Cultural issues that challenge traditional science teaching

Paper presented at the Third Annual New Zealand Science Education Symposium, Massey University, Wellington; Friday 22 and Saturday 23 November 2002

Pauline Waiti and Rosemary Hipkins
New Zealand Council for Educational Research

Abstract

Maori and Pasifika students are over represented amongst students who are underachieving in school science. New Zealand's science curriculum aims to be inclusive of these students and to that end suggests contexts for learning that take account of different types of life experiences. While equity is intended, such approaches may stereotype students, appropriate their cultural backgrounds, and alienate them from experiences of school science learning that could encourage their subsequent participation in science-related careers and/or democratic debates. The conscious juxtaposition of Western science with other cultural views of the natural world has been suggested as one type of response to this complex set of issues. As science educators we face the challenge of debating how best to do this if we really do value learning about the nature of science as a curriculum aim. This paper outlines three models for aligning Western science with other knowledge systems and promotes the view that dialogue about the issues raised is a necessary first step to achieving any change in relevant classroom practice.

Introduction

> If we are to have social cohesion and a more knowledge-based society, we must enable Maori children to participate in science, for the diversity they can bring and the contribution they can make (McKinley 2000, p. 39).
>
> Maori people do not want to live in the past…. The Maori race are a vital, living group of people who want a future, who want to live in the future, who want the best education available to them about the world around them – this provides a challenge for educators to get beyond indigenizing Maori education (McPherson Waiti 1990, pp.185-186).

Recent research on New Zealand students' achievement in science in 'mainstream' New Zealand classrooms carries clear challenges for science teachers. Three different research projects, both international and national, point to a systematic picture of underachievement in science for Maori and Pasifika students in New Zealand schools. At the same time there is growing awareness of the need to take account of diverse cultural views and community concerns about the products of science, especially 'cutting edge' biological and biotechnology research. This points to the need for greater participation of those from other cultures in science, as scientists and as actively involved citizens in the community.

The underachievement of many Maori and Pasifika students is not the only issue at stake in this context. New Zealand's future scientists will come from the ranks of our current school students, including those Maori and Pasifika students who are already achieving well in science. In various research contexts, New Zealand's scientists have recently faced Maori challenges to their thinking about science. Examples include issues of *whakapapa* in the context of genetic engineering (Mead 1997) and indigenous approaches to sustainable management when managing for biodiversity (Millner & Sciascia 1997). For all these future scientists, regardless of their cultural background, an understanding of Maori cultural values will almost certainly be necessary for their future professional lives.

Another development is also relevant to the concerns addressed in this paper. Around the world, indigenous peoples are struggling to assert their unique identity within their nation's social systems, including the education system. Such political initiatives inevitably carry profound epistemological challenges for 'establishment' practices and ways of thinking. For example, the Alaskan indigenous community is making a concerted effort to establish closer links between traditional Western science and the local knowledge that has been built up over centuries of intense observation of natural phenomena to help ensure survival in the harsh Arctic climate. As one of those involved in this innovation points out:

> …Though diminished and often in the background, much of the native knowledge systems, ways of knowing and world views remain intact and in practice, and there is a growing appreciation of the contributions that indigenous knowledge can make to our contemporary understanding in areas such as medicine, resource management, meteorology, biology, and in basic human behaviour and educational practices (Barnhardt & Kawagley 1998).

Raising achievement for students of other than 'white Western' cultures is likely to be just one benefit of the types of changes in teaching that are discussed in this paper. Arguably *all* New Zealand students need to be exposed to at least some learning of this type. However there are issues of power and ownership to be explored before that could happen. And there are professional development issues. A specific focus of this article is the ways in which teachers' 'nature of science' (NOS) understandings are implicated in the types of reforms that have been advocated for ensuring that cultural perspectives of science are taught and learned in our increasingly bi-cultural and multi-cultural classrooms.

What research tells us about Maori students' achievement in science

There is, as yet, very little research to explain exactly *how* Maori students' experiences in school are impacting on their achievement in science (McKinley 2000). But we do know that all is not well. Results from the Third International Mathematics and Science Study (TIMSS) tell us that in 1994/95 the best scores for Maori students in Year 5 matched that of the Pakeha/European and Asian groupings - but more than three-quarters of the Maori students scored below the means for these other groups. Furthermore, a slightly higher proportion of Maori students rated themselves as less positive about science learning than students in other ethnic groups (Garden 1997). This pattern did not change in the repeat round of TIMSS testing in 1998/99. Maori and Pasifika students' science achievement patterns remained skewed towards under-achievement, and the top achieving students did not score as highly as the top achieving European and Asian students (Chamberlain & Walker 2001). Similar patterns of underachievement by Maori and Pasifika students have recently been reported in the first round of PISA data – while our best students were amongst the best internationally, students in these two groups had average scores lower than the international mean (Sturrock & May 2002).

There have now been two rounds of science testing in the National Education Monitoring Project (NEMP). Unlike the 'pencil and paper' focus of most TIMSS testing, the NEMP assessment framework for science has a central organising theme, *Science in everyday contexts*, and many of the tasks are oral or practical. Within this different framework the NEMP results do indicate an improvement in performance for Maori students across the two testing cycles. In 1995 Maori students performed less well than non-Maori students in 61% of the tasks at the year 4 level and 57.6% of the tasks at year 8 level. By 1999 this had dropped to 12% at Year 4 and 44 % at Year 8 (Flockton & Crooks 2000). This increase in achievement on more than half of the NEMP tasks is of some significance. There has not been a similar increase by students in low decile schools, so it does appear to represent a cultural rather than an economic effect. But the improvement is not yet understood, nor have Maori students caught up fully with the achievement of other groups.

Interestingly, a comparison of Maori students in general education with those in immersion settings revealed a much higher proportion of immersion students who were very positive about how good they thought they were at science and about their suitability to be good scientists when they grew up. These students also reported that their school programmes included higher levels of field trips, visits to science activities, and experiences with everyday things. It is not yet clear whether these positive attitudes will be matched by corresponding learning gains for students in kaupapa Maori education. Practical difficulties that were encountered in the first round of testing in te reo Maori have made the early findings open to debate (Flockton & Crooks 2000). The *theoretical* research literature suggests that learning science within a Maori worldview framework could be the factor that makes the difference (Cobern 1996) but this remains to be researched in New Zealand schools.

Ways of viewing 'the problem'

Up until the 1970s, systematic underachievement by any particular group would almost certainly have been interpreted within a 'cultural deficit' framework (McKinley 2000). In this view, the underachieving students would be seen as lacking something – ability, motivation, and/or help at home might all have been held to account. In recent years, a shift of our understanding to accommodate socio-cultural views of school and of learning has moved the focus to include factors such as how students of different groups actually experience their school learning (Rogoff 1990). At the same time, developments in cultural psychology have demonstrated a role for local culture in framing views of the world whose implicit assumptions may be at odds with those of the dominant, more global, knowledge culture (Cole 1996). Within this wider framework, the manner in which culturally-different groups and individuals interact and relate to each other has become an important question to be addressed (Bishop & Glynn 1999; McKinley 2000).

These shifts in understanding about where 'the problem' lies have important implications for teachers' work. But exactly how more traditional ways of teaching should be changed is far from clear. One type of response has been to assume that all Maori students prefer to work in co-operative groups. This has been criticised as an oversimplification – Maori students are as diverse in their learning preferences as any other big group, and in any case all students need to learn to work in a range of different settings (Hill & Hawk 2000; McKinley 2000).

Another type of response has been to suggest that 'discovery learning', often used in science, disadvantages Maori students and should not be used when teaching them. Bishop (1999) points out that when the teacher uses an inductive 'discovery' questioning style the students are always working in the unknown and the teachers in the known. He suggests that this can widen the already existing discrepancies in power relationships between Maori students and their teachers. (Discovery learning is also critiqued by science educators on the grounds that it gives very misleading messages about the nature of science – see for example Hipkins (2002) and Hodson (1988; Hodson 1998). But that is another story!)

Is teaching science in context an adequate solution?

Science in the New Zealand Curriculum (*SNZC*) emphasises the importance of helping *all* students achieve in their science learning. The use of everyday contexts of relevance for students' lives is modeled as one way that teachers could help to ensure success for all students. This 'solution' is not, however, quite as simple as it may seem.

In the first place, many teachers do not appear to have the relevant knowledge and/or resources to address this feature of the curriculum – at least in terms of raising achievement for diverse groups of students. In her survey of issues related to the implementation of *SNZC*, Baker (1999) reported high levels of "don't know" responses when teachers were asked about the support that *SNZC* learning and assessment activities provided for Maori students (25 percent responded this way) and Pacific students (50 percent responded this way). Even if the link is made between teaching in context and 'science for all', there are some tricky teaching and learning issues to resolve. Some teachers may not feel comfortable about using this strategy, especially if they are well practiced at traditional teaching that emphasises science 'facts'. At the other extreme, the science itself could get 'lost' in teaching that places more emphasis on the context (Hipkins & Arcus 1997).

Yet another issue is that there is no one way to 'be Maori' – or any other ethnic group for that matter. Ethnicity is usually a self-identification that will be experienced differently in different contexts. Self-identifying Maori students show wide variations in their physical attributes (which may or may not lead to their recognition as being Maori by teachers and other students) and in the strength of their tribal affiliations/cultural experiences of 'being Maori' (McKinley & Devine 2001). Some students may be no more familiar with 'te hangi' as a context for science learning than many of their peers of other ethnic groups (Hipkins, Joyce & Bull 2000). And those who are familiar with these contexts may feel patronized by their trivialized use as a pat solution to complex learning needs of all students: 'That's us – the Maoris are being put into a box, compartmentalized and put to one side again' (McPherson Waiti 1990, p.182).

A more subtle issue – one that is moving us nearer to the heart of the issues being discussed here - concerns the appropriation of the knowledge and customs of Maori culture to endorse the ideas of Western science. Two researchers recently investigated this question by critiquing the way in which indigenous contexts are portrayed in NZ textbooks. They found that Maori and other cultural groups are invariably photographed in contemporary classroom settings, which supports a "myth of consensus by all to the privileging of science knowledges and ways of knowing" (Ninnes & Burnett 2001, p. 30). The historical settings typically used also give the message that traditional knowledge belongs in the past – before 'superior' science knowledge was available. The researchers found some stereotyped 'messages' about Maori, who were depicted in the text books as always being environmentally sensitive users of resources, living in harmony with their surroundings, eager to use the technologies of the white settlers, and following one common religious practice. Linking Maori to issues with negative connotations, for example Maori smoking or poor housing conditions, suggested that these issues pervade all Maori and no other groups (Ninnes & Burnett 2001). These are clearly stereotypes – misguided, uncritical generalisations of the same type as the idea that 'all Maori like group work'. But the question of whether Maori ways of knowing should be appropriated to unquestioningly endorse Western science ways of knowing in school science learning calls for much more sophisticated analysis and debate.

If we do attempt to make more meaningful comparisons of Maori worldviews and Western science – for example through the use of traditional legends as a context for learning about geological processes – issues of authority and meaning come sharply into view. The issues are a mirror image of those already faced by teachers in the kura kaupapa schools when they teach Western science from within a Maori worldview:

> The use of the Maori language will, in itself, change the knowledge being taught. This is because exact word-for-word translations between Maori and English are not possible, and therefore the two languages cannot symbolise exactly the same scientific understandings (McKinley 2000, p. 35).

What are we trying to achieve by advocating the use of 'Maori contexts' for science teaching? Do we want students to learn the concepts of Western science as the 'one right way' to understand the natural world? In that case, Maori contexts are appropriated as 'props', assumed to motivate the interest of Maori students. Or do we wish all our students, including Maori, to learn that there are different cultural ways of looking at the world, each constructed as a coherent body of knowledge for social purposes relevant to the contexts of its creation? Critics of this view say it is relativist and can lead students to believe that 'anything goes' providing you can make a convincing argument - see for example Matthews (1995). We do not agree with this interpretation. It seems to us that the student who can clearly describe related concepts from the perspective of Western science and other worldviews is at a distinct advantage. Such a student could also to learn to judge when it is important to be rigorously scientific, and to differentiate these situations from those where wider frames of reference might be more useful. Those who work at the cutting edge of the 'science and society' movement would like to see all scientists able to make this important distinction (Irwin 2001; May 2002). In view of our national commitment to the principles of the Treaty of Waitangi, it would appear to be very important for the training of all our future scientists.

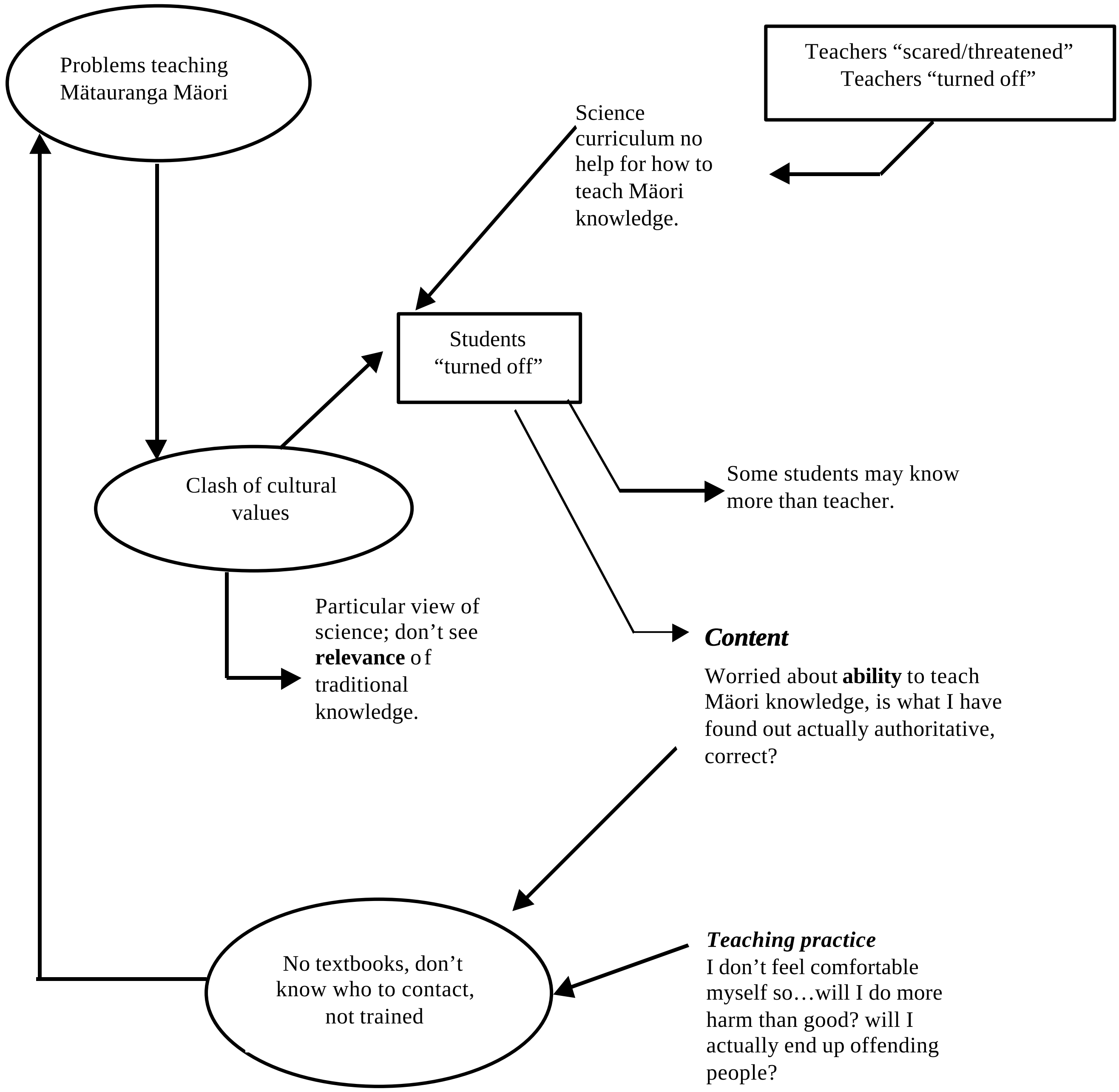
Facing up to 'nature of science' challenges

Meeting the teaching challenge sketched above would require teachers to take more account of cultural differences between the world-views of their Maori students and world-view(s) of science as a specific cultural process for knowledge building. They can only do this from a basis of clear and 'expert' NOS understandings. However a consistent finding of science education research internationally is that most teachers have 'naïve' NOS views that are not easy to change (see for example Gallagher 1991; Abd-El-Khalick & Lederman 2000a). Clearly differentiating between science and science *education* could be the starting point that frees teachers to rethink their curriculum purposes and their NOS philosophies. Since critical discussion of these differences is increasing (Gilbert 2001; Chinn & Malhotra 2002) this is one promising avenue for professional development.

Once teachers know how their students' world-views might differ from science world-view(s), they can begin to act as "anthropological guides"(Cobern & Aikenhead 1998), helping their students see these differences too. The term 'border crossings' has been used to describe this conscious movement from one way of framing knowledge to another (Aikenhead 1996). There are however, several very difficult sets of issues to be resolved before teachers could be expected to feel confident about doing this well.

First, 'border crossings' for students can only happen if teachers feel confident they can cross such borders themselves. For this to happen, a sound NOS understanding is a *necessary* first step, but it is unlikely to be a *sufficient* one (Lederman 1999; Abd-El-Khalick & Lederman 2000b). As Abd-El-Khalick and Lederman point out, teachers also need what they call 'NOS PCK' (pedagogical content knowledge). This requires them to be confident in their fund of stories, activities and ideas for exploring NOS in the classroom.

Improving NOS understandings is just one aspect of this challenge. Many New Zealand teachers will not feel confident that they have the necessary understandings of Maori culture and worldviews. Nor will many Maori want to see their knowledge co-opted (and in the process quite possibly misrepresented or trivialised) in this way. One Maori policy analyst summarised the challenges for mainstream teachers as set out on the flow chart that follows (Howe 1997):



Source: Howe (1997)

We also face a third type of hurdle. As Barnhardt and Kawagley (1998) point out ‘changing teachers is necessary, but not sufficient. Changing in the organizational culture of the school or district is also necessary’ (p. 4). The issue we have in mind is simultaneously philosophical, organisational, and curriculum related. Thus, at least initially, this seems to us to be one for the policy makers and tertiary science educators to debate. The three models described below have all been suggested as ways to relate Western science and indigenous knowledge to each other. All three have their advocates and critics. If we are serious about our intention to raise school science achievement and promote greater participation of adult Maori in science, we do need to debate the issues that these three models raise. Unless we explicitly address these ‘matters of epistemology’ (McKinley 2000) we cannot hope to find a consensus for reform.

Which way should we go now?

The following three models for interrelating science and indigenous knowledge were proposed and debated in a special issue of *Science Education* in January 2001. Key features of each have been summarised and then illustrated with variations on a scenario of our invention.

The cross-cultural perspective

Snively and Corsiglia (2001) argue that science in the school curriculum should be broadened to include traditional ecological knowledge (TEK). They acknowledge that TEK has some features that are ruled out of Western science – for example, spirituality. However, they believe that an accommodation between the best of Western science and the best of TEK can lead to more effective solutions for contemporary problems and so students should be encouraged to draw on both.

> *What this might look like in practice*
>
> Students could be undertaking an inquiry into a water pollution problem in their local area. From Western science they could learn about nutrient over-enrichment of water (eutrophication) and its effect on living things in the waterway. They would probably learn how to identify a variety of indicative species, and various ways of measuring aspects of water pollution. From the perspective of *Te Ao Maori* they could learn about *wairua* - the idea of water having a life force that should be treated with respect. They would merge this with their science understanding/ methods of inquiry to make an action plan for lobbying for solving the pollution problem.

Advantages of this model are that it frames knowledge in an holistic manner, as most of us do in our everyday lives. It widens frames of reference on which to draw when discussing socio-scientific issues, as advocated by many who work in 'science and society' policy settings (Irwin 2001). Knowledge from other cultural systems can be respected and valued. Disadvantages are that this strategy is open to relativist critique, and students are unlikely to increase their NOS understandings because the 'border crossings' are not clearly sign-posted.

The multicultural perspective

Stanley and Brickhouse (2001) argue for debates about NOS itself (which they term "gray areas") to be a focus of study. In this approach, the content known as TEK would serve as counterpoint for exploring and critiquing the cultural features of Western science. Students would learn that there are different ways to think about what science is and how it works. For these science educators, debate about the *contested nature of knowledge* is a key feature of a multicultural education. In the example that follows, students could learn that philosophers of Western science debate whether or not it is actually as value free as some scientists claim (Allchin 1998).

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critics say are missing from the Western science perspective. Students would be helped to identify which of the two world-views underpinned statements they might make as they worked towards a solution of the pollution problem.

In this case the border crossings are firmly in view. Science is emphasised as a distinctive cultural system. However the issue of appropriation of other cultural viewpoints to serve science learning ends, as has been argued by Ninnes and Burnett (2001)for textbook contexts, again raises its head.

The pluralist perspective
Cobern and Loving (2001) take the opposite view to Stanley and Brickhouse. They argue that it is critically important to help students learn about the features of science about which philosophers of science are in broad agreement. They define these features and call them collectively the "Standard Account" of Western science (pp. 57–61). They say that unless students can learn about these features they are left with no reliable basis from which to judge the validity of competing knowledge claims. We have already noted that this position is open to criticism as allowing an 'anything goes' view of science to emerge (Matthews 1995).

Cobern and Loving (2001) make a second point that science can be seen as the 'gatekeeper' to positions of power and prestige in Western society. They say that angling for the inclusion of traditional knowledges within what 'counts' as science simply accedes to the existing 'power game'. They would rather see other world-views and knowledges kept distinctly separate from science - taught and valued on their own knowledge-building terms (which makes an unapologetic space for inclusion of spirituality, for example).

What this might look like in practice

Students could be undertaking an inquiry into a water pollution problem in their local area. They would develop a detailed description of the evidence that suggests the water is indeed polluted, drawing on measurable aspects of Western science (perhaps turbidity, biological oxygen demand, indicative species, etc). They would also learn how what is to be measured is selected by reference to existing theory about the causes of water pollution. They would thus be explicitly taught about the manner in which science description and science theory interact in any process of inquiry. They would represent their learning through an agreed report format that explicitly modeled the manner in which science findings are shaped and reported for peer scrutiny.

In a separate class (perhaps "Cultural Studies"), or in another part of the lesson, they would learn about the way in which the *Te Ao Maori* perspective shows a deep valuing of the health of water. This might include learning *waiata* and *whatatauaki* that describe features of water with its *wairua* intact and its vital importance for the health of the environment. Students might use a narrative format to create a dramatic representation of their personal learning journey.

As a final integrating assignment they might be asked to compare and contrast the two knowledge systems to discuss the manner in which the "framing" of the concept of water pollution allows different but complementary issues/questions to be addressed.

This model potentially deals with the power issue by introducing knowledge systems on their own terms. In a discussion of the challenges inherent in schooling for more democratic societies whilst still valuing diversity, Schutz (2001) imagines schools as places that "encompass a wide range of different discursive spaces that are not equally open to all. A myriad of different teachers might teach in and advise in these different spaces, ensuing safety and 'rigor' within diversity" (p. 296). While the use of very different 'discursive spaces' could help overcome the problem of science teachers not feeling comfortable about their ability to discuss Maori worldviews, there is a danger that they could opt out of any NOS discussion if they are not part of the discussion of other world-views. Ideally, if two teachers are involved, both need to be present to hear and respond respectfully to the various parts of the debate. As Barnhardt and Kawagley (1998) point out, it is the attention to relationships, and the explicit recognition of interconnectedness that links this type of teaching model to cutting edge developments in science itself.

No debate – no progress?

All of these models have been accepted or rejected, in whole or in part, by various science educators. However the least criticised would appear to be the pluralist approach. If we are serious about raising science achievement for Maori students, and increasing the participation of Maori in science related careers, the sooner we begin to debate the relevant NOS and curriculum issues the better.

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