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**Abstract:** Mathematics is an important subject for students to know in order to gain places in further academic study and high-prestige, well-paid positions. However, mathematics and the way that it is taught is enmeshed in Western, generally middle-class values and beliefs. Many indigenous students in attempting to gain mastery of mathematics find that their own background and beliefs come in conflict with these. This paper examines perceptions of mathematics, sequences of student learning, teaching and learning mathematics and languages of instruction so that areas of conflict can be identified and resolutions suggested. Community involvement in mathematics curriculum decision-making is seen as the most appropriate way to overcome cultural conflict.

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## Introduction

Mathematics is a high status subject (Harris, 1997, p. 3) because the world today is considered a mathematical world. Davis (1996, p. 147) suggested that 'we have become as much the products of mathematics as it is the product of us'. Making sense of the world using the abstraction and logic of mathematics has helped some people control the world in particular ways. The importance of mathematics is, therefore, reinforced by those who use mathematics to both understand and manipulate that control (Triadafillidis, 1998, p. 23). Zevenbergen (1996, p100) claimed that because mathematics' abstraction has been valued so highly by society, the passing on of this knowledge and way of thinking has been rigidly controlled.

Davis (1996, p. 145) has suggested that

> [t]he number of mathematics courses taken by a student is commonly regarded as an indicator of his or her potential and ability, not in the least because mathematics wears the mask of impartiality so effectively. Thus courses in mathematics have assumed a "weeding out" or "gatekeeping" role.

For students to have a range of opportunities in regard to jobs, they must do well in mathematics. However, within every mathematics classroom there is an intersection culture which forms students' backgrounds. When there are large differences between what is valued in these cultures, this intersection resembles a clash rather than a successful symbiosis. Such a clash excludes many indigenous students from a successful education unless they become assimilated (Wooltorton, 1997, p. 37). This paper examines some of the literature on the learning of mathematics and indigenous students to determine why a clash may occur. In particular, it juxtaposes perceptions of mathematics and how it should be taught with what is known about indigenous students and the way that they learn. In particular it looks at beliefs about school mathematics, sequencing of student learning, teaching/learning of mathematics and the language of instruction.

In this paper indigenous students are considered to be those who belong to communities who originally controlled the land and developed distinctive cultures before the arrival of Europeans but who are presently attending educational institutions which closely resemble those of industrial countries. These students would include Australian Aborigines, Maori, Pacific Islanders, Native American Indians and the Inuit. There are advantages in using one word to describe a variety of students. However, in using such a term the differences between and within groups are lost. Not all indigenous students will display the characteristics described (see Megginson, 1990, p. 1).

## Mathematics in the school and the community

Beliefs of participants about mathematics influence its teaching and learning. For example, parents' beliefs about mathematics can affect their children's views (Graue & Smith, 1996). Lehrer and Shumow (1997, p. 74) suggested that reforms are rejected learning than those of the school. The Cockcroft Report, *Mathematics Counts,* stated that '[i]t can happen, too, that parents fail to understand the purpose of the mathematics which their children are doing and so make critical remarks which can also encourage the development of poor attitudes towards mathematics in their children' (Cockcroft, 1982 p. 62).

How mathematics is taught in schools is strongly related to teachers' perceptions of it (Hunting, 1987; Thompson, 1984; see Ernest, 1991, p. xiii-xiv, for an overview). If mathematics is considered 'as objective and value free, being concerned with its own inner logic' (Ernest, 1991, p. 26) then it is often taught 'with little or no historical, cultural, or political references' (Anderson, 1990, p. 296). This view does not allow for any consideration of its social construction and therefore there is no conception that there may be other kinds of mathematics. However, it is not a one-way process as this belief about mathematics can be adopted because of the way mathematics has been presented.

> [m]athematics textbooks, pedagogical practices, and patterns of classroom discourse, especially, work in concert to perpetuate the idea that mathematics is the "discipline of certainty". Together with a behaviourist view of learning, this myth has led students and teachers alike to reduce mathematical learning to the acquisition of ready-made algorithms and proofs through listening, memorizing and practising. (Siegel and Borasi, 1994, p. 201)

Recently there have been discussions about the social nature of mathematics production (Davis & Hersh, 1981; Ernest, 1991). In considering the social contexts in which Western mathematics has developed, the mathematical practices which are 'Ethnomathematics' (see Gerdes, 1997, for an overview of the different meanings given to this term) has been the field which developed from this discussion. Vithal and Skovsmose (1997, p. 133) stated that 'ethnomathematics refers to a cluster of ideas concerning the history of mathematics, the cultural roots of mathematics, the implicit mathematics in everyday settings and mathematics education'. Included within these ideas is the consideration of mathematical patterns which may not have a 'direct Western translation' (Eglash, 1997, p. 86). It has been suggested that other cultures may use a related but different kind of mathematics to that used in Western societies (Joseph, 1993).

Indigenous students are expected to achieve better results from the inclusion of ethnomathematical perspectives (Howard, 1995) because students would feel: that their backgrounds and experiences were valued in the classroom; that mathematics can be developed by others outside of Western culture; and that mathematics has relevance to their lives outside the classroom (see Gutstein, Lipman, Hernandez & de los Reyes, 1997; Howard, 1995; Joseph, 1993). As Howard (1995) said

> [t]here continues to be a move, amongst mathematics educators, away from a classroom with a singular emphasis on mathematics content to the provision of a learning environment where the learner develops their understanding of mathematics through the social and cultural context of the classroom and the community in which they live. (p. 32)

Although some national documents on mathematics education (Australian Education Council, 1991;Ministry of Education, 1992) have briefly mentioned these ideas, there appears to be little research on how ethnomathematical ideas have been used in the success of ethnomathematics programs including academic success but also self-esteem and community involvement in the school.

*The relationship between mathematics, school mathematics and mathematical practices*

The terms ‘mathematics’, ‘ethnomathematics’ and ‘school mathematics’ overlap, making distinctions between them hard to recognise. Within this paper the following descriptions are given. Their looseness allows them to illustrate the complexity of the relationships between the terms (see figure 1).

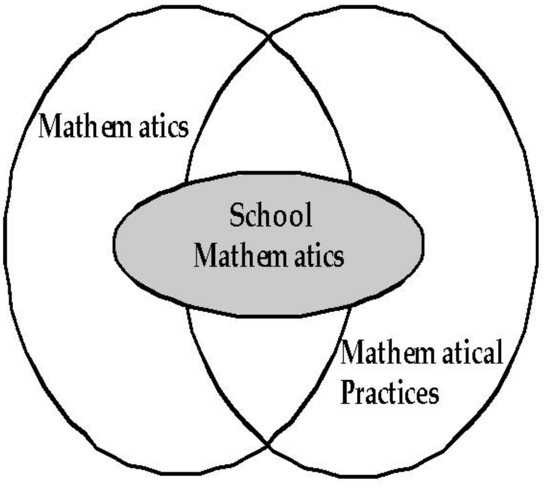
The descriptions of the terms are:

- mathematics which is the study of quantity, relationships and space and is what mathematicians would call the ideas that they work with, such as algebra;

- mathematical practices which are those activities which people from different communities do which could be used to develop mathematical ideas, like making a cake;

- and school mathematics which contains both mathematics and mathematical practices, such as when a recipe is described as an algebraic expression so that it can be adapted easily when changing quantities.

Figure 1: *The relationship between mathematics, mathematical practices and school mathematics*.




There are concerns associated with using mathematical practices from indigenous cultures. These concerns include the choosing of mathematical practices, the mathematical emphasis in the use of these practices, the ownership of knowledge and the marginalisation of students through using mathematical practices.

In the past, mathematical practices used to introduce a mathematical idea or skill have been more likely to reinforce the experiences of boys who were middle class and Anglo-Celtic in background. It has been suggested that this was one reason why other students felt excluded from learning mathematics (Australian Education Council, 1991). However, choosing activities from the experiences of indigenous students can result in the original purpose of the activity becoming lost or denigrated through the concentration on the Western mathematical idea "seen" to be embedded in it (Roberts, 1997).

some, knowledge is not available to all members (Falgout, 1992; Roberts, 1997) and therefore it is not appropriate to use some activities in classrooms. In other communities, there is a belief that '[t]o give knowledge to someone who is not prepared to receive it will result in the abuse of the knowledge and damage to the community' (Rauff, 1995, p. 46). There is also a concern that culture is very rarely homogenous and by presenting an activity as representative of a culture, a teacher could be glossing over differences within that culture (Vithal & Skovsmose, 1997).

The use of indigenous activities must be done with respect and care or they become a tokenistic activity before 'real' mathematics is undertaken. Lerman (1994, p. 99) suggested that if a mathematical practice from a particular culture is used, but is not part of what students need to know, then 'pupils may feel that their culture is being made to appear primitive and backward, even though this is not the intention of the teacher'.

Vithal and Skovsmose (1997) also raised the possibility that, to South Africans in particular, the aims of ethnomathematics closely resemble those of apartheid where perceptions of cultural differences were used to provide different education for different cultures. In order to overcome this potential for limiting the opportunities for some students, they have stated that students' foregrounds should also be considered when choosing mathematics activities. 'Foreground may be described as the set of opportunities that the learner's social context makes accessible to the learner to perceive as his or her possibilities' (Vithal & Skovsmose, 1997, p. 147). Knijnik (1998, p. 188) reported that in the mathematics education program in which she popular knowledge and academic knowledge are qualified, allowing the adults, youths and children who participate in it to concurrently understand their own culture more profoundly, and also have access to contemporary scientific and technological production'. In this way, students themselves could see how the distance between their home culture and the school culture could be lessened. (See also Knijnik, this volume –Ed.)

It seems that although one way of averting a clash of cultures would be to integrate traditional mathematical practices into a mathematics program, there are difficulties with this. The decision on whether the perceived benefits outweigh the disadvantages can only be made by a school community. Some communities may decide not to include any of their mathematical practices (see Fuchs & Havighurst, 1972). Other communities may see these mathematical practices as a bridge to help their students to gain better understanding of Western mathematics (Bucknall, 1995). Still other communities may value the inclusion of mathematical practices which they feel that students are no longer able to learn outside of school. In such cases, the activity itself and not its connections to Western mathematics would be the main reason for it to be taught.

### Sequence of student learning

The first issue, 'Mathematics in the school and the community' considered ideas about mathematics. This can be thought of as the 'what' within a school mathematics program. Sequence of student learning, on the other hand, considers questions of 'when'. Around the world, students spend up to thirteen years in schools (Schmidt, McKnight, Valverde, Houang & Wiley 1997), learning some mathematics in each of others can be developed and children themselves need to mature so that they can understand more complex ideas. Community expectations of the skills and knowledge that children should have at different ages (or sizes) also define the cultural contexts which can be used within the school mathematics program.

*Development of mathematical ideas*

The Cockcroft Report (Cockcroft, 1982, p. 67) suggested that ‘mathematics is a hierarchical subject’, with ideas building upon one another. How this mathematical hierarchy is interpreted within education has changed over the last eighty years. Thorndike’s *The Psychology of Arithmetic*, published in 1922, supported mathematics being broken into small parts which children are expected to absorb through drill and practice (Resnick & Ford, 1981). However, in recent years this natural progression of ideas has been challenged. For example, it was thought that children could only learn negative numbers and fractions after they were competently operating with whole numbers (Scott, 1972). However, use of technology in the classroom has meant that very young children are now dealing with negative numbers and decimals (Groves, 1996).

Although some mathematical ideas are developed from others, there does not seem to be an ‘absolute hierarchy within concept development’ (Filloy & Sutherland, 1996, p. 141) as had been suggested by Thorndike. Rather mathematical ideas can be considered as being connected in a complex web of relationships. Mitchelmore (1995) illustrated this complexity by stating that

> proportion is a multiplicative relation and involves rates and ratios. Division is the inverse of multiplication and is closely linked to fractions. Finding equivalent fractions involves the use of proportion. (p. 65)

Different entries can be made into one idea through any of the other ideas to which it is connected. The most appropriate entry would depend upon students' backgrounds which would consist of both their previous schooling experiences and also their outside schooling experiences. The more connections that are made between knowledge, the more likely the understanding of all those ideas would improve.

However, some sequencing of mathematical ideas may still be necessary, as without any background to a new mathematical idea, children may be unable to learn it effectively. Cockcroft (1982, p. 68) suggested that this would be one reason why only a few students 'are able to tackle the more abstract branches of the subject with understanding or hope of success'. The fear that children could miss out on necessary prior knowledge, prompted Hart (1996, p. 255) to suggest that the order in textbooks should be followed as 'the author of the book has presumably sequenced the content so that it makes sense and in order to address prerequisites'. Teachers will chose their own order to deliver a mathematics program but if students' mathematics education is to be consistent then there needs to be communication throughout the school.

Another aspect of this issue is that of efficiency of the mathematical skills that children use (see Young-Loveridge, 1994). Although children may be able to tackle problems using a range of mathematical methods, they may not always choose the most efficient (Stacey, 1995). Although students may use less efficient methods, sophisticated ways of solving problems.

*Child development and culture*

Decisions about when to teach certain mathematical concepts are often connected to ideas about children's maturity of thought. For example, Mitchelmore (1995, p. 57) stated that 'the fractions concept is now seen to be a very complex concept which can be mastered only when students have acquired the level and maturity of thinking which generally first appears in the secondary school'.

Although there have been other child development theories, such as those of Jerome Bruner (see Bruner, 1960), Jean Piaget's work has had the most significant influence on beliefs about what mathematical ideas were considered appropriate for children of different ages (Young-Loveridge, 1987). Piaget's (1990) basic premise was that children progressed through:

> four great stages, or four great periods, in the development of intelligence: first, the sensori-motor period before the appearance of language; second, the period from about two to seven years of age, the pre-operational which precedes real operations; third, the period of concrete operations (which refers to concrete objects); and finally after twelve years of age, the period of formal operations, or propositional operations. (p. 27)

For Piaget (1979, p. 3), child development was related to the development of logico-mathematical thought as he related ideas about mathematics to 'the earliest structures achieved by the infant (in the sense of what he can do and not what he thinks or says, which come much later)'.

For many years, Piaget's stages were considered universal, in the sense that

> (a) sequence of stages, including their structural properties and the kinds of explanations given by children at different stages, are invariant; and (b) the horizontal decalage (e.g. the order in which conservation of quality, weight and volume are acquired) is invariant (Laboratory of Comparative Human Cognition, 1979, p. 149).

Ideas based on the universality of these stages were incorporated into mathematics curriculums world-wide. For example, at one point the French banned the teaching of counting to children in pre-schools as Piaget's stages indicated that children of that age would not have the necessary development to understand the purpose of counting (Butterworth, 1999).

However, there have been criticisms of Piaget's stages. Young-Loveridge (1994) cites research where even pre-school children were able to use written symbols to represent hidden amounts of things. Watson (1995, p. 122) also queried Piaget's beliefs that children were unable to 'understand probability until they reach the stage of formal operations'. Nevertheless, beliefs about the progression through Piaget's stages still influence mainstream mathematics curriculums.

From their research, cross-cultural psychologists found other difficulties with the stages, especially that of formal operations. For example, work in Papua New Guinea in the 1970s and reported on by Lancy (1983) suggested that children from some cultural groups did not pass through Piaget's stages in the same way as children from Western cultures did. The Laboratory of Comparative Human Cognition (1979) warned that

> failures to find formal operational thinking have engendered suggestions that it is necessary first to establish the end state toward which developmental processes move in different cultures. If this step is not taken, the absence of a concrete formal-operational epitome of developed thinking. (p. 149)

Without this warning, children from non-Western cultures are often considered as lagging behind their Western counterparts. Lancy (1983), for instance, stated that Papua New Guinean children appeared to be three or more years behind their Western peers. Studies such as that by Seagrim and Lendon (cited in Lancy, 1983) suggested that ‘the closer the *home* environment approaches the Western model, the more closely does performance approach the Western standard’. However, suggestions that in order to succeed in mathematics children need a home background similar to that of Western children leave little opportunity for indigenous children to maintain their own culture.

An alternative approach is to use the mathematical practices that children already engage in outside school as skills and understandings that can be built on within the school (Bucknall, 1995). Rogoff (1990, p. 49) stated that it is parents and other adults who ‘determine the activities in which children’s participation is allowed or discouraged, such as chores, parental work and recreational activities, television shows, the birth of a sibling, or the death of a grandparent’. This is because children need to be acculturated into the behaviours expected of adult members of a community from an early age (Kearins, 1991). It may be useful for parents to inform teachers of the mathematical practices that they expect of the children at certain ages. If teachers know the range of mathematical practices children are performing at different ages, they can then adjust their curriculums to take advantage of the background skills and experiences that children bring to school.

expect that children will have had experiences with number before entering school. Children who do not have those experiences are often thought to be at a disadvantage (Carr, Peters & Young-Loveridge, 1994). Teachers then spend their time trying to catch children up rather than looking at the strengths that these children have in mathematical practices and building the mathematics learning onto these experiences. Kearins (1991) reported on research in which Aboriginal children living in both urban and rural settings had much less number knowledge than their non-Aboriginal counterparts but outperformed them in understanding of directions. For such children, it may be more sensible to start a mathematics curriculum based upon the directional understandings that they have and build understandings of number into these.

Mathematics curriculums have traditionally set out expectations of student learning in different stages. The beliefs about what should be taught at what age were based on judgements about: how learning some mathematical knowledge would be dependent on knowledge previously acquired; students' cognitive development; and the mathematical experiences children would have had outside school by society at large. Too often Western, middle class beliefs about a mathematical hierarchy of ideas, child development and what children know outside school have determined the stages within the curriculum.

Mathematics, rather than being a linear progression which had to be learnt in a lock step manner, is in fact an interlinked series of ideas which can be learnt from a range of different starting points. Ideas about child development have been severely criticised in regard to cross-cultural studies which suggested that non-Western in adult cognitive behaviour. This has resulted in different expectations of what children should know at different ages. School communities could investigate the possibility of using children's mathematical practices as contexts for making links to school mathematics. Although there is at present little research evidence to support a claim that such an approach would improve indigenous students' learning of mathematics, it does seem a promising approach given the difficulties many indigenous students experience with the regular curriculum. (See also Civil, this volume – Ed.)

## Teaching and learning mathematics

Although it is possible to both learn without being taught and to teach without anyone learning (Orton, 1994, p. 35), schooling is based on the assumption that children are more likely to learn if there are teachers to guide them. Problems occur when there is a mismatch between teachers' teaching style and students' learning style.

### *Learning in different cultures*

For the mathematics educators who subscribe to them, different teaching/learning theories such as constructivism and the Zone of Proximal Development (see for example Cobb, 1994) are considered to be good practice. However, for indigenous students, this concept of good practice may not be sufficient because it does not include the recognition that some cultures have very different expectations of how students learn. For example, Owens and Wegener (1995) have suggested that

> Aboriginal learning is facilitated by:
>
> - a focus on group performance and arrangements for shared reward
> - doing and observing activities, imitation, and repetition
> - activities which are self-explanatory in themselves, have their own inherent relevance, rather than being a means to a remote end
> - requiring skills that can be demonstrated concretely and situationally rather than conceived abstractly
> - emphasising helping relationships amongst learners, affiliation among peers, nurturance

and care for each other. [Is this a quote? If so, please give page reference.] From a talk not a published paper

In their research of high school Aboriginal students, they found that with an increase in the year at school, there was ‘a steady decline in preference for both competitive and individualistic learning situations, and a steady increase in preference for cooperative learning in relation to competitive learning’. [page reference?] see previous note This contrasted with finding from *mainstream students in Sydney, Perth, New Zealand, the English Midlands, and Minneapolis in the USA where a similar increase in year at school showed an increase in preference for competitive learning. In an earlier study, Owens (1993) found that mathematics teachers spread similarly throughout the world were themselves more orientated towards competition and individualisation than were teachers of other subjects.

Parents have expectations about what children of different ages or sizes need to learn. At Maningrida [describe(an Aboriginal Community in Central Arhnemland in Australia)] where I had worked, there were distinctions not just about what a child should learn at different ages but also how they were expected to learn (Maningrida Community Education Centre, 1997). For example, children were only expected to ask questions about their learning until the ages of about six or seven. After this, children were discouraged from doing this and were expected to learn through observation and imitation.

Bacon and Carter (1991, pp. 2-3) highlighted differences between peoples of different cultures in relationship to field independence and field dependence. These two alternate perception styles are based on ‘how one views oneself in relation to one’s surroundings’ (this quote is on page 2 but the descriptions of field independence and field dependence extend from page 2 to 3). Students who are field dependent have more difficulty organising the information that they are learning unless it is already structured for them. These students have difficulty in classes where material is presented ‘in an open-ended manner to encourage students to discover for themselves relations among concepts’ (this is on page 2). Field dependent students are also likely to have difficulties identifying relevant information in word problems or when writing proofs. However, they learn more easily if the information is within a social context with which they are familiar. Bacon and Carter (1991, p. 2) stated that ‘[m]any studies have found that culture plays an important role in determining whether an individual develops a field independent or a field dependent perceptual style’. Members of a community which favour group rather than individual identification are more likely to be field dependent. Field dependent students are more likely to have difficulty producing their own solutions to problems, but are able to contribute to group problem solving.

There are problems with describing cultural groups as having particular learning styles. Deyhle and Swisher (1997) from examining a number of studies suggested that research on learning styles has been used to stereotype Native American students as non-verbal students. This was often done without critically examining the power relations within classrooms where silence became an appropriate response by students p. 43) suggested that these stereotypes were used to ‘justify remedial, nonacademic and nonchallenging curricula for Native American students’. In introducing an inquiry-based social studies program in a Navajo school, they found that by changing the classroom environment, children became involved in ‘questioning, inductive/analytical reasoning, and ... speaking up in class’

(McCarty et al., p. 52).

Teachers' interactions with indigenous students can also have an impact on the teaching/learning process. Deyhle and Swisher (1997) in examining a number of studies highlighted certain features of teachers which made teaching/learning more effective for Native American students. Some of these characteristics were personal warmth, high expectations, accepting silence, using small group work, being a learner with students and avoiding singling students out. The way that feedback is provided to students can also be culturally inappropriate. For example, feedback that non-Aboriginal teachers give to Aboriginal students can be misinterpreted as personal attacks rather than being about their work. This is because:

> The teacher presents feedback in the way he or she has learnt to do so and the child interprets it in a way he or she has learnt to do so. But neither understands the other. Not only does this communication breakdown make the children and teachers very unhappy, it also prevents the feedback from being utilised in the purposeful learning process. (Christie, 1985, p. 68).

Learning theories such as that of 'cognitive apprenticeship' have emphasised the need for mathematics activity to begin by being 'embedded in a familiar activity' (Brown, Collins, & Duguid, 1989, p. 37). This has resulted in contexts being used as vehicles through which mathematics is taught. For indigenous students, mathematical practices mathematical ideas within school. Boaler (1993) suggested that ethnomathematics:

> is not an influx of new content or context in the curriculum, rather a different perspective and starting point. The essence of this approach is that through discussion and analysis of individually generated methods there is a development of awareness of all the mathematics that is meaningful in specific and general situations. Ethnomathematics is not the replacement of school methods by those that are individually generated, but schools must at least acknowledge the latter and consider why they are used when the former are not. In doing so the elegance of school-taught algorithms may come to be appreciated as well as their underlying structure -why they work and how they may work as usefully as students' own folk or ethno mathematics. This must encourage connections between the mathematics of the classroom and the mathematics of the real world, and in forging these connections make the usefulness of both transferable. (p. 16)

One concern with this approach is that although some mathematics educators have used mathematical practices in the classroom (Barta, forthcoming; Masingila, Davidenko & Prus-Wisniowska, 1996 ), the activities have tended to be those of adults rather than children. Although there are some examples of children's own activities being used (see Masingila, 1996; Presmeg, 1996 ), there is little research on whether students are more successful in learning mathematics using this approach.

If there is too great a mismatch between parents' and teachers' expectations about learning, then children become confused (Deyhle & Swisher, 1997). It may be useful for teachers to discuss with students as well as parents their beliefs about how mathematics is best learnt. By explicitly discussing this, students can discover that different learning strategies can be appropriate in different situations.

This issue is about the languages that are used to facilitate teaching and the impact this choice has on students' abilities to learn mathematics. The relationship between mathematics and language is discussed initially, then how language is used in the teaching of mathematics is considered. As many indigenous students learn mathematics through their indigenous language or through a language which they are learning contemporaneously, these situations will then be considered.

*Mathematics and language*

Halliday (1978) suggested that languages highlight what cultures value in particular situations. Culture does not change what is seen in the world but its language will act as a sieve to emphasise some aspects more than others. This sieve will influence the production of every text, including that of mathematics.

Another way of considering the relationship between mathematics and language is to consider how mathematics is spoken about, listened to, read and written about. The mathematical register of a natural language includes both the terminology and grammatical constructions which occur repeatedly when discussing mathematics. In $\cos\left(\frac{\pi}{6}\right)$, cos is part of a nominalisation (or noun-like group of words) which contains a process or action (see Meaney, forthcoming, or Spanos, Rhodes, Dale & Crandall, 1988 for a more thorough description of the mathematics register). It is the mathematical register which acts as the vehicle through which mathematical ideas are discussed.

perceived. Morgan (1996, p. 4) stated that the use of nominalisation obscures who has done the process in mathematics and as a result 'fits in with an absolutist image of mathematics as a system that exists independently of action'. In reviewing the literature on language used in mathematics, Ellerton and Clements (1990, p. 247) felt that there was a 'possibility that the formal code of mathematics is essentially the construction of white, middle-class, Western males, and that typical mathematics classroom organisations, language patterns and assessment procedures discriminate against working-class children, against females, and against children from non-Western cultural backgrounds'. Students, therefore, need to be aware of how mathematicians express themselves and also of how this language determines what is considered legitimate mathematics. There are added difficulties when the language which is used in classrooms to develop mathematical ideas is not the language or dialect of the students.

*Learning mathematics through language*

With the consideration of learning theories such as constructivism, there has been more awareness of the importance of the role of language in learning mathematics. Frid (1993, p. 38), for example, wrote that 'language is an essential component of the building of mathematical meanings from experiences'. This is particularly true in secondary school where much of what is done happens through mental manipulation of ideas (Gerot, 1992). Spanos et al. (1988, p. 222) went further by stating that '[l]anguage skills are the vehicles through which students learn, apply, and are tested on math concepts and skills'.

attention has been given to the interactions between students and between teachers and students (Yackel, Cobb & Merkel, 1990). These interactions are described by Cazden (1987, p. 1) as ‘in relating inter-individual communication to intra-individual change, we are talking about transformations from conversation to cognition’. Even in a classroom where the teacher controls much of the interactions which occur, students need skills of ‘listening attentively, writing clearly and reading for comprehension’ (Dawe, 1995, p. 231).

Some children experience difficulties with language in their mathematics learning. These difficulties include: misunderstanding vocabulary (Otterburn & Nicholson, 1976); difficulties with the different ways of expressing the same operation (Gibbs & Orton, 1994); semantic structure (Clements & Ellerton, 1996); and comprehension difficulties in word problems (Newman, 1977). Spanos et al. (1988) referred to several studies which showed a close link between language proficiency and achievement in mathematics. Ellerton and Clements (1990), however, suggested that language difficulties themselves may not always cause problems with mathematics, in some cases poor mathematical understanding could produce poor use of mathematical language.

Language problems associated with learning mathematics become more conspicuous with indigenous children. They often learn through a world language, such as English or French, which they are learning at the same time, or through their indigenous language which may not have a mathematics register. In the next sections, three alternatives are presented. These are: a bilingual model where a school uses both their only the local vernacular language. These alternatives belong to a continuum and there are numerous others between each of these positions. It is recognised that although there may educational reasons why one (or more) languages are used within a classroom, more often the choice of a language is a political decision.

*Bilingualism and the learning of mathematics*

In some situations, indigenous students may learn mathematics through two languages, a world language and an indigenous language. Although there has been considerable argument about whether bilingualism has a positive or negative effect on learning (see Cummins, 1996), there is support for the need for a strong first language to gain the most benefits from knowing two languages (Clarkson, 1991b;Ellerton & Clements, 1990; Garaway, 1994). Without a strong first language, students will have less chance of learning the academic register in their second language. Cummins (1996, p. 106) further suggested that 'there may be a threshold level of proficiency in both languages which students must obtain in order to avoid negative academic consequences and a second, higher threshold necessary to reap the linguistic and intellectual benefits of bilingualism and biliteracy'.

Many of the studies which showed the additive advantages of bilingualism were with students who were learning through two different world languages, English and French or Spanish and English. Although Clarkson and Thomas (1993) reported on studies in Papua New Guinea which suggested similar findings for students who were bilingual in an indigenous language and in English, there are problems when one language does not have a mathematical register. Harris (1987) suggested that those would find that

> in many instances, ways of expressing concepts in children's first language will be quite different from ways in which they are expressed in English, thus causing confusion with vocabulary and terminology ... In some case, where concepts are totally foreign to the children's cultures, there will be no concise ways of explaining them in the children's own languages. Thus the children will be required to learn new vocabulary and new concepts simultaneously. (p. 75)

*Learning mathematics in a second language*

Many indigenous students learn mathematics through a language which is being learnt at the same time. There are many reasons why a society or a community may decide that children should learn in a language such as English rather than their mother tongue. In South Africa, for example, using the first language of students as the language of instruction was connected to the inferior education provided by the apartheid government (Setati, 1998). In countries such as Papua New Guinea, where there are hundreds of indigenous languages, a language such as English has been chosen as the official language (Clarkson, 1991a) and some part of a child's education will be conducted in this.

Cummins (1996) suggested that children who learn through a second language will not achieve the same outcomes as those learning through their first language until the later grades of elementary school. This is because, although they may gain conversational English quite rapidly, learning academic registers such as that of mathematics takes much longer. In academic registers, contexts are reduced and so do not provide clues to meanings in the way that they do for conversational language.

difficulty with mathematics problems written in the passive voice. In Navajo, the first noun in a sentence is the thing which has the dominant role. Sentences written in the passive voice, where the doer is often the second noun, are often seen as being absurd by Navajo students. Even where students may speak a dialect of English as their main language, resonances from an indigenous language may remain. Leap (1988) in his discussion of the cultural influences on mathematical problem solving, reported the situation where a Native American student did not solve a hypothetical problem about his brother because it did not match the reality of his brother's actual situation. The dialect of English used did not include hypothetical language.

It was proposed by Clarkson (1991b) that children who speak an indigenous language without a mathematics register, but who learn mathematics through a world language have more difficulties than students whose first language contains a mathematics register. This is not to suggest that it is impossible for learners of English to succeed academically (Cummins, 1996), however, it does mean that teachers of these students need to be aware of what are the potential problems and to provide programs which support their language development at the same time as they support their mathematics learning. Spanos et al. (1988, p. 222) stated that this is best done through a program which 'integrates rather than separates math skills and language skills'. Each lesson would be both a language lesson and a mathematics lesson.

For Harris (1985), Western knowledge, such as mathematics, should be taught in English in bilingual schools on Aboriginal communities. His fear was that if an Aboriginal language was used to discuss non-Aboriginal knowledge, it would not have time to develop its own academic registers which would result in English grammatical structures being incorporated into the indigenous language. Over time, this would have major implications for the language by redefining how Aboriginal knowledge itself could be discussed (Harris, 1990). Barton, Fairhall and Trinick (1998) in examining the development of a Maori mathematics register echoed these concerns:

> Are the rationalism, the objectivism, the tendency to control, and the propensity to technological progress, all of which are inherent in mathematics, being felt within the Maori language, and subsequently in Maori culture? It is almost certainly too early to tell, and may be impossible to distinguish from the contemporary changes of a living language, however it will be interesting to watch as school-room mathematics discourse tips into the playground and then into everyday language. (p. 7)

### *Learning mathematics in an indigenous language*

For as many reasons as there are for choosing a world language as the language of instruction, there are reasons for choosing an indigenous language. However, there are different concerns connected with this choice. Berry (1985) in his discussion of the teaching of mathematics in Botswana, emphasised the 'distance' between the language of the learner and the language of the curriculum developer. In looking at the problems Botswana children were having in learning school mathematics, Berry suggested that even where a mathematical register was engineered in the indigenous language, there could still be a clash between the different underlying cognitive structures of the mathematics register and the indigenous language. This could result in children failing to learn sufficient mathematics to enable them to use it to solve problems (Berry, 1985). Similar problems have been identified by Denny (1980) in the translation of mathematics curriculum materials from English into Inukitut, the Inuit language. Gibbs and Orton (1994, p. 100) stated that although mathematical be effective and there needs to be research on 'the stage in conceptual development when specific mathematical vocabulary items are helpful [and] how they should be introduced'.

As a consequence of the possible problems of a mathematics register, based on that of a world language, being imposed on an indigenous language, Denny (1980) proposed a "learning-from-language" approach where

> [f]or each area of the primary mathematics curriculum we examine the patterns of the Inuktitut words and their meanings, looking for signs of the organization of mathematical ideas. This organization is then employed in lesson-building so that the child's development of mathematical concepts will grow smoothly out of the concepts he has learnt as a speaker of Inuktitut in preschool years. (p. 200)

This approach may overcome the difficulties of the distance between the mathematics register and that of the indigenous languages. It also allows traditional activities to be incorporated into mathematics classrooms with less risk that these activities would lose their identities by being subsumed into school mathematics (Barton & Fairhall, 1995). However, this sort of mathematics register development takes considerable time by many community members in order for the most appropriate ways for talking about school mathematics to be determined.

## Conclusion

When indigenous students' cultures intersect with the culture which surrounds mathematics in classrooms, there are many opportunities for cultural clashes to occur. This often results in poor educational outcomes for these students. This paper has illustrated some of the areas where such clashes are likely to occur and outlined some difficulties. Some of the areas where clashes are likely to occur are in perceptions of: what mathematics is; when mathematical concepts should be taught; how mathematics should be taught; and what language should be used. Clashes are most likely to occur when the teachers and/or education systems believe that indigenous students are lacking by not matching their expectations of what should occur. A more appropriate approach is to use the mathematical strengths that students come to school with as the starting points for mathematical programs.

However, there is no one solution for every indigenous community. The variety of needs and aspirations with which a mathematical education needs to assist means that every community must decide what best suits itself. As Buckley (1996, p. 13) stated ‘It is not so much what curriculum is taught but who is making the decisions and for what reasons the decisions are made’. Without community input into the educational decision making process it is unlikely that cultural clash can be turned into an educational symbiosis.

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