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Rangahau Mātauranga o Aotearoa

Building a future-oriented science education system in New Zealand: How are we doing?

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Table of Contents

1. Introduction

The last few years have seen increasing government acknowledgment of the importance of science and innovation to New Zealand's economic and social future. One result of this has been the establishment, in 2011, of a Ministry of Science and Innovation, later incorporated into the new Ministry of Business, Innovation and Employment. Another was the 2009 appointment of Sir Peter Gluckman as the inaugural Prime Minister's Chief Science Advisor. Science education was to be a key focus of this role, and in 2011 Professor Gluckman, in a paper entitled *Looking Ahead: Science Education in the 21st Century*, set out his view that:

> a forward-looking science education system is fundamental to our future success in an increasingly knowledge-based world. (Gluckman, 2011, p. vi)

His paper goes on to explore how New Zealand's science education system could be strengthened to contribute to our development as a "smart", innovative, knowledge-oriented country, capable of addressing the serious questions we will face in the future, and how we can "engage and enthuse" more young New Zealanders in science. It makes the case for the importance, in a participatory democracy, of all citizens having an understanding of scientific issues, arguing that "science literacy" should be a key focus of science education:

> New Zealand must embrace science and technology and innovative thinking as a core strategy for its way ahead. [T]here is no doubt in my mind that a population better educated in science, whether or not they will actually use science in their career, is essential. (p. 8)

Gluckman says that school science education's traditional focus on providing pre-professional training for future scientists needs to be strengthened to better meet 21st century needs, but this should occur *alongside* the more "citizen-focused" objectives. His emphasis on scientific literacy for all is reiterated in a later report on science communication, where he makes a case for scientists to play a greater role in developing public understanding of science. (Gluckman, 2013)

The *Looking Ahead* report suggests that the citizenship and pre-professional training goals might need to be met at secondary level via different curricula and pedagogies and recommends that attempts are made to improve primary teachers' confidence in science. It also says that health literacy should have an important place alongside general science literacy for secondary students. It identifies fostering closer relationships between schools and the science community as an important area of need, along with secondary teachers' access to modern technologies to allow them to keep up with developments in science.

As these reports acknowledge, these are complex and difficult issues and addressing them will require major changes to current thinking. But what should frame this thinking? What exactly *is* a forward-looking science education system? What is its purpose? Who or what should it serve?

What ideas need to underpin its development? What would it look like? How might it be implemented in practice? What would a scientifically literate population look like? How could we assess this? In this paper we argue that, notwithstanding the recent flurry of activity, achieving a forward-looking science education system in New Zealand is a long way off, as is the goal of a scientifically literate population. Despite many reform attempts, our science education system is framed by 20th century understandings of science, and 20th century understandings of education and learning. As a result, it does little to prepare young people for the "knowledge societies" of the future, but, worse, it actively reproduces the very ways of thinking that most need to change.[1]

In this paper we argue that change is needed in how we think about what science education *is*, what it is *for*, *who* it is for and what we would like it to achieve. By "we" here we mean science educators, but also all the other stakeholders—policymakers, scientists, students, parents and the wider community. Producing this change will require new forms of teacher professional learning, and new, deeper, more sustained and co-ordinated connections between science educators, the science community and the wider community. We argue that it will not be enough to speed up *today*'s processes, or provide more support for—or co-ordination between—them. Nor will it be enough to develop better measures of them. Something new and different is needed.

However, before we set out what we think this should be, we review the present context. We outline some recent policy work in the science education area, and look at some of the range of practical initiatives that have developed from this work. We then evaluate the extent to which this work is likely to contribute to the development of a future-oriented science education system.

[1] See Hodson (2003, 2011) or Gilbert (2005) for more details of this argument.

2. Recent policy work

The key points made in the Gluckman papers—the need for a forward-looking science education system that could engage more young people in science and the need to create a scientifically literate population— were incorporated into the thinking when the National Science Challenges were developed recently.[2] Of ten Science Challenges identified by March 2013, one, entitled "A Better Start", includes the research theme "Education—living in the digital world". Research activities envisaged for this theme include:

- Science, Technology, Engineering and Mathematics (STEM): how to strengthen science skills and knowledge, how to instill curiosity and excitement about science?
- Teaching children in the new digital world: is more of the same good enough?

There is also an overarching "special" challenge entitled "Science and Society". Included in this challenge is a "Science Education in Schools" theme, with the following research activities:

- Enhancing STEM education in primary and secondary school
- Evaluation of innovative STEM experiments done in New Zealand and elsewhere

and a "Public Understanding of Science" theme, with the research activity:

- Promotion of science literacy at schools as distinct from STEM education.3

Implicit in these Science Challenges are the two different purposes for school science education identified in the Gluckman report: growing future scientists and growing scientifically literate citizens. A snapshot of recent available research shows that New Zealand could improve its performance on both of these purposes. Some examples:

- Programme for International Student Assessment (PISA) results[4] show that New Zealand has a good supply of students equipped for scientific careers and offers more science career opportunities than is the case in most other Organisation for Economic Co-operation and Development (OECD) countries. However, only 39 percent of top performers in science said they would like to spend their life doing advanced science—this figure is below the OECD average.[5]

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[2] The National Science Challenges, launched in August 2012, form a major new initiative designed to take a more strategic approach to the government's science investment. Their aim is to bring together scientists from different disciplines to focus on some of the large and complex—but pressing—issues facing New Zealand today. They are supported by a budget of $74 million over 4 years (in addition to the $60 million allocated in the 2012 budget).

[3] See: *Report of National Science Challenges Panel* (2013).

[4] OECD (2009) *Top of the class: High performers in science in PISA 2006* http://www.oecd.org/dataoecd/44/17/42645389.pdf

[5] Organisation for Economic Co-operation and Development (2009).

- Although our top students do very well in PISA, there is a large group of students who do poorly in science, and Māori and Pasifika students are over-represented in this group. Trends in International Mathematics and Science Study (TIMSS) data show that 13 percent of the New Zealand Year 5 students participating in the 2006 data collection did not reach the low benchmark of "some elementary knowledge of life science and physical science". [6]
- Data from both the National Education Monitoring Project (NEMP) and Competent Learners project show that interest in science declines as students move through school.[7]
- The 2012 Education Review Office report *Science in the New Zealand Curriculum—Years 5–8* found effective science teaching practice in less than a third of a hundred schools reviewed in 2011, and wide variation in practice. Knowledge/content-based programmes were more evident than approaches focusing on thinking, talking and experimenting. This report found limitations in teacher knowledge and little professional development in science for teachers. It concluded that science appears to be a low priority in Years 5–8.

From this evidence, it would seem that we are producing enough science graduates to fill our current needs. However, we probably *aren't* producing enough of the kinds of graduates that would be needed in the expanded, innovation-oriented science sector envisaged by Gluckman. It is also clear that we are definitely *not* achieving the science-for-citizenship objectives envisaged in his report.

The Ministry of Education's response to the Gluckman report involves a number of new initiatives. The Ministry included science in the teacher professional development contracts it funded in 2012, and it commissioned three research programmes. These research projects were designed to build teachers' science capability, to develop better connections between schools and the science community, and to look at how science teaching can be enhanced through better access to digital technologies. A further project was set up to explore how the curriculum and qualifications frameworks can be better aligned at secondary level.

Teacher professional development in science

In early 2012 the Ministry of Education allocated funding for professional learning and development (PLD) in science for primary and senior secondary school teachers (through its contracts with the providers Te Toi Tupu and Te Tapuae o Rēhua.) However, alongside this, the last 2 years have seen a proliferation of other[8] science PLD for primary teachers, possibly in response to comments made in the Gluckman reports. Some examples:

- The Open Polytechnic has developed three new "Graduate Primary Science Teaching" qualifications that are taught online. In August 2012 the Mayor of Hutt City announced 49

[6] For more details see Appendix 1 in Bull, Gilbert, Barwick, Hipkins and Baker (2010).
[7] For more details see pp. 27–32 in Bull et al. (2010).
[8] i.e., not directly funded by the Ministry.

Hutt City Mayoral Scholarships (funded by Hutt City Council, Open Polytechnic and GNS Science) for primary teachers in the city to complete this qualification.

- The Sir Paul Callaghan Academy is running PLD for primary teachers. The Academy is, according to its website, "an exciting new, professional development initiative providing a forum for exchange, encouragement and dissemination of 'best practice' primary science teaching."[9] The programme consists of a 4-day residential course, followed by ongoing interaction and support through its alumni network. This is an initiative of the National Science-Technology Roadshow Trust.
- The Teachers' Refresher Course Committee (TRCC) ran two primary science conferences in April 2013, both of which were fully booked.
- The New Zealand Educational Institute's (NZEI's) Centre for Educational Excellence, in collaboration with Victoria University's MacDiarmid Institute, recently hosted a professional learning workshop in science for primary teachers.

In addition, the New Zealand Association of Science Educators (NZASE) runs workshops for primary teachers, as does the Science Learning Hub, and the Teacher Fellowships (funded by the government and managed by the Royal Society[10]) also provide in-depth PLD for primary and secondary teachers. Several of the schools participating in the Ministry of Education-funded PLD are also involved in the initiatives outlined above.

Taken together, these programmes represent a major step up in the science PLD available to primary teachers. This work is likely to make a difference to the science knowledge and confidence of some primary teachers. However, if our aim is to produce a significant improvement in science engagement in the next generation of New Zealanders, or to build a more future-oriented science education system, we aren't convinced that this is the best use of available resources. We set out our reasons for this view later in the paper, but first we outline key findings from the three recent Ministry of Education-funded research projects.

Research projects on science education

In 2011 the Ministry of Education let contracts for three science education research projects, to be carried out between early 2012 and June 2013.**[11]** One project investigated e-learning in science, a second explored the range of linkages between schools and the science community, and the third looked at curriculum support for science teachers. The research work involved teacher and science provider surveys, case studies, focus groups and literature reviews. The curriculum

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[9] See scienceacademy.co.nz/assets/pdfs/2013AcademyDetails.pdf

[10] For more information see http://www.royalsociety.org.nz/teaching-learning/teacher-fellowships/

[11] These three contracts were carried out by the New Zealand Council for Educational Research (NZCER), in collaboration with the University of Waikato and Learning Media Ltd. The work had just been completed when this paper was written.
For the final reports on this project, see Buntting & Bolstad (2013) and Bolstad & Buntting (2013).

support project also involved an audit of existing science resources and the production of some new resources.

Project 1 e-learning in science

This project aimed to look at how teachers are using digital technologies in science classrooms and to identify examples of creative/innovative practice, with a view to scaling up these practices to increase teacher capability and student engagement in science.

Phase 1 of the project included a survey of 343 teachers. Data from this showed a primarily one-way pattern of technology use (retrieving information, finding student activities, and/or having students collect and analyse scientific data). The teachers reported some interactive use (e.g., having students ask questions of scientific experts), but using digital technologies to allow active, two-way collaborations designed to create new knowledge was rare. While there are a few pockets of innovation, digital technologies are, in general, being used to support *existing* practice, *not* to scaffold the development of "next practice". Phase 2 of the project explored further the use of digital technologies in the classroom through two case studies.

In Phase 3 of this project the researchers worked with focus groups of experts from schools, tertiary institutions and the Research & Development (R&D) sector to explore how digital technologies *could* be used to help create a future-oriented science education system. A key theme emerging from this work was the need to move away from one-way, teacher-provided transmission of static, already-known knowledge. Instead, the *networks* that digital technologies make possible need to be central to all activities.[12]

Future-oriented science education would foster students' active engagement in designing their own learning "in the network"[13]—doing "real research"[14] in collaborations with people outside schools, including scientists, as well as with other students. This approach scaffolds, mirrors and engages with real-world, 21st century scientific practice, and it is likely to be far more engaging for students than traditional transmission-of-knowledge approaches. However, implementing it requires a paradigm shift in thinking about learning and schooling and their purposes. As has been well documented, investment in digital technologies does not, by itself, trigger this kind of shift:[15] a parallel cognitive shift—in teachers, school leaders, policymakers, students and the wider public—is also required. However, as the teacher survey that was part of this project showed, the preconditions for this shift are not yet in place.

[13] Part of the new meaning for *knowledge* that defines the Knowledge Age is its creation and location, not in individual minds, but "in the network". See Weinberger (2011) for more on this.

[14] This term is Carl Bereiter's: see his 2002 book *Education and Mind in the Knowledge Age*.

[15] For a summary of the large body of research in this area, see Dumont, Istance and Benavides (2010).

Project 2 School–science community engagement

This project explored how connections between schools and the science community[16] could support more future-oriented science learning for all New Zealand learners. The research comprised surveys of teachers and members of the science community; case studies of specific initiatives; focus group interviews with scientists and science educators; and a synthesis of New Zealand and international literature on school–science linkages.

It found that there are a large number of programmes, initiatives and opportunities for schools to connect with the science community, and that there is no shortage of goodwill, energy and commitment, in schools *and* the science community, to work together to improve science education. However, because these programmes are invariably not the "core business" of either schools or science, some issues arise that limit their potential to support the development of a future-oriented science education system:

- The number and variety of initiatives means that there is a range of very different drivers, origins and purposes. These can be at odds with the goal of developing a future-oriented science education system.
- Some schools are able to forge connections more easily than others: often the connections arise from personal relationships and networks.
- Although some resourcing for these initiatives is available, it is usually insecure or fixed-term, which makes it difficult to build long-term capacity in what is actually a specialist skill area.

Important factors in the success of these programmes were:

- the "partners" having a shared understanding of the purpose of the engagement
- students having in-depth and/or repeated immersive experiences in doing science
- the involvement of "intermediaries" to mediate and liaise between schools and the science community
- planned strategies to ensure the sustainability of initiatives.[17]

There have always been efforts to forge connections between the science community and schools. However, the ad hoc nature of these initiatives, their reliance on the enthusiasm and personal networks of a few key individuals, and on short-term/limited funding, means that they are often not sustained. Thus the initial investment—in people, relationships and resources—is not built on or connected to other similar investments, and the learning that occurs in these spaces is lost to the system.

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[16] In this project *science community* meant working scientists and those who manage science organisations; tertiary science educators and students; science communicators; professionals in science museums, science and technology centres, zoos and aquariums; other people who provide professional support for science or who promote public science engagement.

[17] For the final report on this project, see Bolstad and Bull (2013).

There are a number of reasons why a 21st century science education system needs these kinds of connections—at its *centre*, not on the margins as optional “add-ons”, as they are now. First, the ever-increasing rate of change in science—new knowledge development and new ways of working—means that it is not realistic to expect teachers to be the main “providers” of science knowledge. Secondly, learning and working “in the network” is a key 21st century skill. Thirdly, today’s young people are likely to “vote with their feet” if offered traditional, transmission-of-knowledge-based programmes. Engaging them involves giving them active roles participating in the creation of new knowledge, building relationships with science-knowledgeable people and using those relationships to build their own personal relationship with science itself. Fourthly, if solving the “wicked problems” of the 21st century requires us to work across disparate perspectives,[18] then our education system needs to build the ability to engage with other perspectives, to work productively with different others. All this is important to both the pre-professional training *and* the citizen-focused objectives of science education.

Strategic leadership would be required to put school–science community connections at the heart of science education. Stronger *networks* would be needed—between “science-connected” teachers and between people working in intermediary roles across the space between schools, scientists and the wider community. Debate—and some consensus—would be needed on the *purposes* of school science education in the 21st century, and, following from this, the purposes of school–science community connections. High-level *co-ordination* of the funding, design and availability of these activities would be needed to ensure that they are meeting these purposes, while at the same time also growing our collective knowledge of how to work effectively in the science-education space. There is a need to synthesise and build on the substantial (but fragmented) body of knowledge we already have on school–science community engagement initiatives.

Project 3 Science curriculum support for teachers

This project largely involved the development of resources for teachers; however, it also included a teacher survey, an audit of existing resources and two case studies (one primary and one secondary).

The teachers participating in the survey (*n*=343) said they were reasonably confident in their ability to deliver all of the strands of *The New Zealand Curriculum* document (Ministry of Education, 2007). The secondary school teachers appeared to make little use of the available curriculum support resources, instead mainly using National Certificate of Educational

[18] The term *wicked problem* is widely used to refer to very complex problems that are difficult or impossible to solve—or even define—using the tools and techniques of one organisation or discipline. Because they have multiple causes and complex interdependencies, efforts to solve one aspect of a wicked problem often reveal or create other problems. They are common in public planning and policy, where any solution is likely to require large numbers of people to change their mindset and/or behaviours. The standard examples of wicked problems include climate change, natural hazards, public healthcare and nuclear energy and waste, but the term is also widely used in design and business contexts. *Tame* problems, in contrast, while they can be highly complex, are definable and solvable from within current paradigms. See Conklin (2006).

Achievement (NCEA) exemplars to guide their teaching. Thus their choices of what to teach and how to teach it are primarily driven by the assessment system. The primary teachers surveyed made more use of the available support materials,[19] and said that they used the curriculum document to guide their choice of science topics. Both groups of teachers had only a hazy idea of science's purpose in the curriculum (either as stated in the curriculum document[20] or in any wider sense). If, as seems to be the case, teachers are not engaging with the high-level framing of the curriculum document, then it is unlikely that the Nature of Science strand will produce the changes hoped for by its advocates.[21]

The surveyed teachers appear to see their role as being to "cover" what is specified in the curriculum document and/or what will be assessed. They are not clear about the *purposes* of science education. Nor do they appear to have thought very much about how and why science education might need to be different in the future. This suggests that there is a great deal of work to do if we are to develop a future-oriented science education system.

Some of the work of this project involved adapting existing resources to emphasise the development of the "capabilities" students need in order to be ready, willing and able to engage with science. However, because teachers are likely to interpret—and use—these resources in ways that fit with their tacit knowledge of science education's purposes, resource provision alone will not produce the system shift needed for a future-oriented science education system.

Implications of the three projects

A high-level view of the findings of these three projects, looked at alongside other recent developments, tells us that we have a long way to go to develop a future-oriented science education system in New Zealand. The current emphasis on providing resources and other support to develop/update teachers' science knowledge and/or their capacity to use digital technologies is not enough. While it is obviously important that teachers have access to appropriate resources, knowledge and technologies, what matters most is *how* they *think about* that knowledge and those resources/technologies, how they make sense of—and use—knowledge and resources to achieve the core purposes of school science—as *they* see them. The recent work to support science

[19] Primary schools have access to a number of Ministry of **Education** support materials that are not freely available in secondary schools.

[20] *The New Zealand Curriculum* (Ministry of Education, 2007, p. 17) says that students need to learn science "so that they can participate as critical, informed, and responsible citizens in a society in which science plays a significant role".

[21] More than half the surveyed teachers were either unsure or disagreed with the statement that the Nature of Science strand was changing their practice. See also Hipkins (2012). **The** curriculum support project also included an in-depth case study involving a researcher working with two secondary teachers to foreground the nature of science in their teaching. Despite being willing and interested (and receiving positive feedback from their students about changes they made) these teachers were not able to sustain the changes they made once support was withdrawn.

education is welcome and important: however, it is not enough to drive the kind of change needed for a future-oriented science education system. In the rest of this paper we outline, first, *why* we think change is needed, and, secondly, what we think would be needed to produce that kind of change. Our purpose is to provoke discussion—because, as will become clear, if we are serious about this, there are some hard decisions to be made.

3. Why do we need change?

As outlined earlier, there is currently a strong policy emphasis on science and innovation, and a number of initiatives have been set up to strengthen New Zealand's science and science education system. This work has developed in response to some major international trends, and to the concern that we are not investing sufficiently in the infrastructure needed for our future development. However, we think that, without wider public understanding of the significance of these international trends, this work will quickly be reduced to a few buzzwords and there will be little real change. This is a problem because the need for change—deep and radical change— is now urgent. According to some commentators, the situation we are now in is like an avalanche; for example, a recent report on the future of higher education quotes the historian Norman Davies as saying:

> Historical change is like an avalanche. The starting point is a snow-covered mountainside that looks solid. All changes take place under the surface and are rather invisible. But something is coming. What is impossible to say is when.[22]

For our education system, like many of our other major institutions, something is coming. Under its apparently solid surface, major changes are taking place, but these changes seem to be invisible to those involved. If we do not understand, and take account of, these changes, our education system will be increasingly anachronistic. Here we very briefly outline three of these changes as they pertain to the present discussion.[23]

The first, and most well-known, change is what is known as the "digital revolution". As Brynjolfsson and McAfee (2011) point out, since the 1960s the capacity of digital technologies has doubled roughly every 18 months. As a result, we are moving from what until now has felt like linear growth to the steep part of the exponential growth curve, a period of incomprehensibly fast growth that will have far-reaching and, from today's perspective, unimaginable effects on how we see employment and economic development. This change, already well under way, will require massive organisational—and educational—innovation. Schools, to remain viable and defensible, will need radical reorganisation: they will need to be set up in quite different ways to do quite different things.

The second major change is less well understood. Very briefly, the defining feature of the "Knowledge Age" we are now in is that knowledge has changed its meaning. Knowledge is no

[22] Davies (2012), quoted in Barber, Donnelly and Rizvi (2013).
[23] For more detail see Gilbert (2012) or Royal Society of New Zealand (2012).

longer "stuff" you "get", but something that *does* stuff. It's like a form of energy,[24] or, as one commentator put it nearly 20 years ago, knowledge is now a verb, not a noun.[25] Rather than being something we *have*, knowledge is something we *do*. Knowledge is no longer something that lives in the brains of experts, or in objects that contain it, like books or libraries. These are now way too small. It lives—and is created and replaced—in the spaces *between* experts, books, databases and so on. It is no longer a "thing in itself": it exists in—and is a property of—networks. Knowledge, in the Knowledge Age, isn't a stable body of facts or truths, it isn't masterable and it doesn't necessarily reflect the world; rather, it is networked expertise. This doesn't mean that the network *is* knowledge, that the network creates meaning or that it is some kind of conscious super-brain. It's not. Rather, the network *enables* connected groups to take ideas further and faster than any individual could. The knowledge they create is *in* the collaborative space, not in individual heads.[26]

This "networked" model of knowledge is closely linked to a third big change—the shift in emphasis from things—individuals, groups or ideas, for example—to the spaces *between* things, or "third spaces". The ability to function in these third spaces—to be able to connect, translate and/or work across the space between different expertise (or different cultures) is, according to some commentators, *the* key Knowledge Age skill.[27]

From this, the stable, linear, production-line archetype of 20th century thought has been replaced by the "network" metaphor. The talk is of connections, partnerships and synapses, of complexity, ecologies and relationships. What matters is the ability to connect, to create new knowledge in third spaces and to innovate. If we accept all this, then a 21st century education system is one that can prepare students, not, as is the current focus, to "achieve" in 20th century terms,[28] but for innovation, for work in "third spaces". Tony Wagner, in a book called *Creating Innovators*, sets out some of the conditions that, research shows, facilitate innovation.[29] His point is to contrast these with the conditions our education system is set up to provide in order to show just how much schooling needs to change if it is to foster the innovative thinking Gluckman says is crucial for New Zealand's future development.

These ideas are obviously very different from those underpinning the present system. Because they are so different, it would *not* be helpful to try to add them onto the existing system and

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[24] Castells (2000).
[25] Barlow (1994).
[26] See Weinberger (2011) for the full version of these ideas.
[27] See, for example, Bauman (1992, 2000).
[28] For example, the current education "target" is, by 2017, to have 85 percent of 18-year-olds achieving NCEA Level 2.
[29] These include: opportunities for thoughtful risk taking, trial and error, exploration, pushing boundaries; opportunities to create, to produce new things; emphasis on multidisciplinary thinking (STEM + liberal arts—together); intrinsic motivation—"passionate play with a purpose"; valuing difference and unconventionality; having space to follow interests and to develop deep knowledge in those areas; opportunities to collaborate, to work with others with different expertise to solve problems that all participants care about. See Wagner (2012).

expect it to adapt. It wasn't set up for these ideas, and, like all large systems, it has a lot of inertia. Moreover, it is already expected to do far too many different things.

Ideas are important, but, on their own, they are *not enough* to produce the kind of change that is needed. As constructivist learning theorists have argued for a generation or more, adding new ideas to an existing schema does not usually change the schema. The new ideas are assimilated or made to fit with the existing schema, or, if this can't be done, they are put aside and/or rejected.[30] Cognitive change requires a change in the underlying schema. It requires a change, not in *what* we think, but in *how* we think, a change in the system we to use to represent, organise and *give meaning to* ideas.

[30] See, for example, Mezirow (1997).

4. How could this kind of change be produced?

Cognitive change is deep—and slow—change. It requires the learner's active engagement and sustained contextual support. Is this kind of change possible within the existing system? We think it is—if there is a long-term commitment to change. There are some steps we could take right now, steps that could mesh easily with the current system, while at the same time also scaffolding what is needed for change.

Building on what is now known about learning and human development, in an earlier report[31] we suggested that the focus of science education should be different at the different levels of schooling. In Years 1–6 the emphasis should be on stimulating students' interest and curiosity, and in Years 7–10 socio-scientific issues should be the focus, along with opportunities for students to see possible future careers for themselves in science. At senior secondary level, students could continue to study an issues-focused programme, but parallel courses in pure or applied science would also be offered. If this model was adopted, building the "library of experiences"[32] young children need to be ready to learn would be the focus of primary science, as would structured classroom talk designed to develop children's engagement with science and their capacity for subject-specific reasoning.[33] Teacher professional learning could easily be designed to support primary teachers' skills in these areas, while at the same time also challenging how they think about school science and its purposes. If the focus of the middle years was on socio-scientific issues, there are obvious opportunities for scientists and science educators to work together to produce "units of work" exploring some of the complex issues that affect New Zealand's future development (health issues, for example). LENScience already provides a model of how this could be done.[34] As outlined above in the description of the school–science community engagement project, there are people out there who could do this work. The specialist science educator role—people who can work in the "third space" between the science community, school communities and the wider community—could be formalised.

Thinking about these "first steps" raises several issues. One is that it is time to acknowledge that it is now unrealistic to expect *all* teachers to be able to do *all* of what is needed in 21st century

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[31] Bull et al. (2010).
[32] Bull (2010).
[33] See Osborne (2007) for more detail. Resnick, Michaels and O'Connor (2010) use the term *accountable talk* to refer to talk that attends to, and builds on, the ideas of others; emphasises logical connections and the drawing of reasonable conclusions; and encourages speakers to make the evidence behind their claims explicit.
[34] http://www.liggins.auckland.ac.nz/uoa/lenscience

schools. Students need access to people with a range of different types of expertise. A second issue was highlighted in comments made in the expert focus groups set up for the *e-learning in science* project described above. A recurring theme in these groups was that it is very difficult to imagine what hasn't yet been experienced. While there is a lot of talk about the kinds of experiences 21st century *learners* need, there is much less discussion of what 21st century *teachers* need, or of the difficulties involved in expecting teachers to offer experiences of a kind that they themselves have not had (and, as a result, don't understand).

New kinds of teacher professional learning are needed to scaffold the change described in this paper, and we could easily begin work on this now. However, teachers cannot be expected to do all of the work needed. We need informed public discussion of what we want our science education system to do in the 21st century, and we need more opportunities for schools, the science community and the wider community to work together to develop the kind of science education we, together, agree is needed for New Zealand's future.

Developing science education that is a better fit for the times we live in is a massive undertaking and it is unrealistic for schools to do it on their own. As well as rethinking the relationships between schools, the science community and the wider community, and investing in teacher professional learning, it will also be important to find ways of educating the wider community as to why these changes are necessary. It will also be important to explore new ways of assessing learning in science that more accurately measure students' capabilities to engage with science in their everyday lives. If we really want students to be able to deal with complex messy problems, then we need to value the ability to *find* problems, not just solve them.[35] Finally, if any of this is to get any traction there needs to be some sort of co-ordinated approach that encourages diversity while also ensuring that resources are used effectively.

[35] Perkins (2009).

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