Tikanga Reo Tātai: Issues in the Development of a Māori Mathematics Register

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Over the last twenty years, New Zealand has provided a crucible for indigenous language instruction in mathematics. There has been deliberate vocabulary and syntax development, curriculum construction and text writing occurring over a relatively short period. All three authors of this article have been closely involved: as mathematics teachers, as resource writers, as curriculum developers and as observers of and commentators (albeit subjective) on an exciting linguistic process.

Although every cultural context is different, an examination of this situation can be instructive for others contemplating indigenous language instruction, as well as for those interested in the relationship between mathematics and language. This article details some of the background, influences and consequences of a self-conscious mathematics discourse production. It examines effects on the language itself, and asks questions about the effects on mathematics and on mathematics education.

In particular, we argue that both language and mathematics are caught between opposing forces: the risk of becoming fossilised on the one hand and the danger of being corrupted on the other.

1. Introduction

Should mathematics be taught in indigenous languages? This question is not a great issue for indigenous speakers of languages like English, French, Russian or Mandarin, for whom mathematics and its applications can be discussed at the highest levels. However, for small indigenous groups, this is a critical question.

Among such groups, the question has been answered in many different ways, from an extreme of first language only at all levels (e.g. Hebrew in Israel) to that of world language use from the start of formal mathematics education (e.g. French in New Caledonia or English in the Solomon Islands): in between co-exist many different recommended ages at which the transition from first language to a major world language should take place. Arguments for and against these positions have been advanced based on a range of grounds: theories of learning; availability of texts, resources or qualified teachers; political imperatives; parental preferences; language learning criteria. In New Zealand, for example, arguments based on all of these grounds have been used at one time or another in the history of Māori education - and most of them have been used to argue both for and against more indigenous language instruction.

The debate is particularly strong among indigenous groups emerging from a colonial past and/or during a cultural renaissance: language is a carrier of culture, and without it such a renaissance is difficult. However, the context of each group is different. Thus, for example, on the one hand, Zulu education in the new South Africa is promoting English as an early language of instruction, because enforced use of Zulu alone as the language of instruction was a weapon of apartheid (see Setati, 1998 - this issue). On the other hand, Māori educationists in New Zealand are advocating the use of Māori throughout the school system, partly because the use of English as the language of instruction was a means of colonial assimilation of Māori into European culture.

It is therefore not easy to generalise one group's experience to any other group. Their experience is not likely to be repeated, nor are the mathematics learning consequences likely to be the same. However, it is useful to have accounts of what has happened in particular instances: the effects on the first language, on first language use, on mathematics, on mathematics learning, and on children's attitudes to mathematics and to their language. Such accounts may warn of potential pitfalls and alert us to unexpected possible benefits.

There is a further gain to be had in examining the effects of language of instruction in mathematics education. Through these crucibles of interaction between mathematics and language, it may be possible to obtain information about the fundamental nature of mathematics itself. If different languages force change on mathematics as well as *vice versa*, then this is good evidence for the dependence of mathematical thought on the language in which it is expressed.

This article describes some aspects of the movement over the last twenty years towards Māori language instruction in mathematics at increasingly higher levels. The significant feature is that this was a conscious, short-term process. Thus, the article documents in detail an example of what can happen - and explores some consequences for both mathematics and language.

It took fifteen years for Māori mathematics vocabulary to change from intermittent informal use in primary classrooms to its use in curriculum documents up to the end of secondary school. This article is one of a number which have been written to record the processes and effects of this development. Others can be found in Barton and Fairhall (1995), CSMTER (1990, 1993, 1995) and Te Puni Kōkiri (1993).

The second section briefly outlines the context for Māori language development in mathematics, and tries to identify some of the reasons why it has happened. The next section describes the processes used in the vocabulary development The fourth and largest section identifies some of the linguistic and mathematical characteristics of the new Māori mathematics discourse, examining linguistic issues which have arisen and highlighting those processes which are distinctively Māori and those which have had an effect on contemporary Māori language. Section 5 offers a first look at the effects of such language development (and instruction in a 'new' language) on mathematics itself, and on the learning of mathematics

2. The context for Māori mathematics

The Māori people colonised New Zealand/Aotearoa about 1000 years ago, developing an agricultural/fishing society which was Polynesian in tradition and language. Many of these traditions contained mathematical elements (Riini and Riini, 1993) and formal educational institutions existed (Best, 1923).

European colonisation began in the early 1800s, initially under a treaty between Māori and the British, but increasingly under a European colonial parliament This colonisation involved British-style missionary and state education including imported curricula. The missionaries turned Māori into a written language using the Roman alphabet, and literacy became widespread amongst the Māori people. For about 30 years, Māori language was commonly a medium of instruction in schools.

In the 1860s, a period of Land Wars alienated much of the country from Māori and the legislated destruction of parts of Māori culture began. The Māori population declined from over 200,000 to less than 50,000 by 1920, and assimilation policies were widely practiced. These included banning of Māori traditional *tohunga* (knowledge experts) and banning Māori language in schools Although the Māori population eventually recovered, the language and traditional knowledge continued to decline.

In the 1970s, an increasingly political Māori renaissance became visible. It centred on reaffirming the founding Treaty of Waitangi which guaranteed Māori sovereignty, Māori culture, land ownership, Māori language and developing Māori education These elements continue to be intertwined in contemporary initiatives.

In particular, Māori/English bilingual and Māori language immersion education grew from two bilingual primary schools in 1976 to fifty-four *Kura Kaupapa Māori* (Māori-based immersion schools) at the start of 1997. Five of these are secondary schools. These schools had developed out of community frustration at the inability of state schools to provide immersion education for young children whose first language was Māori. The right of parents to decide the language of instruction was strongly felt, although it was not legitimised in law until the 1980s when Māori became the second official language of New Zealand. There are now nearly 100 students who have had Māori-only language instruction in all subjects (including mathematics) up to the end of secondary schooling.

By the mid-1980s, development of an explicit Māori mathematics vocabulary had started through groups of teachers of bilingual classes (Barton, Fairhall and Trinick, 1995a). Two rounds of meetings (in 1990 and 1995) all over New Zealand took place at which possible mathematical terms were explored with teachers, language experts and mathematicians The Māori Language Commission became involved and two Māori mathematics dictionaries for schools have been produced (Māori Language Commission, 1991 and 1996). In 1994, a complete school curriculum in Māori for Māori was produced in parallel to - but not as a translation of - a new mainstream document (Ministry of Education, 1994; Trinick, 1997).

The particular context of Māori in New Zealand with respect to language is that school instruction in Māori does not imply children are denied access to English English is the predominant language in the media, in shops and at recreational facilities. Māori children - like all New Zealand children - live in an international youth culture and are fluent users of the English language The community-led impetus for Māori language instruction comes from a desire to increase contact with the Māori language, not to avoid English This is not just a matter of a child's education: it is seen as a necessary step if the Māori language is to survive at all in this country where Māori are in a minority (roughly 15% of the population) Early research into secondary bilingual classes (and subsequent research into Māori-based schools) found that the positive desire for the Māori language was, for some parents, more important than effective mathematics learning (Ohia, Moloney and Knight, 1989; Aspin, 1995).

These motivations gave rise to an interest in linguistic reasons for Māori language mathematics education by those arguing for such a development Theories such as those of Krashen (1982) suggested that language was acquired through exposure to comprehensible input This supported immersion instruction in each school subject without regard to the effect on the learning of that subject. However, later, the focus returned to mathematics education, and the questions debated concerned 'how best to deliver mathematics in Māori' rather than 'how best to establish the Māori language through education' Attention turned to Cummins' (1986) idea of the need for threshold language levels before bilingual benefits became apparent, and the work of Spolsky (1986) specifying conditions under which second language learning can take place.

3. Processes of vocabulary development

Processes of vocabulary development in mathematics have been described in general terms by Halliday (1975): much of the Māori development fits his categories. Transliteration was the most common method of vocabulary development in the nineteenth century, and Māori texts of the time contained more transliterated vocabulary than anything else (Taratoa, 1858). The content of these texts was identical to that of the English mathematics texts of the day, but the syntax was a mixture of classic Māori and English structures

The bilingual education movement of the early 1980s created an urgent need for classroom vocabulary. The result was an *ad hoc* coining of words using whatever

means were at hand: for example, transliteration (e.g. *wāriu* for 'value'), circumlocution (e.g. *whakarara ripeka* - meaning "parallel crosses" - for 'grid') or the translation of the English term in its everyday meaning rather than in its mathematical one (e.g. *whakarau* for 'multiply', which is a translation of the procreation meaning, as in "go forth and multiply"). This reached extreme forms with, for example, the translation of the term 'axes' by *toki* (which are chopping instruments).

From the mid-1980s, teacher meetings were being held with the express aim of developing mathematics vocabulary other than by means of transliterations. Vocabulary continued to be initiated within bilingual mathematics classrooms, and the meetings (which included mathematicians) became collection points for such language where decisions were made, whence the vocabulary returned to the classroom as the ultimate testing ground.

When the vocabulary developed by communities in several places was brought together for standardisation by the Māori Language Commission in 1990, the Commission noted several general principles which it adopted in making vocabulary decisions. They were (Māori Language Commission, 1991, p. 5):

1. The terms should be consistent with each other.
2. The terms should be as short as possible without oversimplification.
3. The word should sound correct to a native speaker of Māori, both in itself and in context.
4. The usage should be grammatically correct.

These principles were clearly different from the way in which early writers went about translating mathematical texts and from what was happening within the bilingual primary school communities at the time. But the Māori Language Commission principles did reflect the self-conscious attitude of the process being used within secondary mathematics development. (For further discussion, see Harlow, 1993.)

As the development continued, the processes became more conscious and more diverse. Some of the explicit linguistic techniques and existing linguistic forms were used to construct the new meanings required in mathematics. Examples include the following.

(a) *Gerunding*: The gerund ending *-nga* which transforms verbs into nouns was used for terms such as *hurihanga* - 'rotation' (gerund of *huri* - "to turn"), *ahunga* - 'bearing' (gerund of *ahu* - "to move in a certain direction").

(b) *Particles*: The manipulative particles *ki, e* and *mā* were used for grammatical constructions of mathematical operations, e.g. *wehewehia te waru ki te whā* - "divide eight by four" (*ki* indicates the instrument or agent of the division).

(c) *Re-duplication*: The repetition of a syllable is a common Māori construction to change the meaning of a word by emphasising one aspect. This was adopted in mathematics to change *raupapa* ('order') into *raraupapa* ("repeated order", i.e. 'sequence').

(d) *The prefix 'whaka'-*: This common causative prefix has been adapted to create mathematical terms such as *whakarea* - 'to multiply' ("to make many"), *tau whakarahi* - 'scale factor' ("the number which makes the size").

(e) *Other prefixes*: Other distinctively Māori prefixes, e.g. *tō-* a prefix indicating placement, used in *tōrunga* ("placed above") for 'positive integer'. Another example is *pū-* a prefix with two meanings. The first is a sense of centrality which gave *pūrahi*: that is, *pū-* applied to the word for largeness to give 'centre of enlargement'. The second indicates doubling, and was adopted to indicate powers: *pūrua* ("two doubled") for 'squared'.

(f) *Adverbs*: A particular example involved the attempted use of the adverbs *ake* and *iho* (which mean "upwards" and "downwards" respectively) to indicate positive and negative numbers. This attempt failed when the transformation of these adverbs into adjectives was found to have moved into playground conversation. The corruption prompted the Māori Language Commission immediately to discourage this usage in the mathematics classroom.

Where an exact translation was not available, old words, ones which had fallen out of general use, were resurrected with slightly altered meanings. Examples include:

(a) *hōkai*: an early choice for 'diagonal' derived from its meaning of "a brace or stay", like the crossed diagonal braces used to keep an eel-pot open;
(b) *ine*: a word meaning "to compare" or "to measure" was resurrected to give the mathematical meaning of 'measure';
(c) *tatau*: an old word meaning "to count".

Metaphors were a common method of vocabulary development in both formal and informal settings. Early development meetings employed a conscious process of mathematics teachers discussing the meaning of a particular term while Māori speakers listened and suggested words carrying that meaning as a metaphor. An example was the development of *rere* and *arawhata* as early translations of 'continuous' and 'discrete' as applied to statistical data, the metaphor being that of a flowing stream or one proceeding in a sequence of waterfalls.

In the classroom, students often made suggestions based on the images these mathematical terms created for them. An example is the use of *waewae kuri* ("dog's leg") or *tuna* ("eel") to refer to the graph of a cubic curve, and *mangopare* ("hammerhead shark") for the hyperbolic curve. Some of these words have since become established terminology - probably only possible because of the small numbers of people involved in teaching mathematics in Māori at that time.

Another technique was making up totally new words (Barton, Fairhall and Trinick, 1995b). The prime example of a made-up word is *pāngarau* to mean "mathematics" itself. This word arose in a meeting at which the overall meaning of mathematics was discussed and the idea of relationships became crucial. *Pā* is a participle with the sense of "concerning" or "having to do with". This was transformed using the gerund into a noun *pānga* with the mathematical meaning of "relation(ship)", and pluralised with the suffix *-rau* meaning "many". Mathematics was then translated as *tikanga pāngarau* ("conventions of many relationships").

Another example is the original word for 'calculus', which was made up from the last syllables of the two words *pāronaki* ('differentiation') and *pāwhaitua* ('integration') to give *tuanaki*. It was only subsequently that it was discovered that this word was a legitimate Māori word with the meaning "to move with an even motion"!

When difficulty arose in finding a term for a whole mathematical concept, one strategy was to find a term which would successfully translate part of it. For example, *tango* meaning "to subtract" translates the idea of 'taking away' but not the full technical meaning of subtraction.

Early in the development process, it was realised that vocabulary development had to be systematic, that words for related terms needed to show that relationship. As well as building on existing terms, a genealogy of mathematical terms was constructed in English and used to expose the relationships between terms. These were often the basis for terminology construction.

The most important base word was 'number'. The term to be used for 'number' had to be chosen so that it would combine naturally with prefixes and adjectives to form many other words. When this was done successfully, a large number of other terms 'invented themselves'. *Tau* ('number') generated, for example, *tau pūmau* ("established number", hence 'constant'), *taurea* ("multiplying number", hence 'multiple'), and *tauhanga* ("constructing numbers", hence 'arithmetic').

4. Māori mathematics language

Discourse characteristics

As a result of the vocabulary and grammatical development, a new discourse has emerged - a Māori mathematical discourse. There are several distinct characteristics of this discourse, some of which reflect mathematical discourse in general (Halliday, 1975; Pimm, 1987; Dale and Cuevas, 1987). For example, it is conceptually dense, multi-directional and jargon-filled. However, other characteristics are peculiar to Māori mathematical writing and may be attributed to vocabulary and grammatical development processes. Each of the following characteristics is a source of tension in the interplay between the languages.

The use of the passive mood is more common in Māori than in English, and this is reflected in the mathematical discourse - even allowing for the increased use of the passive as a means of objectivising in English mathematical discourse (Laborde *et al*, 1990). However, the passive form has also led to a corruption of the language. In traditional Māori, the adverb and the manner participles had to agree with the main verb - this was achieved by using a similar ending to that on the verb. New speakers of Māori (who include most of those involved in mathematics education) often omit this construction through ignorance. Manner participle corruption is occurring in all subjects, not just in mathematics.

Laborde *et al.* (1990) also note a tendency to nominalise in general mathematical discourse. However, gerunding - the creation of nouns from other parts of speech - is a traditional Māori language construction. It has been used in the vocabulary developments as noted above, but there appears to be a greater use in mathematics discourse than elsewhere. For example, there has been the creation of more than one gerund of the same word: *āhua* ('shape') is commonly gerunded into *āhuatanga* ('form'). But in mathematics it is also gerunded into *āhuahanga* ('geometry'), using a suffix form not previously associated with *āhua* in order to avoid confusion, but also as a play on words (*hanga* as a verb means "to build"). An example of unnecessary gerunding is the use of *huinga* (gerund of *hui* - 'a meeting') for the mathematical term 'set'. It is unnecessary, because *hui* is already a noun, and could have been adopted directly with a specialist meaning in mathematical discourse.

The 'over-creation' of nouns in Māori mathematical language provides an example of how the English language has dominated the mathematical concept. Traditional Māori language would often use verb phrases for an English noun. In an effort to translate the nominalised English mathematical terms, the English noun form is also translated instead of the mathematical idea alone. An example is the long debate over the term 'discount'. In Māori, the natural way to refer to a discount is to use a verbal phrase, thus every attempt to create a noun equivalent broke the third criterion of the Māori Language Commission (see above).

Another Māori characteristic is differentiated vowel-length: long (indicated by a macron - a line above a vowel - or double vowel) or short. It has been a general trend in modern texts of all kinds to omit the long vowel indicator, and, for new speakers of Māori, to be careless over its use. However, in technical vocabulary like mathematics, there is an increased need to indicate vowel length in order to get the most meaning out of the term. For example, the word for 'mathematics' is *pāngarau*, not *pangarau*. The former is clearly identified with "relationships", the latter means "many guesses". One carries the meaning of mathematics as well as its name - the other misleads.

As in English, mathematical discourse includes words with a specialised technical meaning which is different from their everyday meaning. 'Range', 'integration', 'identity' are three examples in English. However, some of the Māori terminology of this kind has derived from translations of the common meaning of English words, adding another level of complication. This is known as *calquing* (Halliday, 1975).

For example:

- *mahere* means "to plan to do something": in mathematics, it means "plan", as in planar view;
- *uara* means "to value" or "to prize something", or "values" as in moral values: in mathematics, it means "value of a number";
- *whakarau* means "to multiply" in the procreative sense: in mathematics, it means "multiplication".

It is necessary in mathematics to have words with very specific meanings. The creation of a Māori lexicon provided an opportunity to have terminology which was self-explanatory rather than obtuse. Examples are:

- *pāheko takirua* - "an operation by twos", hence 'binary operation';
- *rārangi weherua* - "a line which divides into two", hence 'bisector';
- *tapamaha rite* - "many equal sides", hence 'regular polygon';
- *tau whakahau kore* - "a number which cannot be made into a fraction", hence 'irrational number'.

An extension of this idea was the re-generation of terminology from its original source. Thus, 'sine', which originally derived from the Arabic word meaning "chord", is translated in Māori by a word with this meaning. The tension in this feature is between creating new terminology and adopting universal terminology: 'sine' is an accepted mathematical term in all major international languages, not just in English, and the form 'sin' is used universally on calculator buttons.

Effects of mathematical discourse on language

Although Māori mathematics vocabulary development has been consciously in progress for over ten years, only now are some consequences and effects being noticed.

The grammatical structure of a language reflects its ethos, and cognitive development must be linked with this ethos and the world-view created by the language: see Christie (1995) and Roberts (1998 - this issue) in relation to Aboriginal languages. The creation of Māori mathematical discourse has moved the language towards English modes and conventions. This can be seen as having some insidious implications for new and young speakers of Māori: there is a fine line between linguistic evolution and interference of another language. True bilinguals have two conceptual pathways available - there is a danger that new Māori speakers will still only have one.

Particular corruptions to the language evident in Māori mathematical discourse (and often elsewhere) include:

- an inability to handle the passive successfully;
- insistence on word-for-word equivalence to the detriment of structural convention;
- incorporation of grammatical changes used in specialised mathematical terminology into general everyday discourse;
- grammatical corruptions specific to mathematics discourse, e.g. in Māori, the word 'graph' is translated separately both by a noun *kauwhata* and by a verb *tuhia*. However, students use the noun as a verb: *kauwhatatia he pānga* ('graph a function')

But further corruption arises from the fact that mathematics discourse is totally translated from English: none of school mathematics arises from within Māori itself. This has led to, for example:

- an inability to recognise English idiom, or, perhaps, too great a readiness to translate idiom rather than meaning;
- an unwillingness, or inability, to utilise those aspects of Māori language which permit the expression of ideas which cannot be expressed in English.

An example of the latter in the quantitative domain is that Māori distinguishes between counting things and counting people - this gets ignored in mathematics even when the context is appropriate for its use, such as in arithmetic word problems. Another example is that Māori has several words for 'large': *tini, maha, nui, rahi*. All of these can be numerical, but *maha* and *tini* are solely numerical, whereas the others can be used for size also. Furthermore, *maha* is the most neutral, in that it can be used to ask 'how many?' when only a few are involved. Yet all these terms have become interchangeable.

The push for syntactical equivalence has led to an unnecessary twisting of the language. For example, the term for 'data' is *raraunga,* a noun form of the adjectival word *rarau*. But the correct use would be *rarau kōrero*: however, this was thought by some to be too long for such a key word.

Recent work in this area involves taking another look at the role of passives, agents and particles in traditional Māori discourse. The suspicion is that their distinctive uses are not properly utilised in modern Māori mathematical discourse, despite this being the subject which most needs the preciseness of expression which they offer.

A more fundamental example has only recently emerged. In everyday English discourse, numbers are used grammatically like adjectives: three chairs, six books, etc. Learning to think mathematically involves learning to use numbers as nouns, as things-in-themselves. There is some evidence that, in traditional spoken Māori, numbers are used grammatically as verbs. This is difficult to explain in English, but it is as if, when requesting three books to be put on the table, one would say "three-ify the books on the table". The depth and consequences of this difference are under present investigation.

The overall effect of these forces on the language is beginning to concern Māori educators. The rush to produce appropriate resources for immersion classes may do more damage to the Māori language than anticipated. If thought and language are interdependent, then more than English words are being translated: the thought patterns that English allows and encourages are also being adopted. The language changes, not the curriculum, in this process.

An unexamined idea is that Māori language is further affected by the ethos of mathematics. It is now accepted that mathematics carries particular values (Bishop, 1990). 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 Māori language, and subsequently in Māori culture? It is almost certainly too early to tell, and it 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 thence into everyday language.

Today's educators are trying to establish long-term goals for the new linguistic generation of children. If it is desired to have a truly Māori mathematics curriculum, it will be necessary to look hard at the Māori language and see which thought patterns it allows and encourages, and then use them in mathematical discourse.

5. Effects on mathematics and mathematics education

The idea that mathematics might change in the process of developing discourse in another language is not widely discussed. What follows are some ideas suggested by the experiences of the authors during the last fifteen years.

Effects on mathematics

The conscious development of vocabulary, and in particular the use of a 'genealogy of terms' in order to develop terminology which is ordered and reflective of relationships between concepts, has the danger that it may fix meanings more than necessary. Mathematics grows through changing

concepts as much as through creating new ones. If the terminology ties the concept, then a view of mathematics as absolute may be reinforced at a time when its relativity is just being recognised.

Another effect which will make mathematics different for speakers of different languages is that many mathematical concepts are multi-factored: there are several possible aspects to their meaning. Terminology, especially if it is metaphoric, tends to emphasise one aspect over another. Hence, speakers of a particular language may 'see' mathematical ideas in different ways.

Furthermore, the syntax of the language may emphasise different aspects. For example, in Māori the possessives have more status within the language: there are two categories of possessive indicating inferiority or superiority of the possessed object with respect to the possessor. It is not possible to avoid this distinction (cf. gendered constructions in French). What effect does emphasising possessor/possessed relationships have on mathematics?

Another example is passivisation. This is a common linguistic construction in all Māori, but in English it is much more common in mathematical discourse than elsewhere, where it has the function of objectivising. Does it carry the same 'weight' in Māori mathematics discourse?

The rise of a mathematics curriculum in Māori for Māori raises the idea of Māori mathematics. Is there such a thing? Without going into the considerable literature on ethnomathematics, the effect of the literature on mathematics and culture has been to push out the boundaries of the definition of 'mathematics' to include some culturally-based activities or concepts which were not previously regarded as part of the subject. The more mathematics becomes 'owned' by children of Māori (and other indigenous) culture(s), the more these boundaries will be tested.

Effects on mathematics education

Some of the benefits to mathematics education are explicit: for example, the construction of more meaningful terminology. There are, furthermore, assumed to be fluency and motivational benefits for those students for whom Māori is their first language or who identify strongly with Māori culture.

In addition to these explicit effects, there is the bilingual benefit of having two modes of thought available (Cummins, 1986). In those classrooms where two languages are used, there are benefits from forced re-phrasing (Lopez-Real, 1997) and code-switching (Adler, 1998 - this issue).

As part of the process of establishing instruction in Māori, concentration has centred on these and other positive benefits. However, there are possible negative aspects which need further research. Explicit classroom difficulties might arise from, for example, specialist terminology being linked to inappropriate English words resulting in misconceptualisation. It may be the case that motivation works in reverse for children who, rightly or wrongly, feel isolated by indigenous language instruction.

A further danger which has been observed in New Zealand is the promotion of a false idea of culturally appropriate 'Māori learning'. In the search for a cultural identity, it sometimes happens that old ways are mistakenly adopted. Apprenticeship learning, rote learning and algorithmic teaching have all been suggested as culturally appropriate for Māori. However, they may simply be based on memories of how people did things in early colonial days, and thus be a reproduction of traditional colonial teaching methods, rather than truly traditional Māori modes. In any event, the removal of any tradition from its total cultural context into a contemporary mathematics classroom is unlikely to be effective.

Finally, a further feature which has been noted is the emphasis on vocabulary learning in the mathematics classroom. Particularly in the early days of bilingual mathematics classes, there was considerable time spent on vocabulary learning. Does this have a positive or negative effect on mathematics learning? Under what conditions will one or the other occur?

6. Conclusion

One aspect of this description of the conscious development of a mathematics discourse in an indigenous language is the diversity and creativity of means available for language generation. It highlights both the complexity and the multiple directions of language evolution. However, the theme of this article should be seen as a balancing of the Māori language between fossilisation and corruption.

On the one hand, Māori is in danger of being fossilised if it cannot adapt to the requirements of the modern world. In order to survive, it must function as a living language, one used in all situations, growing and changing. If it is assumed, for example, that mathematics is at odds with the existing state of the language or culture, and that therefore mathematics must be taught in English, then Māori will be fixed in a past from which it will not escape. The past fifteen years have demonstrated clearly that Māori can develop, that it can grapple with mathematical concepts. Māori has been shown to be living and capable of abstract technical expression.

On the other hand, the use of Māori to express areas of knowledge which have had a long development in English and its precursors has had a corrupting effect on Māori linguistic expression. The danger is that this will not only change the language, but will also alter distinctive Māori thought patterns and conceptual pathways.

Is it possible to balance these competing tendencies, and to develop mathematics in a Māori way? The authors of this article believe that it is possible, but that this involves an openness to changes in mathematics itself, and a high-level of linguistic awareness, i.e. a sophisticated understanding of mathematics and its symbolism, and how this relates to the English and Māori registers.

It is an intriguing thought that mathematics, as well as Māori language, may be caught between similar poles. Internationally, mathematics is being communicated and conducted increasingly in the English language. Is it being fossilised into modes only expressible in that language? Are new avenues of mathematical thought being cut off by not doing mathematics in new languages? Is it possible that a new generation of mathematicians, brought up through an indigenous language, may be some of the most creative mathematical thinkers of the next century?

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