Time for critical thinking in secondary science?

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Abstract

Teaching approaches which support the development of students' "critical thinking" skills, and the use of socioscientific contexts for learning, have both been advocated as necessary and desirable directions for secondary school science education. In 2004 we were asked to evaluate a teaching resource, distributed to all New Zealand secondary schools, which aimed to support both these approaches at Year 10 level. We found low levels of uptake and use of the resource (called Entering the debate on Genetic Modification by developing a critical thinking response) *in schools. In this paper we reflect on the evaluation findings, and other research evidence about senior secondary science education in New Zealand. We put forward the proposition that there is a mismatch between the espoused "big picture" goals of science education, and the three "message systems" of schooling: curriculum, assessment, and pedagogy. Drawing on recent developments from the current New Zealand Curriculum/Marautanga Project, we consider how opportunities are opening up to begin to reframe school science education to align it visibly with the big picture goals and aims that it is intended to achieve.*

Introduction

What are the most important things for students to gain from secondary science education? Over the last few years, in various research projects related to secondary school education, we have had the opportunity to ask many different teachers and students these questions (e.g. Bolstad, forthcoming; Boyd et al., 2005, in press; Hipkins, Vaughan, Beals, & Ferral, 2004). Often, we have noticed interesting contradictions between teachers' and students' perspectives. For example, science teachers have told us that the purposes of students learning science at school include:

> [for students] to get a better understanding of their environment and who they share it with. To get a better understanding about contemporary issues, e.g., GE, so that when they leave school, when they are voting, they are better informed. (Science teacher, cited in Bolstad, 2002)

or:

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> Science is objectivity, you get a question and you evaluate it, experiment on it, problem solving, thinking about what's going on. (Science teacher, cited in Bolstad, 2002)

These kinds of ideas about science, and why it is important, align comfortably with statements in the introduction to *Science in the New Zealand Curriculum*, that "learning in science is fundamental to understanding the world in which we live and work. It helps people to clarify ideas, to ask questions, to test explanations through measurements and observation, and to use their findings to establish the worth of an idea" (Ministry of Education, 1993b, p. 7). When directly asked, science teachers generally have little difficulty articulating these "big picture" aims of the science curriculum. They consider that learning science (if it is done well), will help students to develop knowledge, transferable skills, abilities, and aptitudes that will serve them for a lifetime, and prepare them to be well-informed, contributing citizens in the future.

However, *students'* answers to our questions sometimes leave us wondering what is actually happening in New Zealand science classrooms to support these goals, given the messages some students seem to be receiving about the purpose, value, or importance (or otherwise) of learning science at school. For example, some Years 9 and 10 students have told us that the most important thing for them to learn in junior science is how to use a Bunsen burner. Such responses could be interpreted as an indication of the part of junior science that students most *enjoy* (and who could blame them – we confess that we enjoyed melting the heads of our ballpoint pens as high school science students)! They might also reflect students' impressions of junior science as a "training ground" for learning basic skills or information that they will need for their senior secondary science classes – for where else, outside school, would most people ever need to use a Bunsen burner?

But does knowing how to use a Bunsen burner take students a step closer to the "big picture" goals of science education that the curriculum, and science teachers, espouse? Our interviews with students often suggest quite the reverse. For example, a group of Year 10 students recently told us that their science classes were "just about learning facts" (Boyd et al., unpublished data). Yet the students were convinced that:

> …being smart isn't about knowing all the facts, like an encyclopaedia. Being smart is knowing about what's really going on in the outside world. (Group interview with eight Year 10 students, unpublished data, Boyd et al., 2005, in press)

These and other comments from students in different research projects suggest that, in contrast to the "big picture" aims of science education outlined in *Science in the New Zealand Curriculum*, many learners see science classes as more or less irrelevant for their future. Even when students talk about school *in general* as not being that useful for helping them to develop the kinds of skills, abilities, and knowledge they will need in their lives, science is often the subject they pick to illustrate this idea:

> [The most important thing to learn at school is] personal development. Finding out who you are, where you want to go with your life. Instead of learning that if you put magnesium with something else, it's going to blow up. That's cool to know, but I don't think school focuses enough on personal decisions, and how to be a good person in society. (Year 12 student, cited in Bolstad, Eames, Cowie, Edwards, & Rogers, 2004, p. 106)

So should we be concerned when students tell us their science classes are filling them with facts and information, instead of helping them to become "smart"? Is this really what happens in secondary science classes? If so, why, and more importantly, what might be done about it? In this paper, we explore these questions by discussing findings from an evaluation of one small New Zealand initiative: *Time for critical thought* (Bolstad & Hipkins, 2004b). This initiative involved the development and dissemination of a teaching resource that aimed to support "critical thinking" teaching and learning approaches in secondary science classes. We begin by discussing the thinking that underpinned the initiative, and we look at how teachers perceived it, and what happened when the resource was used in a secondary school.

This example leads us to a discussion of the contradictions and tensions that result from a mismatch between the espoused "big picture" goals of science education, and the existing "message systems" of schooling, that is *curriculum*, *assessment*, and *pedagogy* (Bernstein, 1971). Researchers have long argued that changes in one message system (e.g. assessment) can affect the working of the others; conversely, attempts to change one message system (e.g. pedagogy) can stagnate when the other two remain fixed. Some recent reform efforts have taken this into account. For example, developers of the Queensland New Basics project noted that:

> Effective school reform demands that the three message systems be aligned and not work at cross-purposes. For instance, to achieve a focus on higher order thinking or on fostering strong citizenship attributes, assessment practices need to be focused in that direction, as well as pedagogies (Lingard & Mills, 2003, p. 4).

What do these challenges mean for science education in New Zealand? Drawing on recent developments from the current New Zealand Curriculum/Marautanga Project, the paper ends by discussing opportunities that are currently opening up in the curriculum message system to reframe school science education to make it more consistent with the big picture goals and aims outlined earlier in this paper.

A New Zealand resource for critical thinking

In 2003, the Royal Society of New Zealand, the New Zealand Association of Science Educators (NZASE), and Agcarm Inc sponsored the production of a teaching resource called *Entering the debate on Genetic Modification, by developing a critical thinking response*, also known as *Time for critical thought* (*see* Figure 1). Two copies of the resource were sent to all New Zealand secondary schools. The *Time for critical thought* resource uses the controversy surrounding the introduction of genetically modified crops as a starting point for developing students' critical thinking skills. The resource includes templates and activities designed to help students analyse pieces of text about the GM debate from magazines and newspapers, and develop skills such as: analysing an argument; understanding how premisses and statements are used to develop and support arguments; looking at differences between "fact" and "opinion"; and judging for bias or "errors in thinking".

The resource also suggests activities to help students learn how to communicate their views about the GM debate. It includes a CD ROM which contains an audio "radio play" about GM, written and performed by a group of high school students, and interviews with two New Zealand GM scientists. The resource designers suggest the resource could be used in a range of subject areas, including science, mathematics, and English.

In 2003/2004 a regional programme of workshops was implemented to introduce the resource to teachers and to explore its potential use with their Year 10 pupils. The workshops particularly targeted science teachers, although it was also suggested that teachers of other subjects could find the resource and the workshops useful.

In 2003 we were asked to carry out an evaluation of the uptake, use, and effectiveness of the *Time for critical thought* resource. The evaluation included:

- a survey of 58 teachers who attended regional workshops about the resource;
- a case study of the use of the resource with four Year 10 classes in one secondary school; and
- interviews with two science HODs who were familiar with the resource but were *not* using it with Year 10 students.

In this article, we focus on data from the second part of the evaluation, the case study of the resource in use. (For full details of the evaluation, see Bolstad & Hipkins, 2004).

Time for critical thought in use: one school's experiences

Initially, we hoped to find at least three schools that we could case study as they used the resource. However, our enquiries, and the emerging evaluation findings, indicated that uptake and use of the resource in schools was disappointingly low. Finally we identified one school, Rimu High School (a pseudonym) which was using the resource with Year 10 science classes in term 3, 2004. In August 2004, we visited the school for 3 days to interview staff and students and observe the use of the resource in classrooms.

When the resource first arrived in the mail at Rimu High School, the science HOD used parts of it with Year 12 biology students but at first did not see the resource as something for Year 10 students. A confluence of factors stimulated the HOD to consider using the resource with Year 10 students. First, she attended a *Time for critical thought* teacher workshop. Not long after, School Support Services ran a professional development workshop at the school about "effective teaching", in which GM was used as a context for thinking about this kind of teaching. Finally, the HOD learned more about the resource when she met its designer at a science teaching conference. She decided she would find a way to use the resource with Year 10 classes at Rimu High School.

The HOD sought assistance from the school's resource teacher for learning and behaviour (RTLB), who was an expert in literacy and language development teaching strategies. The RTLB was attracted by the resource's emphasis on critical thinking. She collected additional resources and materials relating to the topic of GM and developed a 5-lesson unit plan, in consultation with the HOD. Her focus was to develop materials and activities that would scaffold students' entry into the topic of GM, and into the critical thinking activities. For example, she felt there was a significant amount of new vocabulary that the students would need if they were to start to make sense of the materials and activities.

About a week prior to the teaching, the RTLB ran a lunchtime session to introduce the unit plan to two other science teachers. All three science teachers (the HOD and the two others) subsequently used the unit with the four Year 10 classes they taught. The teachers did not have to follow the RTLB's suggested lesson plan and sequence rigidly, and there was some variation in the order and mix of activities observed in different classes. However a general description of the unit is outlined in Box 1.

Box 1 The 5-lesson unit plan for "Genetic Modification by Developing Critical Thinking Skills" for Year 10 students at Rimu High School

Lesson one

In the first lesson students are introduced to the theme of GM. The teacher aims to discover how much the students already know about the topic, and introduces the students to some of the "essential" vocabulary. This is done through a mix-and-match activity. Students have to match up 10 cards with GM words or phrases to their correct definitions. The terms are *genetic engineering*, *genetically modified*, *organic farming*, *DNA*, *moratorium*, *chromosomes*, *pollination*, *mutation*, *recombinant DNA*, and *transgenic*. Working in pairs, students take one GM word or phrase and its definition, and turn this into a poster to put on the classroom wall as a glossary (Figure 2).

Lessons two and three

After recapping the vocabulary they learned in the previous lesson, students are given a set of cards with statements about GM. They have to discuss and sort these statements into two piles: "advantages" of GM (for example, "Crops can be protected from weeds, diseases and insects thereby reducing the need for chemical pesticides" and "disadvantages" (for example, "Genes could escape from crops into related wild species. This could create indestructible weeds." Once the students have done this, each student selects a few of the advantages or disadvantages and goes to a computer lab to make these into a 5-slide PowerPoint presentation (Figure 3).

Lesson four

This lesson uses an adapted version of an activity from the *Time for critical thought* resource called "distinguishing fact from opinion". Page 18 of the resource shows a continuum between fact and opinion, and lists seven statements organised sequentially along the continuum. For example, at the "Fact" end of the continuum is the statement "involves numbers or measurements", while at the "Opinion" end is the statement "is based on someone's beliefs or feelings". Statements in between include "is based on the experience of many people" and "will possibly happen in the future". Students are given a sheet with the seven statements out of order, and have to discuss in their groups how to arrange them on the fact-opinion continuum.

Lesson five

In this lesson students work through "Fact and Opinion" activities taken from the *Time for critical thought* resource. These activities present a passage of text from newspaper articles about GM. Working in pairs or groups, students have to go through the text sentence by sentence and decide whether each statement is a "fact", an "opinion", or "neutral/unsure". The teacher then discusses with students the meaning of the term "bias", in relation to the articles and statements students have just read.

Additional activities

Some additional activities are available for teachers to use during the unit. These include a GM word-find activity, and a role-play activity in which students are given cards with "roles", for example:

- Role: Journalist. Opinion: Wants to tell the public about individuals who could be cured of their rare genetic disease through genetic engineering research.
- Role: Organic farmer. Opinion: The public should protest against genetic engineering because GM in New Zealand will jeopardise successful organic farming.
- Role: Scientist. Opinion: Genetic engineering should not be banned and continued research should be funded.

The role cards come with a set of dice with question-starter words like "where", "why", "what", "can", and "will" on them. Students are supposed to roll the dice and ask each other questions about GM, each playing the role of the person described on their card.

What did students think?

We interviewed small groups of three to six students from three of the Year 10 classes after the third or fourth period of their work on the GM unit. Although the Rimu High School classes were only just beginning to explore new ways of learning science, as far as students were concerned, the difference between the GM unit and their regular science learning was enough to make this unit more interesting and enjoyable than their previous science units. Students' comments suggested two main reasons for their positive attitudes towards what they had done so far. First, some students considered that the GM topic was "more relevant" than other things they had learned in science:

> It's all over the news, and you read about it, maybe kind of get an idea. (Year 10 student)

> [The GM unit is] more interesting, it's actually to do with our society and what's happening at the moment. (Year 10 student)

Second, students thought the way the unit was being taught, and the kind of activities they were doing, were more enjoyable than previous science topics. In science, (and in most other subjects), students said they often spent a lot of time listening, and copying down information, which they found boring:

> Basically all subjects are the same: teacher talks, we listen. Teacher writes, we put it down. We don't get much say in most subjects I would think…it's pretty cool that [in the GM unit] we get to discuss it in a group as well, and kind of relay information off each other. (Year 10 student)

> [The unit is] pretty good – not just copying [information into our books]. We are actually taking it in. (Year 10 student)

However, despite the students' positive comments, classroom observations suggested that the Year 10 science classes at Rimu High School were making only tentative first steps towards a "critical thinking" approach to classroom practice. In all four classes we observed, the teachers certainly spent more time moving around the classroom as students worked through the activities than standing at the front of the classroom addressing the whole class. However, from the classroom observations alone it was difficult to assess the depth of students' engagement with the activities they were doing. The classrooms were all characterised by high levels of conversation and discussion among students, although often this conversation was unrelated to the teaching activities. Some students spent a considerable amount of time drawing their GM word-and-definition poster for the classroom wall glossary (see Figure 2). Although we noticed a few instances of students debating with one another during the "distinguishing fact from opinion" activities, we also saw examples when students seemed confused or uncertain about how to proceed with some activities. We heard few student comments or questions that would indicate that the students were engaging with the tasks at more than a procedural level of task completion.

Making space for students' views and experiences in the "critical thinking" classroom

The *Time for critical thought* resource says the following about "critical thinking":

> Critical thinking can be facilitated by a collaborative working environment that encourages these personal dispositions: valuing open mindedness; valuing fair mindedness; respecting evidence and reason; respecting clarity and precision; and tolerating ambiguity… Critical thinking can be facilitated by a collaborative working environment that encourages these cognitive skills: asking questions; examining evidence; defining a problem; analysing assumptions and bias; and considering other points of view (Clark, 2003, p. 4).

It is suggested that the *Time for critical thought* resource can be used to encourage the development of these skills and abilities in students, to move them to a position where:

> The critical thinker intentionally applies these abilities in a variety of situations to make reasoned judgements (*ibid*).

Interestingly, the above discussion does not comment directly about the place of students' *own* ideas and points of view in the "critical thinking" classroom. This might be implicit in the suggestion that "critical thinkers" are able to consider *other* points of view – presumably, other to their own – and that they have personal dispositions of open-mindedness, fair-mindedness, and respect for evidence and reason. In other words, they are not dogmatic in their own views and understandings. Thus, an important part of critical thinking is being able to recognise one's *own* knowledge, views, and opinions, and being willing and able to hold these up for examination, critique, and scrutiny alongside the ideas, information, and opinions one encounters – for example, in a science classroom. As Facione (1998) states:

> Beyond being able to interpret, analyze, evaluate and infer, good critical thinkers can do two more things. They can explain what they think and how they arrived at that judgement. And, they can apply their powers of critical thinking to themselves and improve on their previous opinions (p. 5).

This implies that to engage students in the process of becoming critical thinkers, there should be a way for students to explicitly bring their own views and experiences into the learning experience.

We were curious about how often, in general, students felt they had the opportunity to bring their own ideas, experiences, and opinions into class. Students said that, in most subjects, their ideas and opinions were rarely brought into their classroom learning:

> Hardly ever. The only time I think that ever applied to a subject was social studies, where we get to choose our own topics. (Student)

> In science, we get to discuss our ideas/opinions – but [the teacher] gives us a timeframe, he says 'You have a certain amount of time to do it' [e.g. 5 minutes]. When we're just getting into it, that amount runs out. (Student)

Students noted that in some subjects (including maths and science) the sequence of topics they covered was already set up in advance, and this meant less flexibility or opportunity to bring their own interests or ideas into the learning activities. As a contrast, one group of students discussed being able to include their own ideas and opinions into their learning in dance/drama classes:

> [The dance/drama teacher] listens to our ideas, and puts them across. [Whereas] in other subjects they set up units for us to do across the term.

We asked the students whether they thought learning to think critically was important, whether school helped them to be able to "think critically" or make up their own minds, and what teachers could do to help them develop these skills. The students had trouble responding to the questions about "critical thinking", since this was not something that was explicitly discussed in the classroom. However, when prompted, students said their teachers did talk to them about "thinking for themselves" or "making up their own minds" on issues like GM. Some students felt that they normally had few opportunities to express their opinions in school, and they felt that secondary school didn't seem to emphasise this idea particularly strongly, or help students to make their own choices. The students suggested some ways that teachers could do more to help students in this respect:

> Most of our teachers should just listen to us more. We go off-task, we get bored writing. We'd like more of what's happening today, rather than what happened years ago. We want to know what's going on around us, it's more relevant. We can understand it. (Year 10 student)

> They could maybe ask what our opinions are of the subjects they are talking about. Maybe take it a bit slower, so we can process it, think about it, and think about what we actually think about it. (Year 10 student)

The challenges of teaching with a critical thinking approach

At Rimu High School, we found science teachers who were willing and interested to try a "critical thinking" approach to teaching about GM. The teaching approaches promoted by the *Time for critical thought* resource were felt to align with a recent emphasis in the school on exploring new kinds of pedagogy, particularly at the junior level. One teacher suggested that the *Time for critical thought* unit:

> …takes what we are trying to do in our normal practice a step further. We have a focus on not just literacy but high-level thinking. We're trying really hard to get away from 'recipe science'…not just to collect the data, but to analyse it, and to evaluate what we've been doing. (Science teacher)

When asked what a really successful "critical thinking" classroom might look like to an observer, the teachers described it as follows:

> [You would see] students questioning. Teachers may have some strategies for getting students to analyse particular parts of the lesson, or parts of texts. There may be prompts on the wall, with certain statements about processes you can go through to arrive at conclusions. Teachers may have activities to elicit the students' thinking on a particular topic, e.g. the validity of sources. (Science teacher 1, cited in Bolstad & Hipkins, 2004, p. 22)

> [Students] wouldn't be sitting in rows. You'd be attempting to develop group work and strategies with sharing of information. You'd be attempting to develop analysis, reason, and logic…. Textbooks could be used, but not in a traditional sense. Hopefully you would see kids being asked to pull a topic [text] apart – what are the key points – rather than answering

> the questions at the end of the piece of text. (HOD 1, cited in Bolstad & Hipkins, 2004, p. 37)

However, one Rimu High School teacher suggested that traditionally, critical thinking skills have not been explicitly taught in science, and that most teachers needed support to be able to do this well. She was finding that it took a lot of time and preparation to teach in this way and she "couldn't do it for five lessons a day". Another teacher agreed:

> We [science teachers] teach more the 'hard factual' side of science, rather than the social biology or the social issues that have traditionally I guess been left for social studies… Already I find that I'm not able to perhaps get the lesson going as I would like because I lack some of those [teaching] skills and experiences…. I'm quite keen to develop skills in looking at the social issues of science, and make science less of a rather cut-and-dried subject…. I would think that many of the other [science] teachers would not mind science being taken out of the basket that it's been in. (Science teacher)

Read together, the students' and teachers' comments above suggest that the moment was right for a change in pedagogy – one of Bernstein's three "message systems" – in the Year 10 science classes of Rimu High School. The students wanted more active involvement in their classroom learning, and thought an issue like GM was more interesting and relevant than some other science topics they had studied. Even the small changes to normal practice that they experienced with the GM unit were well received. The teachers were also ready to take their science teaching in new directions, and were exploring ways to bring their classrooms closer to the "critical thinking" classrooms that they could describe as an ideal.

However, this way of working in the science classroom involved a significant shift away from the "norm" for both teachers and students, and both parties identified some reasons why this kind of practice didn't seem to happen very often in their classrooms. In particular, both noted the amount of information/content that the classes had to learn over the course of the year, and the amount of time that was needed for students to cultivate their critical thinking (or, as a student put it, "to think about what we actually think about it").

At one level, these tensions could be viewed as arising from school-level constraints, such as curriculum plans and timetable structures. As one teacher said, "Critical thinking takes time.":

> It's really difficult with the way that secondary teachers work, because you have an hour, and the most interesting and most difficult part of the lesson is right at the end. So it is definitely an issue. (Science teacher)

Another teacher commented that there were a lot of topics to "get through" during the year in the current school science curriculum. The teacher felt the science department could make topics more relevant for students by having many fewer achievement objectives within each topic:

> That will give us room within the timeframe of the topic to go off on tangents, or for students to do more group-work on particular side issues. [At the moment] I just feel the course is so full that we don't really have time for that luxury. (Science teacher)

This push for "curriculum coverage" as a driving force in secondary science teaching seems very widespread and is something we discuss further below. It obviously creates challenges for teachers who aspire to cultivate a "critical thinking" and "issues-based" approach to teaching and learning in their science classrooms. With this in mind, the remainder of the paper explores the idea that the tensions experienced by the teachers and students at Rimu

High School resulted from a misalignment between the new pedagogical direction that the teachers were trying to move in and the existing curriculum "message system" operating in New Zealand secondary science classrooms.

Critical thinking in the current science curriculum

The *New Zealand Curriculum Framework* (Ministry of Education, 1993a) identifies critical thinking as an essential skill that all students should develop through their schooling. The *Framework* indicates that these kinds of skills should be integrated and developed across all the seven essential learning areas of the curriculum, including science.

Although the two integrating strands[2] of *Science in the New Zealand Curriculum* (Ministry of Education, 1993b) allude to the development of critical thinking, the four science contextual (i.e. "content") strands[3] have continued to dominate science teaching practice in New Zealand schools. From the very outset of its implementation, some teachers simply repackaged their existing courses to make them "fit" the new approach (English, 1995). A recent survey of 744 New Zealand secondary school teachers found that just 13 percent wanted to see overall content reduction in the curriculum[4] they taught (Hipkins & Hodgen, 2004).

New Zealand teachers are not alone in making this type of "coverage" interpretation of their curriculum. Internationally, adherence to the coverage of large amounts of content as the key focus of science programmes is widely seen as an impediment to reforms of science education. This issue has been commented on by research panels investigating curriculum and teaching reforms in the United Kingdom (Millar & Osborne, 1998) and in Australia (Goodrum, Hackling, & Rennie, 2000), to name just two examples. The emphasis on large amounts of content, too quickly covered, has been identified as a major impediment to student enjoyment of, and continuation with, school science (Osborne & Collins, 2001). So there is an issue of *tradition* in curriculum interpretation to be addressed. However, we believe that to say this is the extent of the challenge is to dismiss the deeper issues too lightly.

Notwithstanding the dominance of traditional "coverage' interpretations of the curriculum, Hipkins and Barker (2002) have argued that there are multiple ways to interpret *Science in the New Zealand Curriculum,* and that the document has the flexibility to allow teachers to introduce innovative new teaching approaches in science. One such approach is to base science teaching around topical issues. Currently, there are clear opportunities for senior science students to investigate topical science issues, particularly in biology. Biology Level 3 Achievement Standard 90714 calls for students to "Research a contemporary biological issue", and Unit Standard 6319 asks students to "Make an informed judgement on a contemporary biological issue". However, Hipkins (2001) argues that it is not necessary to wait until students are near the end of their secondary schooling – by which time, many students have already opted out of science anyway – before they can start learning about "real issues" relating to science. She suggests that many younger students would find science more personally relevant if they were able to enjoy stimulating debates about issues, at a level with which they can appropriately engage. Hipkins suggests genetic modification (GM) as one

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[2] These strands are: making sense of the nature of science and its relationship to technology, and developing scientific skills and attitudes.

[3] These are: making sense of the living world, making sense of the physical world, making sense of the material world, and making sense of planet Earth and beyond.

[4] These were teachers of many curriculum areas, not just science.

such issue – the teaching of which could be well supported by resources like *Time for critical thought* and others which would support students to engage with both the science, and the social debate, that surrounds this area (e.g. France, 2003).

Curriculum and teacher autonomy

However, just because *Science in the New Zealand Curriculum* could be interpreted in ways that support "topical issues" or "critical thinking" approaches to science teaching, does not mean that it necessarily *will* be. Nor does it mean that teachers can easily pick up resources like *Time for critical thought* and integrate them into their practice. In a companion paper to this, Hipkins has argued that teachers' actual curriculum decision-making space may be much less than we seem to assume when we expect them to be the sole agents of change in classroom practice. Many factors act to limit their autonomy. Some, such as timetable structures, are obvious and have been mentioned above. Some of the conditions that would help science teachers to take critical thinking/issues-based approaches in their classroom pedagogy may ultimately require changes at the whole-school level. For example, changing school timetable structures might enable junior classes to have longer periods, and thus more sustained opportunities for critical discussion. This would obviously impact on the entire school timetable. If science teachers could collaborate with teachers in other subject areas, they could develop cross-disciplinary or integrated-curriculum approaches to teach critical thinking. This would help students to recognise critical thinking as something which can be learned and practised across all areas of learning. Once again, this requires whole-school thinking about ways to enable collaborative or inter-departmental planning and teaching.

Aligning the message systems

What is needed to support schools to move in these directions? We think that the answer lies in creating a much clearer alignment between *pedagogy* for "critical thinking", and the other two message systems of schooling: *curriculum* and *assessment*. We need to move from a curriculum message system that *allows* this kind of pedagogy to occur (or not to occur, as the case may be), to one which actively supports and promotes it. (While it is beyond the scope of this paper to discuss *assessment*, clearly curriculum and pedagogy that support "critical thinking" must be supported by an assessment system that supports, rather than works against these goals.)

It may be that changes currently being worked through in the New Zealand Curriculum/Marautanga project provide the impetus for the types of teaching changes that the current science curriculum, in the end, did not deliver despite the best intentions of its writers.

In particular, the replacement of the essential skills with a New Zealand version of the OECD "key competencies" (see, for example, Rychen & Salganik, 2003) may challenge science teachers to find ways to increase student autonomy in their learning. At the time of writing this paper the five competencies are named as[5]: relating to others; managing self; belonging; pursuing knowledge; and using languages, symbols, and texts. They are currently being

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[5] The consultation process has resulted in several revisions of the titles used, as a shared understanding of the scope and complexities of the intent of each develops. The titles may yet change again.

woven into the new integrating strand of the revised science curriculum[6]. The interweaving that is intended is illustrated by the way the key competency "using languages, symbols, and texts" has been interpreted as entailing a focus on literacy and the critical investigation of various modes of communication used in science. Many aspects of *Time for critical thought* would fit directly into this new focus, making a better match at Year 10 than is possible with the current curriculum.

Similarly, the key competencies "pursuing knowledge" and "managing self" (which has a strong focus on the development of personal autonomy) together support learning to think critically in a context where students access and use information that is already "out there" in the world. And the key competency "relating to others" supports the intention to develop these skills through group discussion.

Perhaps most challenging is the key competency called "belonging" (Rutherford, 2004). Originally called "participating and contributing" this has been interpreted in the science curriculum integrating strand as involving a type of action competence – that is, being able to use the knowledge learnt in personally meaningful ways related to one's own life. This broad aim, as we outlined at the beginning of this paper, is not new. But requiring that it actually be demonstrably put into action certainly is. Again, a resource such as *Time for critical thought* could lead the way in supporting this type of curriculum development.

At the whole-school level, a curriculum built around the "key competencies" provides a basis for conversation across different subjects and disciplines in secondary schools about how the specific learning goals, aims, and practices associated with different subjects can contribute to students' key competency development. Such discussions about the overall school curriculum could open up avenues for changing whole-school structures, including timetabling, and the possibilities for teacher collaboration within and between subjects.

While the challenges for bringing critical thinking approaches into secondary science teaching and learning are great, these seem outweighed by the potential benefits this would have in terms of developing students' interest, understanding, and ability to engage with scientific issues now and in the future. Surely, this is the purpose of school science education.

[6] At the same time, the contextual strands are being revised and streamlined, hopefully helping to reduce "coverage" pressures.

Figure 1 **The resource**

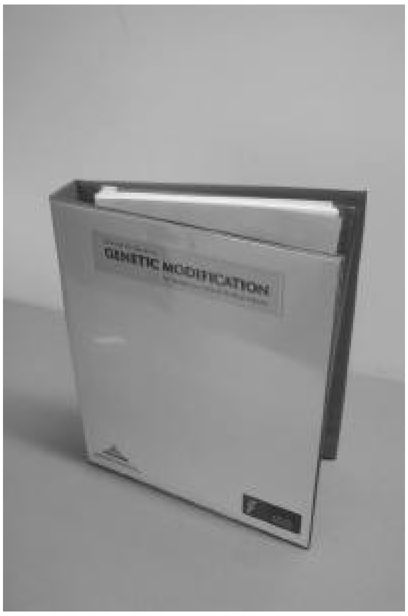

Figure 2 **Student posters for wall glossary (lesson one)**

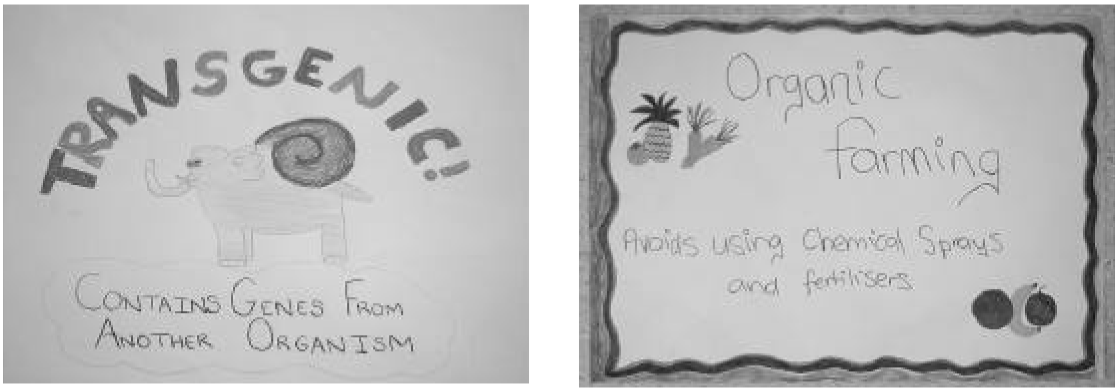

Figure 3 **Deciding on advantages and disadvantages of GM (lessons two and three)**

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