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Pragmatic Mathematics: Representations of Thought and Action

By Neil Hooley

This philosophical essay canvasses a number of themes in relation to a more inclusive approach to school mathematics for both Indigenous and non-Indigenous students. As an alternative to current arrangements, the term ‘pragmatic mathematics’ is suggested as an organising concept of primary and secondary mathematics that emphasises learning by doing and reflection. Accordingly, the essay criticises school mathematics as being overly formalist and procedural and lacking a basis of socio-cultural practice. On the other hand, it is argued that pragmatic mathematics builds upon the enquiry philosophy of Dewey (see McDermott, 1981) and encourages long-term cycles of reflective practice where original and personal mathematical ideas are constructed from personal experience. Learning outcomes are uncertain and are not specified, but do occur within a framework of recognised mathematical knowledge. Clearly, pragmatic mathematics must be democratic and interpretive in orientation and not impose predetermined truth on learners.

Background

School mathematics in Australia is an excellent example of cultural imperialism. It is the one place in the school curriculum where truth is expressly predetermined and where the main outcome is the transmission of unaltered knowledge from teacher to student. This makes it extraordinarily difficult for learners to interact with knowledge so that meaning can be made personal and fluid. In discussing the history of school mathematics for example, Teese (2000, p. 128) noted the ‘intensified demands on the cultural resources of the students’ and how:

> Cognitive growth, confidence with numbers and numerical abstractions, aesthetic interest and appreciation of mathematical form (symbols and structure), manipulative dexterity, the power to concentrate and the pleasure of self-

> projection through mathematical accomplishment all pointed back to the intellectual milieu of the family and the schools that reinforced this or compensated for its inadequacies.

The socio-political basis of school mathematics however has not gone unchallenged (Ornell, 1996). Many teachers particularly at the primary level have attempted to include more active and inquiry-based approaches into their teaching of mathematics, but this may often result in what might be called an amendment to rather than a fundamental redrafting of pedagogy. Under these circumstances, it is easier said than done for Indigenous and non-Indigenous children to find their own avenues into learning mathematical ideas, avenues that draw upon their own cultural understandings and life experience and which may be allowable in other areas of the curriculum. One thesis suggests that there is an unspoken reliance in school mathematics on the ideas of the Greek philosopher Plato, who suggested that there exists a world of ideal forms that were beyond the direct experience of humankind (Davis and Hersh, 1981). If this is so, then humans need to discover such mathematical forms in some way and then use them in their quest to understand the nature of the universe. In eliminating the cultural basis of learning it is easy to see why all children will struggle to comprehend material that is presented in classrooms as immutable truth.

There appears to be little reason why school mathematics itself should be considered in only Platonist or formalist terms. Society or the educational profession could of course make this decision It may be that there are properties of the universe that exist independently of human will, or even of human understanding, properties that we have labelled mathematical, but that does pose some difficulty for the process of definition. Under these conditions, how do we know what is mathematical and what is not and consequently, how do we decide which techniques are to be used to study each? How do we design a school curriculum around ideas we do not understand? The theory of Platonist concepts that can only be discovered rather than created by humans and described by a set of inviolate axioms, takes us down an intellectual dead-end road.

The mathematician Kurt Godel (2005) had a view about this. He proposed in 1931 that mathematical statements can be true but unprovable, similar to their English equivalent of 'This statement cannot be proved true'. If true, the statement is false, if false the statement is both true and false at the same time. Godel's famous incompleteness theorem, together with the work of Schrodinger, Heisenberg and quantum mechanics generally, places added complications on the human capacity to discover universal truths. Once they are agreed as fundamental, how do we ensure that we understand them fully? What we have here is a certain arrangement of matter called human trying to comprehend other arrangements of the same matter called universe but never really being certain that the mechanism being used called axiom or mathematics, can be relied upon. Working arrangements can be agreed so that bridges do not fall down, but whether the structure is obeying fundamental truth is unclear.

On the other hand, can a property of the universe that we call mathematics be opened up to human intuition and interpretation? (George and Vellerman, 2002) The only problem with so doing is that the universe then becomes uncertain both in our understanding and how it actually operates. In the broader realm of science, these issues were confronted when quantum mechanics emerged from the shadow of a clockwork classical mechanics placing doubt on a predictable past and future. Of course, one of the objectives of modern science has been to secure a more certain existence for humanity making the prospect of the only certainty being uncertainty a little challenging. How is it possible for humans to formulate an equation that accurately expresses the interaction between any two particles in the universe? Can this be true? Rather, are the laws and equations of modern science merely a rough guide based on our best understanding at the present? Philosophically there is no problem with this outcome as different people interpret and intuit the world differently in all other fields as they embark upon the great journey of truth.

Contrary to Platonism, formalism and intuitionism as means of understanding that which already exists outside of our control, it may be that humans are able to construct their own mathematical knowledge from the ground up. That is, humans take what they already know and undertake ongoing investigations of what they do not, until they are comfortable with explanation. At one point then, it may be thought that the earth is flat and that all other celestial bodies rotate about it, while at another time, different views are considered. This approach sees knowledge not as being discovered, but as being created through human experience. What we have defined as mathematical can also be built in this way, understandings that are not independent of cognition but are determined by it. A constructivist mathematics therefore will not set out to reveal truths to the uninitiated, but to involve everyone in a joint project of participating with a developing knowledge as it twists and turns throughout history (see Stiff, 2001).

These three sets of ideas regarding fundamental properties of the universe and how they apply to school mathematics, the Platonist/formalist, the interpretive/intuitionist and the constructivist will generate their own principles and practices. All three can rely on the search for a pre-existing truth, although the constructivist can begin with a blank slate and keep an open mind on outcomes. All three can develop procedures and algorithms that are reasonably fixed, although the constructivist can see such techniques as merely the best guide that is available at the time. The present-day explanation of particle theory must be able to deal with new challenges or elaborations such as string theory and the ideas of Wolfram for a science based on patterns, entropy, complexity and emergence (see Hayes, 2002). It may not be necessary for the practising mathematician working on the modelling of weather patterns, military equipment, car design, or satellite navigation systems to have the philosophical basis of daily activity constantly in mind, but it is essential for school mathematics.

Indigenous mathematics

Do Indigenous and non-Indigenous people think differently as far as mathematics is concerned? Harris (1991, p. 18) highlights the importance of 'world view' when considering an Indigenous approach towards mathematics and how each culture's world view provides a framework for survival and social cohesion. Questions of specific epistemology, culture and world view are extremely difficult given the assumptions that lie beneath them. The first assumption concerns the existence of a separate domain of knowledge or human understanding that we can label mathematics. If this domain does exist, then it constitutes a universal frame of reference for all humans regardless of culture. Again and depending on our definition of culture, different groups would come to mathematical understanding differently, because of our distinctive life practices and histories. This is a cultural interpretation of the idea of thinking differently. Another interpretation of course would concern the brain itself, that is a view that different people have different neural mechanisms that enable them to have different mathematical understandings. Perhaps these are questions that cannot be resolved at present, while we attempt to work within a different and more equitable conceptual frame in thinking about mathematical knowledge. ‘Garma Maths’ for example has been developed at the Yirrkala Community School in Arnhem Land, Northern Territory, Australia, as a culturally-based approach to mathematics learning. Robinson and Nichol (1998, p. 11) explain that the term ‘Garma’ means ‘an open meeting place where everyone comes together’ and that the Garma Maths program articulates the formal logical concepts of ‘life and thought’ of the local Yolngu people. Specifically:

> Curriculum materials in Garma maths are not based on the repeated introduction of numbers and symbols, but on how basic mathematical and logical concepts relate to the Yolgnu world. This is then tied into Western mathematics in the form to the Northern Territory Department of Education Mathematics Course of Study.

The notion of ‘ethnomathematics’ has also been advanced to help our expedition across this difficult terrain. Ethnomathematics is a relatively recent addition to the literature (D’Ambrosio, 1985). It refers to the way that people from particular cultural backgrounds approach their thinking and acting mathematically. This matter has not as yet gained purchase in the Australian education system, but it has the possibility of challenging the domination of traditional mathematics in the curriculum. The notion of ethnomathematics is generally discussed as a means of moving from a specific cultural experience to the more abstract ideas encountered in Australian schools, a series of stepping stones if you like. The mathematical ideas involved in the geometry of fishing nets, of weaved mats and the decisions made during travelling, hunting and cooking for example. On the other hand, there does not appear to be a strong emphasis on recognising cultural settings as providing a valued system of mathematics in its own right that does not have to compete with or be inferior to regular school mathematics. For Indigenous Australians, the existence of ethnomathematics offers some hope that cultural domination can be broken in schools, but there is a huge amount of work that must be done in developing the concept before it can function as a Trojan Horse within the regular curriculum.

Problems with school mathematics

Regardless of how mathematical truth is conceptualised, school mathematics can have a different view. It can also be handled differently at different levels of the schooling system as well. It does not necessarily follow that a mathematical truth discovered and agreed by humans throughout the centuries is then mechanically exposed to young children in school for adoption. Many schools do however accept this approach to the curriculum in all studies. For example, the truth of ‘river’ may be delivered to students in the form of a relationship between sounds and letters on paper with the correct ordering of this relationship being promoted as truth for remembering. The question here is whether truth is the spelling of river or the river itself. If the latter, then how do adults and education systems encourage children to come to an appreciation of truth, through an abstraction on paper, or through jumping in the river itself?

Many schools around the world do follow an essentially Platonist/formalist approach to teaching and learning, even if this is not explicitly stated. It is most unusual for example for such a position to be recorded in state policy and school curriculum documents and for teachers to discuss. More likely, schools are seen as places where known knowledge is transferred to the student through an emphasis on procedure. While there may be some weakening of such techniques in other subjects, both English and Mathematics are often characterised by procedure rather than experience, that is, teacher instruction rather than student construction. A constructivist approach can be found in some schools and classrooms, but this is still not a general trend across the curriculum. In historic terms, it is also relatively new without the benefit of decades of embedding and experience and the most appropriate methods of adoption are still being explored.

Within Australia, many efforts have been made to implement a more student-centred approach to teaching and learning and perhaps a systematic process of inquiry across the curriculum. This movement gained impetus during the 1960s and built on the notion of whole language and more integrated approaches to knowledge. Somewhat in opposition at this time, ‘new mathematics’ was being introduced in the United States as a reaction to the perceived deficiencies of the West in science and technology during the Cold War period. Emphasis here was placed on deductive reasoning, set theory, rigorous proof and abstraction (Herreva and Owens, 2001). Australia followed this trend, but the approach was unsuccessful in both countries with a rejection by teachers and students, resulting in a back-to-basics period gaining credence. In the 1980s, a standards-based approach was advocated involving the connection of mathematics to the real world, an integration of topics, problem solving and the introduction of new content such as statistics. This was an attempt to show application in real world contexts and to involve students more in experimentation and data analysis.

Moses and Cobb (2001, p. 5) in their seminal work that links their experience of black activism with school reform in the United States shows the importance of mathematics as a social movement:

> In today’s world, economic access and full citizenship depend crucially on math and science literacy. I believe that the absence of math literacy in urban and rural communities throughout this country is an issue as urgent as the lack of registered Black voters in Mississippi was in 1961.

The examples given in the book of attempts at making mathematics and algebra more accessible to black youth are highly commendable, although probably familiar at least in broad terms, to many Australian teachers. The authors link their extensive experience of working with local communities with classroom approaches, particularly in regard to making the ideas and concepts of mathematics more understandable and relevant to everyday life. They endorse a process of taking students into the community, followed by a personal description of key ideas and discussion for refinement and finally, the introduction of mathematical knowledge. The intention however seems to be the understanding of knowledge rather than the construction of independent and original knowledge by learners.

The history of school mathematics since World War II shows a curriculum in a state of flux with many issues unresolved and subject to community, political and economic pressures. This is still the case in Australia and similar countries. Currently, school mathematics in Australia is one of eight Key Learning Areas (KLAs) which provides an optional overall framework of development and an extensive list of learning outcomes at various levels. It is noticeable that the mathematics KLA moves from a much more practice and inquiry-based approach in the primary years, to a more abstract and procedural approach in the middle and senior years, indicating the conflict between the three philosophical positions discussed above. To be consistent, the philosophical nature of school mathematics should be made explicit and accordingly, the approach taken towards teaching and learning should be consistent across all year levels. It is clear that school mathematics in Australia is confused on this point.

Pragmatic mathematics

It is entirely possible to conceive of mathematics generally and therefore school mathematics specifically in terms of pragmatic philosophy as enunciated by Dewey and others. That is, humans construct their own meaning and truth from thinking about their own experience. This does not imply that absolute truth does not exist, but that human understanding of it must emerge from a long process of experimentation and inquiry. The prominent ideas that have held sway for perhaps centuries can always be overthrown. How and whether humans can conceive of an absolute truth accurately is a matter of conjecture. Within this framework, a pragmatic mathematics can be implemented in schools where students of all ages engage ideas through systematic projects of inquiry over extensive timelines. Recognised procedures will be encountered not as the final outcome of mathematical understanding, but as the components of an intellectual toolbox for the conduct of investigations.

A pragmatic mathematics will centre on the construction of mathematical ideas, objects and relationships as a means of exploring and creating knowledge. It will also explore the nature of procedures already in existence such as rectangle, graph, volume, with students being encouraged to work with their own definitions and understandings. In other words, the outcomes of pragmatic mathematics is not a verification of known procedure but an exploration of unknown properties from the point of view of the learner. When the truth or trustworthiness of a proposition or hypothesis cannot be demonstrated in practice, this will provide the basis for ongoing study. An emphasis will be placed on the practical construction of ideas whether on the bench or electronically so that intellectual constructs can engage with practical expressions and artefacts. This is the difference between the purely cognitive constructivism and the practice/theory unity of constructionism, where ideas are constructed and manipulated in practice and do not only reside in the brain.

Not only will more time be required for pragmatic mathematics, but connections with all other knowledges need to be made to maximise the experience that can be brought to bear on specific dilemmas and projects. The implications for the general curriculum here involves fewer individual subjects with more integrated studies, fewer and more general learning outcomes that focus on the process of learning rather than the take-up of predetermined procedure and assessment regimes that do not check slices of the known, but that discuss the coherence of the unknown. A curriculum organised around four integrated studies of the arts, humanities, sciences and technologies may be appropriate to support such learning. Provision of resource centres, workshops and laboratories must be made for all schools so that the connections between practice and theory are untangled in all studies. The concept of pragmatic philosophy and mathematics is a deeply reflective concept and it may be that all schools attempt to arrange a curriculum framework that will establish the conditions for such endeavour over time, rather than expect all classrooms to be achieving such outcomes at all times. The differences between the early, middle and senior years must also be carefully considered.

Representation of knowledge

The standards-based era mentioned above included the notion of representation (see NCTM, 1987). This is the notion that humans have an intellectual structure in their brains that in some way accords with real objects and reality. In proposing that there must also be consideration of the interaction between the two, Pape and Tchoshanov (2001, p. 126) note that the implications for school involve:

- students being able to practise interaction so as to produce external representation and the internalisation of ideas
- representations being produced through social activity
- a variety of teaching techniques being used
- representation is a process for thinking and learning not something to be taught as procedure.

This approach is very similar to the broad process of inquiry and constructionism where the process emerges through the negotiation and conduct of integrated projects. The distinction can also be drawn with proposals that concentrate on different learning styles and multiple intelligences. Klein (2003) for example suggests that there are weaknesses in both approaches and argues instead for an understanding of particular representations of knowledge within the curriculum. This may be very difficult to achieve for all classes at all times, but a framework of pragmatic philosophy may enable broad outcomes to be achieved especially if conceptualising over a number of years of the curriculum.

In an early and major Australian study regarding the application of computers for combating disadvantage in schools and elsewhere, Hooley (1988, p. 75) noted that “The outstanding feature of the computer is its capacity to display and represent ideas and knowledge in a variety of ways whether it be in terms of text, graphics, sound, colour, or a combination of these”. He goes on to comment that “Facilitation in the area of knowledge representation, means the possibility of making abstract ideas more concrete, more workable and more directly allied to personal experience”. This direction located the power of new information and communication technologies in the domain of reconstructing knowledge through the internalisation-externalisation processes of representation and was released at the same time as the promotion of such ideas in the standards-based mathematics movement. A comparison of the different philosophical approaches to school mathematics is outlined in Table 1 below.

In their discussion of constructivism in mathematics classrooms, Cobb and Yackel (1998, p. 163) propose that inquiry mathematical processes are “truths rather than instructions” and that according to this view, “members of a community such as teachers and students in a classroom interactively construe the truths that tell them how the world is or ought to be and these truths constrain their individual activities”. This guideline can be used to evaluate the table and distinguish between approaches, a guideline that indicates whether truth is laid down or not, is constructed or not and by so doing, how it impacts on all participants. The approach taken towards knowledge production and learning in each column may not be completely distinct as various traditions overlap in individual schools and classrooms. It is intended that the table describe in broad terms how schools go about their curriculum arrangements, rather than a pure definition of a philosophy of mathematics itself.

The development of a complete set of teaching units to illustrate the implementation of pragmatic mathematics at all levels is beyond the scope of this paper. In addition, this may not be necessary, as the approach of inquiry over time means that knowledge is integrated rather than separated enabling the learner to utilise all cognitive functions when appropriate. If mathematics is to be integrated across the four study areas suggested above then mathematical thinking will be similarly incorporated. Following a conference in 2001 where four teachers in three different schools had worked with their Year 7students using algebraic activity, Brown (2002, p. 6) reported the conference

Table 1. Philosophical comparison of school mathematics

	Platonist Formalist	**Intuitive Interpretive**	**Constructionist Inquiry**	**Pragmatic Reflective**
Knowledge	Predetermined Independent of human will Procedural Logical Discovered	Predetermined Different understandings Procedural Discovered	Predetermined or constructed Different understandings Experiential Created	Constructed Informed Personal understandings Experiential Created
Learning	Passive	Active and passive	Scope for active investigation	Constructed Inquiry Practice/theory Collaborative
Teaching	Teacher-directed	Teacher-directed	Student-centred, teacher-guided Semi-autonomous	Student-constructed Autonomous Facilitated
Curriculum	Prescribed	Prescribed	Mix of choice and prescribed Thematic	Integrated Holistic Projects Negotiated
Assessment	Competitive Repeat of given knowledge Graded	Competitive Repeat of given knowledge Graded	Part-competitive Repeat, some initiative Graded	Description of personal knowledge Democratic In progress Ungraded

brainstormed some of the key elements of thinking mathematically as being organised, systematic and analytical, predicting and generalising, considering big picture and particular direction issues, questioning and raising ‘what if’ challenges. These views can be seen as applying to many current subject areas and again suggest that mathematics is not a separated area but has strong links with knowledge generally. In this light, it was perhaps not surprising that the adumbration of ‘language and mathematics’ as a combined area of knowledge by the Victorian State Government (1984) did not cause a controversial reaction.

Pragmatism and equity

Mandawuy Yunupingu (Wignell, 1999, p. 1) summarises the above issues when he makes a comment about what he calls ‘double power’: ‘My experience as part of Yothu Yindi illustrates the meaning of ‘double power.’ In Yothu Yindi we bring together music, ceremony, lyrics and technology from two cultural traditions into a fusion which produces something new and different.’ This is an evocative way of looking at how different cultures can complement rather than attack each other and certainly provides a model for schooling. In a similar way when discussing the literacy of Aboriginal children in the early childhood area, Simpson and Clancy (2002, p. 1) point out that progress will not occur until children ‘have acquired the socio-cultural practices to navigate the new setting.’ This view can be generalised across the formal school curriculum and for all children, that ways and means of moving within and across different cultural domains are the bedrock of learning and that the intended building of organisational and pedagogical barriers makes learning almost impossible. The issues being confronted here are however huge and encompass the great philosophical ideas of our era. That being the case, we need to conclude our discussion of school mathematics that will benefit Indigenous and non-Indigenous children alike, with some more general observations regarding knowledge and schools.

In one of the most famous statements of modern science, Stephen Hawking (1988, p. 185) announced to the world that:

> if we do discover a complete theory, it should in time be understandable in broad principle by everyone, not just a few scientists. Then we shall all, philosophers, scientists and just ordinary people be able to take part in the discussion of the question of why it is that we and the universe exist. If we find the answer to that,

> it would be the ultimate triumph of human reason – for then we would know the mind of God.

Earlier, Hawking had noted that in the eighteenth century philosophers had considered all of human knowledge together, rather than splitting off certain areas such as mathematics and science as occurred later. This lack of holism makes it difficult to devise a 'theory of everything' that can explain the nature of the universe in a small set of equations and axioms, uncertain as they may be. The quest continues however to understand the finest details of how the universe functions and the place of humans within it. The design of school curriculum, the specification of knowledge and the identification of truth for children needs to consider the twists and turns that separate Plato, Newton, Bohr and Hawking.

It would be interesting to conceive the world today if Plato had supported a view of knowledge that relied on human creation rather than discovery. Exactly why his views have remained so strong for many centuries is difficult to explain, although causal linkages between national economies and conservative religious thought provide some insight. Whatever the case and in contemporary terms, progressive thinking and subsequent action will always to vigorously opposed by dominant conservative thought, power relations are very difficult to dislodge and as a form of power so too with knowledge. In a very practical sense, the transformation of schools to a fundamentally different philosophical position will be quite expensive as well. Nevertheless, many attempts have been made and radical experience and aspiration still continue to be found in the hearts of teachers everywhere.

The way forward

Pragmatic philosophy enables school mathematics to be structured not only around the ideas of a thought/action unity, systematic inquiry, reflection on experience, knowledge construction and representation, but critical pedagogy as well. That is, the engagement of ideas within the context and framework so outlined promotes critique of learning, knowledge and of learners themselves. It recognises that experience and reflection on objects, relationships, structures and organization provides the springboard for experience and reflection on values, beliefs and practices, leading to substantial personal change of individuals and teams. The most significant aspect of social change is that which occurs personally, change that is not focused on social organization but social being. To reconceptualise school mathematics in the way envisaged above, to abolish as a separate content area and integrate as an enabling process across all learning, to replace the textbook with the laboratory for robotic design and application, to take up notions of complexity and emergence, to consider the psychology of computer interactions and of artificial intelligence, to be immersed in the interpretation of authentic data and authentic outcomes, will be extremely challenging and confronting for many teachers, students and families in all schools. One cannot remain aloof and unchanged.

Given this possibility, it may be a little easier to understand the rigidity of the teaching of mathematics in schools, or why teachers and members of the public should adopt such calcified positions. Mathematics in schools has only a short history and many students do not continue with a study of the subject in senior secondary years if given the choice. Even the study of English and language is often treated with greater flexibility and children are given the opportunity of experimenting with words and ideas without being locked necessarily into a correct framework of procedure. There is also a dissonance between school mathematics and the active life of practical inquiry that many mathematicians pursue. Whatever the explanation, the isolated, compartmentalised, mysterious area of school mathematics appears to occupy a position of truth in schools that is used in very conservative and unfortunate ways to exclude students from a more comprehensive learning. The chasm between school mathematics and a more democratic epistemology must be bridged.

What this essay has suggested therefore is that a radical reconstruction of curriculum is necessary if progress is to be made on fashioning more inclusive and democratic schooling for Indigenous peoples. Not only must realistic strategies be found for a curriculum structure that embodies Indigenous culture and ways of knowing, but that specific subjects such as mathematics need to be fundamentally recast as well. A rich country like Australia certainly has the wherewithal to implement a more progressive arrangement for schools if it so desired, or more particularly, if those in a position of wealth and privilege so desired. As the discussion has shown, reconstructive attempts have been made around the world regarding the ideas of pragmatic and inquiry learning, ethnomathematics and in Arnhem Land, Australia, Garma Maths, but the problem of mainstreaming for the benefit of all children remains. A curriculum structured along the lines of pragmatic reflective learning would engage many more Indigenous and non-Indigenous students with deep and challenging knowledge and make the schooling experience one of personal fulfilment rather than inevitable alienation. As Behrendt (2003, p. 126) so tellingly comments, ‘It is perhaps the biggest indictment on Australia’s institutions that many of the rights that Indigenous people are seeking are ones that other Australians unquestioningly enjoy.’ In adopting this approach towards education, a country that worked for a genuinely inclusive education system with epistemological integrity would make a major contribution to humanity and reconciliation amongst its own people.

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