreciation of the beauty of mathematics;
- the ability to think logically and critically, learned through Mathematics; and
- an automatic expectation that mathematical thinking will play a key role in their understanding and problem-solving in every part of their lives.

From reviewing the perceptions expressed above, a dichotomy starts to emerge. On one hand, we have mathematics as a powerful tool to solve real world problems through its objective nature, that is, its rigour, precision and logic. Through this objectivity, it is believed that absolute truth is found since we are reducing the real life situation to its essential components or, in other words, we are removing subjective notions that could bias the situation. Yet we also discuss mathematics using such terms as beautiful, a social construct and a practice like music suggesting that mathematics is also situated within the subjective. We could ask the question does beauty exist in objectivity. Is mathematics only beautiful in a "cold and austere" fashion or is there more to the beauty of mathematics.

Revisiting the question

Matthews (2008) gave another perspective on the question what is mathematics, which is encapsulated in the Figure 2.

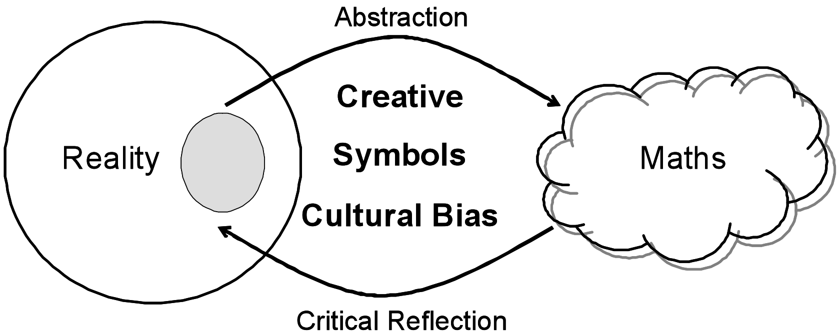

Figure 2: The Cloud Model (Matthews, 2008)

As outlined in Matthews (2008), Figure 2 forms a cycle with the development of mathematics starting with the reality of the observer. Matthews (2008) summaries the cycle as follows:

> *'The observer chooses a particular part of the reality (represented by the grey circle), and then creates an abstract representation of the real-life situation using a range of mathematical symbols, which are put together to form a symbolic language we call mathematics. The observer uses the mathematics in its abstract form to explore particular attributes and behaviours of the real life situation and to communicate these ideas to others. From the mathematics, it is essential that the observer critically reflects on their mathematical representation to ensure that it fits with the observed reality. Consequently, the abstraction and critical reflection processes form an important cycle where mathematics and its knowledge are created, developed and refined.'*

The Cloud Model in Figure 2 has three main interconnecting ideas that inform the process spelt out above, that is, creativity, symbols and cultural bias, which will be addressed separately below.

Creativity

The Cloud Model strongly demonstrates the abstract nature of mathematics which is explicitly linked to the reality of the observer i.e. it is an abstract representation of the observer's reality. By virtue of this dynamic, mathematics is a creative act and is similar in nature to other artistic pursuits such as music, dance, language and visual arts. In each of these, the artist reflects on their world, develops understandings of a particular part of their reality and then creates symbolism through various forms (i.e. pictorial, movement, sound) to communicate these understandings. Mathematics is no different to these other artistic expressions except that mathematics as a particular lens on the world through the notion of quantification (measuring) and explores how these quantities connect, relate and interact. These relationships form patterns and structures of mathematics that strongly reflect the patterns and structures in our reality whether it be the rainfall patterns across Queensland or the growth of a sunflower. In my view, this is where the beauty of mathematics lies and it is not a beauty that is "cold and austere" but a beauty that is alive and connected with our experiences of the world.

Unfortunately, many students experience of mathematics is in its abstract form only (i.e. within the Cloud) and is therefore disconnected from their lived experiences. This leads to very common comments from students such as why I'm I learning this, I will never use this again in my life and why are we now using letters. This disconnection is also evident in Figure 1 where participants did not talk about creativity in relation to mathematics nor could they relate mathematics to applications beyond cooking, trades and money, where the emphasis is on functionality and problem solving. There is an overwhelming need to create a new pedagogical paradigm where mathematics is seen first and foremost as a creative act and students have the opportunity to reflect on their reality (not constructed worded problems), create mathematical relationships and use mathematics to convey these understandings. In essence, students would have an opportunity to express themselves through mathematics in a similar fashion to music or visual arts.

Symbols and Mathematical Language

In Figure 2, mathematics is an abstract representation of a perceived reality. Consequently, symbols are an important aspect of this model since they embody a meaning or concept from the perceived reality. Mathematical symbols generally have individual meaning but more importantly these symbols are constructed into a symbolic language that we call mathematics. Like any language, mathematics has a strict convention so that ideas are communicated readily but is also flexible, evolving over time with the introduction of new ideas and concepts. The symbolic language of mathematics obviously has a strong connection with oral language since concepts are communicated first through the oral language of the observer (Shäfer, 2010). However in mathematics education, we can mistakenly apply strict conventions to oral language (e.g. English) and classify this subset of the English language as 'the' mathematical language. This extra layer of convention can create another barrier particularly if the student does not speak English as their first language and can lead to pedagogy that has an over emphasis on learning a particular language (or mathematics register). In terms of the Cloud Model (Figure 2), the 'mathematical language' will be defined as the symbolic language of mathematics and not part of a specific oral language. As part of the notion of self expression, students should use their own (oral) language to communicate and explore ideas and concepts that are embodied in these mathematical symbols and their application to the reality of the student. This expression of oral language will vary and be heavily dependent on the context of the student.

Cultural bias

In Figure 2, mathematics is a social construct that is inherently culturally biased. As discussed in Matthews (2008), cultural bias exists in all aspects of Figure 2. The observer expresses their cultural bias in the way their perceive reality and the significance they place on the part of the reality they are focusing on, that is, the ideas, concepts and processes. During the abstraction processes, cultural bias exists in the oral language of the observer and the mathematical symbols that are created to communicate these ideas. Finally, the critical reflection processes is underpinned by the cultural bias in the observers' perception of reality and the abstraction process. Essentially, mathematics is a cultural artifact and, in its history, mathematics has been developed and heavily influenced by many cultures around the world and, in some cases; many authors are reclaiming the numerous cultural identities of mathematics (Lumpkin, 1997). The cultural bias of mathematics should not be considered a negative since all knowledge is heavily grounded in a cultural worldview. We simply need to recognize this cultural bias and see it as an opportunity for students to move freely within their worldview to engage with mathematical thinking (i.e. the ideas and concepts) and create expressions of mathematics with the objective of gaining an appreciation and a deeper understanding of the current conventional mathematical language. Under this model, the perception of mathematics shifts from a rigid, objective discipline that must be learnt within the abstract to a creative process where students can engage in mathematical thinking and express these ideas through their own language and creativity.

The Cloud Model (Figure 2) was developed from an Australian Research Council (ARC) project that explored the question how can mathematics be taught to Indigenous students so that mathematics connects with their cultural identity (Matthews et al, 2005). To answer this question, I was continually lead back to the question posed at the start of this chapter:

What is Mathematics? As demonstrated above, to understand mathematics provides an opportunity to explore the connection between mathematics and people and, consequently, with culture. Hence, Figure 2 is a product of exploring this question which can be used as a theoretical framework to develop new pedagogies in the teaching and learning of mathematics through cultural expression. In the following sections, I will explicitly outline the application of the Cloud Model to new ideas in the teaching and learning of mathematics for Indigenous students. However, first we must explore some further perceptions, that is, perceptions of Indigenous people in relation to mathematics and science and education within these fields.

Indigenous people and mathematics education

In Howlett et al (2008), four Indigenous students, who were enrolled in degree programs through Griffith School of Environment, provide their story regarding their experiences in undertaking an environmental science degree at Griffith University. One participant stated the following:

> *"So I even had my own perceptions that we would have trouble learning mathematics. You know. I even had them myself … I felt terrible that I actually recognised, my goodness, that I already had my own preconception that our people couldn't get to a standard like that. I don't know why. I don't know why I had those preconceptions there."*

The student goes further by talking about her schooling experience stating that "A lot of us ended up wagging school because we couldn't handle the maths". Howlett et al (2008) also documented similar statements from the students in regard to a fear of science. These statements are similar in nature to a comment an Indigenous student made in Howard (1998) that you must become 'white' to succeed in education. Education, particularly in mathematics and science, becomes an affront or simply not part of your Indigenous identity and you are not meant to succeed within it. It is important to ask the question how do these perceptions start and are they continually perpetuated through the education system. From the discussion around Figure 1, the education system can inadvertently create barriers for any student to engage in and excel at mathematics through perceptions that require people to fit within a predefined stereotype: an innate ability to comprehend the incomprehensible. Obviously, these perceptions are also barriers for Indigenous students; however, there is an extra layer of perceptions that Indigenous students deal with, that is, non-Indigenous perceptions of Indigenous people.

It has long been recognised that the educational system has been established by the colonisers for the colonisers (Owen et al, 2011). Additionally, the educational system has a plethora of relationships that are acted out everyday, for example, the relationship between teachers and students, teacher and parents, school and community, relationships between students, relationship between teachers and so on. Given that the majority of Indigenous students are taught by non-Indigenous teachers and the majority of schools are run by non-Indigenous principals and teachers, the relationship between Indigenous and non-Indigenous people is very significant. This relationship is currently dysfunctional (Reconciliation Australia, 2010). We need to ask does this dysfunctional relationship contribute to Indigenous students' underachievement, which is continually reported in government statistics, and does the emphasis on underachievement reinforce the dysfunctional relationship.

Terra Nullius: owning our shared history

Australia was colonised under the doctrine of Terra Nullius which means land belonging to no one (Reynolds, 1987). This doctrine was the starting point of the relationship between Indigenous and non-Indigenous people within Australia; a relationship that denied the existence and value of Indigenous people, their cultures, their languages and their knowledges. As argued in Matthews et al (2005), Terra Nullius not only devalued, dispossessed and marginalised Indigenous people but it also created a population of non-Indigenous people who has not had the opportunity to know about Indigenous people. This dynamic has created a void in the psyche of mainstream Australia which has been filled by stereotypes that has misrepresented Indigenous people and their cultures. One of the main misconceptions of Indigenous people originates in the ideas of social Darwinism which positions Indigenous people as a stone-age, primitive people that passively existed on the land at the whim of nature. From this perspective, Indigenous people were a relic from the past and were expected to eventually die out (Reynolds, 1987) making way for the next stage of evolution. Consequently, Indigenous people, their knowledge and culture have no relevance in a modern technological advanced industrial society.

Even though these misconceptions are being refuted in academic papers (Pascoe, 2011; Gammage, 2008), the silencing of Indigenous people still continues today and one example of this is the story of David Unaipon. David Unaipon was born in 1873 on the banks of the lower Murray River a member of the Ngarrinjeri people. He has been recognised as Australia's first Aboriginal author and inventor, and was described by one newspaper as Australia's Leonardo da Vinci (Simons, 1994). In 1907, David Uniapon invented the modern sheers that revolutionised the Australian sheering industry. From reading Newton's Laws of motion, Unaipon converted curvilinear motion into linear motion to invent the hinge that drives the modern sheer: a more efficient design. Even though he was commissioned by an Adelaide firm to examine the design of the sheers, Unaipon could not secure the funds to keep the patent for the device. Subsequently, the idea was stolen from him and he never received any economic benefit or recognition for his invention (Simons, 1994; Shoemaker, 1989). To add to this tragedy, David Unaipon has been silenced in Australia's history even though, through his invention, he revolutionized the sheering industry; an industry that was a significant driver in the development of Australia's economy. In my lectures, I always ask the question who has heard of David Unaipon. The silence is deafening.

If we are to improve the relationship between Indigenous and non-Indigenous people within Australia, there is a need to break the silence and overturn the mindset of Terra Nullius. This can only be achieved if we all accept that the doctrine of Terra Nullius is our shared history. In doing so, we must take the time to understand what Terra Nullius means for both Indigenous and non-Indigenous people and articulate what type of relationship this has developed over the history of Australia. Recently, Reconciliation Australia undertook a survey about the perceptions of Indigenous and non-Indigenous Australian regarding their relationship and was called the reconciliation barometer (Reconciliation Australia, 2010). In summary, the barometer clearly showed that both Indigenous and non-Indigenous Australians (who participated in the survey) valued a better relationship; however, the barometer highlighted that the current status of the relationship was poor with the majority of respondents believing that there is currently no trust between Indigenous and non-Indigenous peoples. In essence, we need to unlearn what we have learnt, value what we have historically devalued and start developing a trusting relationship.

Indigenous Education: a mathematical relationship?

The development of positive relationships is fundamental to the teaching and learning of mathematics. This is not only between educators, parents, students and community, but also between all people and mathematics itself. At the moment, there are views within the literature that actively disconnects Indigenous people and mathematics, which upholds the social Darwinian notion of Indigenous people. For example, Deakin (2010) who was commenting on an Indigenous mathematics strand in the National Curriculum stated the following:

> *'However, I will argue here that these passages envisage the introduction into the National Mathematics Curriculum of a topic (Indigenous Mathematics) which, strictly speaking, does not exist. It is no derogation of Aboriginal or Islander culture to recognise this fact. Indigenous Australians did not build Gothic cathedrals either. We all know this and no-one thinks any the worse of them on this account. Attempts to discover an Indigenous Mathematics are undoubtedly well-intentioned, but ultimately ill-directed. It is neither useful nor beneficent to bestow on aspects of Aboriginal and Islander cultures a significance that they do not, in fact, possess.'*

What is interesting about this statement is that the author out rightly states that Indigenous mathematics does not exist. I would argue that to definitively make this statement you would need to define what you mean by mathematics (and Indigenous mathematics) and you would also need to have an in-depth knowledge of the many Indigenous cultures within Australia. In my view, it is derogatory to simply connect the construction of Gothic cathedrals with mathematics (a particular cultural expression of mathematics) and thereby dismiss all Indigenous knowledges as having no relevance to mathematics. In terms of the National Curriculum, my understanding of the Indigenous mathematics strand was to explore connections between Indigenous people and mathematics and from these connections create meaningful educational experiences for all students that values Indigenous people, knowledges and cultures: to overturn the mindset of Terra Nullius.

The view also can manifest itself within mathematics education research. Jorgensen (2010) from her experiences in mathematics classes in a remote Indigenous Community stated the following:

> *'…my goal is to draw out the need for new education and research paradigms that may seek to explore the complexity of assimilationist education. This proposition may be construed negatively but I contest this. By its very nature, Western education should be considered to be assimilationist. It represents particular worldviews that are incongruent with many Aboriginal cultures. Coming to learn school mathematics requires a conscience effort to take on board the knowledge structures of Western thinking and rationalism.'*

Again, there is an underlying assumption that mathematics (and other disciplines within education) only exists firmly within Western knowledge frameworks which leads the author to the notion of an assimilationist education paradigm. Hence, Aboriginal cultures have no connection with mathematics, its thinking and rationalism. Such a paradigm would be a return to the dynamics experienced under the assimilation policy where you must turn your back on who you are as an Indigenous Australian to become educated and succeed within

Australian society: it devalues Indigenous people. Jorgensen (2010) has come to this conclusion after only 12 months within the Community and in a similar fashion to Deakin (2010) has positioned themselves as the knower. If we are to conduct mathematics education research in Indigenous communities and with Indigenous students we can not afford to start from the premise of an assimilationist education paradigm that positions Indigenous culture as deficit.

Mathematics as storytelling: creating a relationship

If we are to create meaningful relationships between people and mathematics we need to see mathematics as a social construct or a cultural expression. From this view of mathematics, we can then allow different cultural expressions of mathematics to emerge and, in a similar fashion to art or music, allow students to express themselves through mathematics. This view is encapsulated in The Cloud Model (Figure 2), which is currently being used to create new pedagogy for the teaching and learning of mathematics that will connect with and value the students' cultural background and the knowledge they bring to the mathematics lesson[1]. Through a lesson or a series of lessons, students must move through the cycle in Figure 2 and experience mathematics as a creative process avoiding the unbalanced educational experience of mathematics as an abstraction. Working within the abstract is still important for mathematics education but it cannot be the sole experience when learning mathematics, because it disconnects mathematics from the students' world and lived experiences.

The first pedagogical approached developed from The Cloud Model (Figure 2) is 'Maths as Storytelling' (Matthews et al, 2005), which focused on the following:

1. pre-algebra and explicitly connecting algebraic concepts with arithmetic, that is, avoiding the cognitive gap;
2. using the notion of creativity to teach mathematics; and
3. through creativity allowing students to express themselves and value their current understandings and knowledge.

In its first iteration, Maths as Storytelling has the following steps (Matthews et al, 2005):

1. **Understanding Symbols:** Exploring the use of symbols in constructing abstract representations and its connection to significant concepts and knowledge through storytelling;
2. **A Simple Maths Story:** Students act out a simple mathematics story, for example, two groups of people walking together is a simple story for addition. The teacher discusses with the students the various elements to the story i.e. the start of the story (two separate groups), the subject of the story (two groups of people), the action that occurs (walking together, joining) and the end of the story (the two groups have now become one group).
3. **Students' representation (unstructured):** The student is given a blank piece of paper and is challenged to represent the above story using their own symbolism. However, their representation must clearly show the start of the story (two separate groups), the action that occurred (joining) and the end of the story (two groups

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[1] The Yumi Deadly Centre at Queensland University of Technology (QUT) has been conducted a professional development program that was centred on the Cloud Model. Note that the Yumi Deadly Centre named the model RAMR which stands for Reality, Abstraction, Mathematics and Reflection. For more information see the website ydc.ed.qut.edu.au.

become one group). The students then have an opportunity to share the symbolism with the class and how the symbols are connected to tell the story.

4. **Students' representation (structured):** Since we are interested in moving towards the recognized mathematical convention for addition, we also lead the students through a more structured representation of the story using concrete materials but still relying on the student's creativity. This is also important for the pre-algebra concepts in the next step. In this step, the students lay out the two groups using concrete materials and are asked to draw their own joining symbol, which is placed between the two groups. The students are also asked to create a symbol for "becoming" or "leads to" to represent the transformation of the two groups into one group. The student then places this symbol alongside the joining construction and also uses concrete materials to represent the result of the joining i.e. one group.
5. **Sharing Symbol systems:** In this step, the teacher and/or the students can select one of the set of symbols and represent another maths story with the chosen symbols. This will enable students to shift between symbol systems and reinforce the idea that the meaning behind the system is more important than the symbol itself.
6. **Modifying the story**: This stage is when algebra concepts are introduced. This is done by removing one unit of the concrete materials from step 4. The teacher asks the students whether the story makes sense, which is usually a resounding no since the student is familiar with their own construction. Setting some ground rules, the teacher challenges the students to find different ways for the story to make sense again. This playing with concrete materials leads to algebra concepts like compensation and balance rule.

As an example, a year two student's representation of a 'joining story' is given in Figure 3.

Figure 3. Year 2 student's representation of 4 + 2 = 6.

The student explained that his joining symbol was a vortex that sucks the two groups together and the cloud gently picked them up and placed them neatly together. Not only did the student exhibit creativity in his symbolism but he also created a whole story that explains the meaning behind his symbols. The student also clearly demonstrated that he understood the main concepts of joining and transformation. From this type of pedagogy, it is evident that students can start their learning in mathematics through self expression which values the students' current knowledge. Teachers also have an opportunity to learn from the student and get an understanding of what interests the students, insight into their lived experiences and home life (or world view) and insight into how their students conceptualise ideas.

Maths as Dance: an extension of Maths as Storytelling

In 2010, I worked with a cluster of schools through the Australian Association of Mathematics Teachers (AAMT) national mathematics education project for Indigenous students called Make It Count to develop and plan a maths camp. To organize the camp, an Indigenous Education Worker (IEW) worked tirelessly to promote the camp within the Indigenous community and to bring members of the Indigenous community and the school community together to organize the camp. As a testimony to extensive promotional work, 28 students (somewhat reluctantly) attend a maths camp and the students ranging from years 5 to 9.

During a planning day, I presented the Cloud Model above to the participants with the idea of developing new mathematics activities to connect Indigenous culture and mathematics. Fortunately, one of the Indigenous participants, who was also an IEW in one of the schools, was a Song Man from the region and had been teaching Aboriginal song and dance, and the knowledge associated with song and dance, for many years. During my presentation, he immediately connected with the ideas and saw how they connected with dance. As a result, Maths as a Dance, a new approached was trialed for the first time.

Maths as a Dance was an extension of Maths as Storytelling, since we used the same basic concepts, but we changed the pedagogy to connect with the idea of learning dance. Maths as Storytelling mainly focused on student's experiencing the abstraction process by considering a story and allowing them to create the abstraction for that story. In contrast, Maths as a Dance starts with the abstract; the following key steps are given below:

1. **Starting in the Abstract:** The students were put into four separate groups and each group was given a mathematical expression like $\mathbf{4 \times 3 = 12}$. Note that each group had a different operation. Each group was told that they had to create a story for their mathematical expression, create a dance for the story and perform the dance.
2. **Symbolism:** To connect the idea of the story to the mathematical expression, the symbolism is worked through on a whiteboard, that is, each symbol has a meaning that connects it to our reality. In short the symbols are explained as follows: the numbers within the story are the subjects of the story, the operation is the action that occurs within the story, the action occurs to the two groups of your subjects (left hand side) and, after the action, we have the end of our story (right hand side). Also in terms of operation, I also explained that we only have two types of operations, that is, separating (–,÷) and joining (+,×), which is applied differently for each operation.
3. **Students' create their story:** Students use the constructs in step 2 to create their story to decide on the subject of the story, the context of the action and the context for the end of the story.
4. **Students create a dance for their story:** the Indigenous education worker and Song Man presented to the group the process of creating a dance from a story and how various movements and sound can create meaning and provoke feelings and emotions pivotal to the story. He then went around to each group to help the student create movements and sound to tell their story.
5. **Students perform their dance:** The students then share their story through dance. After the dance the students then have an opportunity to talk through their mathematical expression and how it connected with their story.

The students at the maths camp created amazing stories for their dance. There were stories about hunting kangaroo, gathering food and rain drops falling from a cloud: contexts not usually used within a mathematics classroom plus a context that is created and owned by the student. In addition, the Song Man painted the students before the last dance and while he painted the symbolism of the body paint he also relayed the meaning behind the symbols and the story the symbols are connected to. The grand finale was a dance that both students and teachers performed together. The dance was about the mission period where Aboriginal people where split up and sent to different mission within Queensland (separating or dividing) and, after many years, there was a homeland movement where the Aboriginal people moved back to country to unite as one people again (joining groups or multiplication). The story was then connected to the operations of dividing (moving to mission) and multiplication (homeland movement) and that divide and multiply are inverse operations. The notion of inverse could also be experienced emotionally through the dance, that is, sadness when been moved to mission and the joy and celebration of the homeland movement. I would argue that dancing the various operations gives a stronger mental picture of the meaning behind the various mathematical expressions. The students were also exposed to different types of abstractions and its symbolism, from a mathematical perspective as well as from an Indigenous perspective, and the connection between these types of abstractions.

Students after the maths camp were surveyed regarding they experience at the camp (Morris and Matthews, 2011). Out of the 28 students that attended the camp, 10 students made explicit statements about “a new way with maths”. Also, students stated that “maths does not have to be about sitting at a desk looking and copying off a board” and “I like dance and the culture of the maths we are learning”. One poignant statement was made by a student as follows:

> ‘We mixed our culture and maths together and it surprised me. I can now walk away with a different understanding of Math and my Aboriginal heritage.’

This last statement is exactly what we were trying to achieve: to support a positive sense of student’s Indigenous identity while learning mathematics. However, this could have only occurred with a meaningful and productive relationship between Indigenous people and the school communities. It was also a meeting of knowledges: the knowledge of the Song Man and his talent to teach this knowledge to the students and the knowledge of mathematics. Unfortunately, IEWs are paid at a very low rate and, in the general, the system seems to be ignorant of the knowledge and expertise they bring to the school and the long hours of work they do both inside and outside of school hours. Consequently, sustaining such initiatives becomes a major problem.

Conclusion

From decades of mathematics education in Australia, there are many perceptions about mathematics that have been created and reinforced through the education system. I would argue that the most damaging is seeing mathematics as a discipline that transcends people and from this transcendence we reinforce the notion of objectivity as a pathway to absolute truth. Consequently, we must reconnect the discipline of mathematics to people by seeing mathematics as a cultural product. From this view, we can then allow learners of mathematics to connect with the discipline on their terms and even create mathematical representations through their own cultural lens. The Cloud Model (Figure 2) was developed from this view point, which clearly shows the importance of moving through the abstraction cycle for the teaching and learning of mathematics. We need to move away from the unbalanced approach of teaching only within the Cloud (abstract) and allow students to experience the process of abstraction and to critically reflect on these abstractions. This chapter also provides examples that allow students to express themselves within the mathematics classroom through the creation of symbols both pictorially and through dance. These episodes allow students to learn from the current knowledge and to also learn new knowledge while supporting and valuing their cultural identity as Indigenous people. However to sustain such pedagogy, schools must start their journey to develop positive relationships with the Indigenous people of their region particularly through the leadership of principals. All educations workers must accept and understand their position within the nations shared history of Terra Nullius since it is the starting point of the relationship between Indigenous and non-Indigenous people. It is imperative that non-Indigenous people understand their cultural worldview and question what they understand about Indigenous people: unlearn what they have learnt. Schools need to provide a space within their schools for Indigenous people and start a meaningful dialogue about their children and their children's education. Only through a meaningful and trusting relationship can we start to overturn the mindset of Terra Nullius and move to a better future for all Australians. The beauty of mathematics is not in the cold closed form of the elite. For me, beauty is in a mathematics that is alive: a knowledge that connects with all people allowing different expressions of ideas and the emergence of new ideas.

Exercises

1. **Understanding cultural contexts and mathematics:** Within groups, allow students to write down what they understand by the word ***culture*** and on a separate piece of paper what they understand by the word ***mathematics***. Encourage students to be honest and write down any ideas and perceptions they may have. Get students to report back to the whole group and scribe all perspectives on to a whiteboard about both culture and mathematics. Depending on the response, the teacher can draw out more perceptions about these terms from asking questions such as 'Who does mathematics?' and 'What mathematics do these people do?' (see Figure 1 as a guide). Students should then be encouraged to discuss the connection between culture and mathematics i.e. is mathematics a cultural product.
2. **Owning our shared History:** Allow students to work through what they understand about Terra Nullius on paper. After this process, should write Indigenous on one side of the paper and non-Indigenous on the other side. Under each heading, students can write down, in general terms, the experiences of each of the people under the doctrine of Terra Nullius. Encourage students to move on from facts and write down any perceptions and/or feelings that are part of this space. Students should then consider the question: What relationship has developed under this doctrine? In doing so, students can circle words on their paper that inform this relationship. Students should then consider how we can change this relationship and how does this inform the way you would approach teaching to Indigenous student and to non-Indigenous students.
3. **Understanding the model:** Use the Cloud Model (Figure 2) to critique 'Maths as Storytelling' and 'Maths as Dance'. What are the advantages and disadvantages of the approach? Were are the pedagogies situated within the cycle in Figure 2? How could you improve these ideas?

4. **Create your own:** Decide on a particular mathematics concept, for example, fractions and use the Cloud Model to create a new pedagogy for the mathematics concept. Test your ideas with a group of willing students and reflect on this teaching experience.

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