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Primary and Secondary School Science Education in New Zealand (Aotearoa) – Policies and Practices for a Better Future

Prepared by
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Established by the
New Zealand government in 1995
to facilitate public policy dialogue
between New Zealand and
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Dave Vannier
Wellington, August 2012

EXECUTIVE SUMMARY

In 2006 and again in 2009, New Zealand (Aotearoa) students caught the attention of the world with their outstanding performance in science among their peers on the Programme for International Student Achievement. The triennial survey from the Organisation for Economic Cooperation and Development suggests that these 15-year olds are on track to tackle the complex challenges that confront society, such as global warming and pollution. While these results point to the strength of the New Zealand education system, there is growing evidence that too many children are not doing well in science and do not have access to effective instruction, especially at the primary level. This inequity is compounded by the observations that students who do less well are likely to be of Māori or Pasifika descent and from lower socioeconomic backgrounds. Accordingly, the education and science communities have recently called for increased attention to science instruction in New Zealand schools. Their concern is not merely with preparing future scientists but relates to enabling each child to "successfully participate in a society that is increasingly based on knowledge and innovation.[1]"

This report reviews science education in primary and secondary English-medium schools (as distinct from Māori-medium schools) in New Zealand and seeks to make sense of the current policies that guide it. It aims to connect the dots between education policy, successful science programmes, student and teacher engagement with professional scientists, research from the past fifteen years, and realities in the classroom. Personal interviews with stakeholders and a case study of primary schools engaged in highly-effective science instruction[2] are presented along with current education data. This report is intended to serve as a guide to policy makers, school officials, scientists, and others who have an interest in improving science education.

The case study analysis found commonalities among the schools succeeding in science instruction. Policies that promote these attributes are thus likely to be successful in improving science instruction and are the basis of the recommendations in this report:

- Science was valued, and staff were dedicated to the on-going improvement of its instruction. Schools focused on engaging students and teachers with science that was current and relevant to their lives. Inquiry-based, hands-on experiences were central to motivating students to learn.
- Strong leadership promoted a shared vision for student success. Principals supported teachers in being innovative and taking learning risks with their students as they strove to realise this vision.
- Teachers were highly-collaborative and consistently worked in teams to plan and implement instruction. Principals and other school leaders worked diligently to establish and support an effective team-based system.
- Principals were creative in the ways they deployed staffing and budget allocations to bring in people and resources towards improving science

[1] Education Review Office (2012) p. 22
[2] Schools were identified as engaging in highly-effective science instruction by the Education Review Office as further described in their 2010a and 2012 reports

instruction. They also structured the school timetable to create shared planning periods for teacher teams to meet.

These attributes directly addressed many of the common challenges to effective science instruction.[3] Strong leadership and team-based staff support improved the confidence, knowledge, and abilities of all teachers in science instruction. The dedication to the on-going improvement of science resulted in the development of instructional practices and assessments with a focus on student understanding and ability. School staff worked as one to deliver effective science instruction that engaged both the students and teachers. With the exception of the first point above, none of the attributes is necessarily specific to science. Engaging in these practices should help schools succeed in all educational areas. These strategies enabled the case-study schools to have highly-effective practices in science instruction because they applied them towards improving their science programmes.

The Tomorrow's Schools reforms[4] placed school governance in the hands of the principal, staff and a Board of Trustees comprising community members. While the Ministry of Education (MOE) coordinates education nationally by guiding curricular and governance documents, schools set their own curriculum in response to community needs and circumstances. The MOE provides schools with varied resources towards implementing the New Zealand Curriculum (NZC). These include professional learning opportunities, curriculum exemplars, internet-based learning networks, and information for boards, parents and whānau (families). Many of these resources are subject specific, but science has not been a major focus of the MOE since the release of the Mathematics and Science Taskforce report in 1997.

Schools are not the only entities engaged in primary and secondary science education. Scientists at universities, research institutions, and businesses provide an array of education programmes for students and teachers. They also offer analysis and advice to policy makers on improving science instruction. These many players create what is seen as a patchwork of autonomous programmes and opportunities across the country. This institutional autonomy makes strategies towards improving the overall system challenging. Professional science, business and community groups do what they will, based on their own interests and on their passion for the potential for all children to succeed in science. Although this patchwork of programmes is not coordinated, it allows for each entity to be innovative, responsive to the needs of their communities, and to take full ownership of their work.

The findings from this report seek to promote an environment where all students are engaged in learning science that is meaningful to their lives, teachers are confident and capable in science instruction, and science is nurtured as an essential component of everyone's education. To fulfil this vision in schools, teachers and principals will need consistent and tailored support in science. Policies must enable and reward collaboration in schools. Teachers will need opportunities to gain science knowledge and pedagogical understanding in pre-service programmes and in the classroom. Providers of science education programmes must be dedicated to on-going evaluation and improvement. Most importantly, all stakeholders must come together on

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[3] Most recently described in Education Review Office (2012)
[4] Taskforce to Review Education Administration (1988)

recognising the importance of science to the success of the individual and society. The 2007 NZC articulates this vision well. While the New Zealand science education system is composed of many independent parts, a common vision of excellence will increase the opportunities for all children to succeed.

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INTRODUCTION

> *Many of the major challenges and opportunities that confront our world need to be approached from a scientific perspective, taking into account social and ethical considerations.*[5]

Science is one of the eight learning areas that the 2007 New Zealand Curriculum (NZC) describes as "important for the broad, general education" that each child should receive.[6] Education researchers[7] and Ministry of Education (MOE) officials[8] view the upper primary years as a critical period to engage students in science for later success, yet surveys from the past decade[9] show that science is not consistently taught throughout primary school classrooms. The introduction of National Standards in 2009 has further pushed the learning areas of literacy and numeracy to dominate the primary-level curriculum. At the same time that the New Zealand government is seeking to spur innovation in science as a means to improve the economy, less and less emphasis is being placed on science instruction in primary schools.

This report reviews the current state of science education in primary and secondary schools in New Zealand (Aotearoa) and seeks to make sense of the policies that guide science instruction. It aims to balance these policies with the realities in the classroom and to identify actions to improve science instruction for all students. This report synthesises data from:

- education studies from the past 15 years;
- personal interviews with policy makers, educators, principals, teachers, and students; and
- a case study of six schools that are taking a balanced approach to science instruction in the upper-primary years.

It is intended to serve as a guide to both policy makers and school officials who have an interest in improving science education.

In 1988, New Zealand instituted a bold systemic change in its education system where each school became an autonomous entity. The Tomorrow's Schools reforms[10] placed school governance in the hands of the principal, staff and a Board of Trustees comprising community members. While the MOE coordinates education nationally through curricular and governance documents, schools set their own curriculum in response to community needs and circumstances. Each school develops a charter, an agreement with the MOE that includes goals and targets for student achievement. The charter is reviewed annually by Ministry officials. Through regular on-site visits, the Education Review Office (ERO) monitors the progress of each school towards meeting its instructional goals within the Ministry's guidelines and the school's charter. As such, the New Zealand education system provides a unique opportunity

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[5] Ministry of Education (2007) p. 28
[6] Ibid. p. 16
[7] Bolstad and Hipkins (2008)
[8] Author interviews 1 and 4 February 2012
[9] Summarised in Ministry of Education (2009a) and Education Review Office (2012)
[10] Taskforce to Review Education Administration (1988)

for schools to be innovative and take ownership of their practices, all towards the goal of providing the best education for the children of their community.

There is no standardised national testing of educational achievement in New Zealand. Instead, a national monitoring programme, known through 2010 as the National Education Monitoring Project (NEMP), uses a variety of measures to assess the achievement of primary school students. The qualifications and assessments within the National Certificate of Educational Achievement (NCEA) measure the progress of secondary school students. Both NEMP and NCEA are discussed in more detail in Chapter 2.

In 2007, the MOE released a new curriculum framework that coupled traditional learning areas with overarching competencies and values that all young New Zealanders are expected to acquire during the course of their 13 years of schooling (Table 1):

Table 1 – Directions for Learning in the New Zealand Curriculum[11]

Values	**Key Competencies**	**Learning Areas**	**Principles**
Excellence	Thinking	English	High expectations
Innovation, inquiry, and curiosity	Using language, symbols, and texts	The arts	Treaty of Waitangi[12]
Diversity	Managing self	Health and physical education	Cultural diversity
Communication and participation	Relating to others	Learning languages	Inclusion
Ecological sustainability	Participating and contributing	Mathematics and statistics	Learning to learn
Integrity		Science	Community Engagement
Respect		Social studies	Coherence
		Technology	Future focus

The NZC document shifts the instructional focus from a prescriptive list of topics to be covered, to one that aims to develop the whole learner. In the words of one science educator, "it put the professionalism back in the teaching profession.[13]" While the 2007 curriculum was well received by the profession, it has been challenging for many principals and teachers to understand and implement.

The learning area of science saw a shift in philosophy with the 1993 curriculum

[11] Ministry of Education (2007) p 7
[12] The Treaty of Waitangi, New Zealand's founding document signed in 1840, is an agreement between the British Crown and Māori chiefs.
[13] Author interview 6 April, 2012

guidelines in which ‘the Nature of Science’ was introduced as a component.[14] This was further emphasised in the 2007 NZC. Here the overarching Nature of Science ‘strand’ is where students learn what science is and what scientists do. Science is described by the verbs understanding, investigating, communicating, participating, and contributing. The Nature of Science is not a topic in and of itself but rather a means of approaching the four traditional content strands: the Living World, Planet Earth and Beyond, the Physical World, and the Material World. While the 2007 NZC presents a vision for science instruction that is engaging, relevant, inquiry-based, and student-centred, this change in approach has been a challenge for many teachers to implement. In brief, educators have trouble making students aware of the processes of science beyond the traditional “fair test” experimental design.

International student achievement studies paint a complex picture of science education in New Zealand. Many older students do quite well when compared to those in other developed nations. Younger students, on the other hand, perform more towards the median among their international peers. A series of reports on student achievement and classroom practice in elementary school highlights areas of concern, including little time for science despite student interest, few hands-on experiences, and teachers with insufficient knowledge and confidence in science instruction.[15] The picture in secondary school is improved, but there remains concern that students with less aptitude for science will be left out. Research also shows a high variation of achievement within schools, with many students from low socioeconomic backgrounds doing well and a significant proportion of students from high socioeconomic backgrounds who don’t.[16] These striking results have caught the attention of those outside the field of education, including leaders in the science and business communities.

In 2011, the Chief Science Advisor to the Prime Minister, Professor Sir Peter Gluckman, released *Looking Ahead: Science Education for the Twenty-first Century,* a report taking a critical look at science instruction. Sir Peter and many others share the vision for New Zealand as a “smart country where knowledge and innovation are at the heart of both economic growth and social development.[17]” He suggests bolstering science inquiry at the primary level, engaging the science community at all levels, and providing two tracks of science courses in secondary school – one for pre-professionals and another for citizenship in the 21st century. The Gluckman report spurred a conversation on science instruction within the MOE and led to the funding of three studies currently under way by the New Zealand Council for Educational Research (NZCER).

My Axford fellowship commenced at a time when primary and secondary school science education had a heightened profile, and both the education and science communities were focusing on its improvement. Ideally this report will be a useful document for education policy makers, the science community, school leaders, and teachers. It is organised in the following manner:

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[14] Ministry of Education (1993b)
[15] These observations are summarised in Bull and others (2010) and Education Review Office (2012)
[16] Caygill (2008) and Telford (2010)
[17] Gluckman (2011) p. 1

Chapter 1 details the policies that guide instruction in New Zealand schools today; the NZC, *Te Marautanga o Aotearoa*, the National Standards, and the NCEA. It describes the MOE's vision for science and the challenges schools face in implementing this vision. It ends with the observations from a 2012 report that few schools are engaged in effective science instruction in Years 5 through 8.[18]

A more complex picture arises in Chapter 2 where data from national and international studies on science teaching and learning are considered. New Zealand 15-year olds perform near the top of the science survey in the Organisation for Economic Development (OECD) Programme for International Student Assessment.[19] This assessment measures how well students apply their science knowledge to solving real-world problems. However, New Zealand has one of the widest distributions of scores of any participating OECD country. In international comparisons that measure science content knowledge in younger students, New Zealand performs just above the median score of 31 countries.[20] The differences between these assessments are discussed. ERO and NEMP data shed some light on these results by describing the teaching environment for science in Years 4 and 8.[21]

Chapter 3 describes the set of reports coordinated by Professor Sir Peter Gluckman that lays out a vision for science education in the twenty-first century. The Royal Society of New Zealand and other science-mission organisations also have an active interest in primary and secondary education. All promote a closer association between the professional science community and schools. Examples of these partnerships and their potential are highlighted.

To balance the national policies and actions of the MOE and science organisations, I conducted a case-study analysis of six schools across New Zealand. The ERO identified these schools as being engaged in highly effective science instruction in Years 5 through 8. Chapter 4 describes how these schools are succeeding in primary science when too many others are not.

The concluding chapter brings the information sources together and suggests actions to improve science instruction in primary and secondary schools. Fifteen years ago there was also a heightened sense of urgency to improve science instruction and the Minister of Education convened a Mathematics and Science Taskforce comprising educators, teachers, and principals to address the problem. I review the recommendations from their 1997 report[22] and reflect on their impact. I examine the science education system as a whole and point to challenges and opportunities for change. While this is a study of the science education system in New Zealand, I conclude with lessons that all others can learn towards improving instruction in their schools.

New Zealand and the USA see science and innovation as a key to securing a better economic future. There is a push in both countries to improve science instruction for all students, especially those in traditionally low-performing groups. At the same

[18] Education Review Office (2012)
[19] Telford (2010) and Telford and May (2010)
[20] Caygill (2008)
[21] Crooks, Smith and Flockton (2008) and Education Review Office (2010) and (2012)
[22] Mathematics and Science Taskforce (1997)

time, we are in the midst of worldwide financial crises where governments are showing little interest in funding new sweeping initiatives. The New Zealand science education system is composed of many autonomous parts. While this promotes innovation, the ability to meet community need, and ownership of practice, it creates challenges for policies aimed at improving the system overall. The recommendations in this report strike a balance between these tensions and point to a number of strategies towards improving science instruction for all.

1 THE CONTEXT FOR SCIENCE IN NEW ZEALAND SCHOOLS

The vision for learning in primary and secondary education in New Zealand is guided by two documents from the MOE, *The New Zealand Curriculum* (NZC)[23] for English-medium schools and *Te Marautanga o Aotearoa*[24] for Māori-medium schools. These documents set the direction for student learning and serve as guidelines for a school in designing its own curriculum. Descriptions of specific learning areas, subjects such as mathematics and science, are but one component. “Although they come from different perspectives, both start with visions of young people who will develop the competencies they will need for study, work, and lifelong learning and go on to realise their potential.[25]” As such, the learner and the learning environment are at the centre of the holistic vision for education described in each document. This report focuses on science instruction in English-medium schools and refers nearly exclusively to the NZC.

The 2007 New Zealand Curriculum

The 2007 NZC replaced the MOE’s curriculum framework that had been implemented in schools since 1993. During 2000 to 2002, a review of the old curriculum was conducted and a process for setting new guidelines was established. In 2006 a draft was released for public comment, and the current framework was released in November 2007. All public English-medium schools were required to adopt this new NZC by February 2010. Although there were challenges to implementation, schools were receptive to the new curriculum due largely to the careful and collaborative process used in its development.[26] The NZC described a vision for education that is broadly embraced – to develop “young people who are confident, connected, actively involved, lifelong learners.[27]”

Many refer to the 2007 NZC as having two distinct parts, a front end and a back end. The front end describes the vision, values, key competencies, and principles that set the learning environment. This emphasis is expanded in the 1993 curriculum guide.[28] The back end of the NZC contains a more traditional description of the eight learning areas (subjects) and specific achievement objectives for each area. The achievement objectives show the progression of knowledge and skills that each student should gain over 13 years of instruction. The objectives are not grouped by individual years, but by eight levels of two to three years each to allow schools flexibility in designing their curriculum.

Schools are required to provide instruction in all eight learning areas from Year 1 to 10. In Years 11 through 13, schools have more freedom to allow students to pursue their own interests. This is also the time that secondary school students seek to gain formal qualifications through the three levels of the National Certificate of

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[23] Ministry of Education (2007)
[24] Ministry of Education (2008b)
[25] Ministry of Education (2007) p. 6
[26] Cubitt (2006)
[27] Ministry of Education (2007) p. 7
[28] Ministry of Education (1993a)

Educational Achievement (NCEA). The NCEA is structured around a set of standards, and schools use "a range of assessments to measure how well students meet these standards.[29]" Assessments for the NCEA are administered by the New Zealand Qualifications Authority (NZQA), a Crown Entity[30] separate from the MOE. NCEA Level 2 is seen as the gateway qualification for a young person to succeed in further education or the workforce after secondary school. In 2010, 69% of school leavers had attained this level or higher[31]. A recent MOE goal is to have 85% of 18-year olds achieving the NCEA Level 2 by 2017.[32]

Science in the Curriculum

> *In science, students explore how both the natural physical world and science itself work so that they can participate as critical, informed, and responsible citizens in a society in which science plays a significant role.[33]*

This rationale for the study of science conveys that it is more than a body of knowledge to be learned. It is a discipline that we use to navigate society and understand the modern world around us. Science is one of the eight learning areas in the 2007 NZC, and it is described by five strands:

- the Nature of Science,
- the Living World,
- Planet Earth and Beyond,
- the Physical World, and
- the Material World.

The Nature of Science, which was reshaped in the 2007 NZC, focuses on what science is and what scientists do. It provides contexts for learning in the four other content strands. The NZC achievement objectives describe the Nature of Science under four broad categories:

- Understanding about science,
- Investigating in science,
- Communicating in science, and
- Participating and contributing.

The Nature of Science overarches and unifies the four other science strands and potentially connects with the values and key competencies that reach across all subject areas. Its communication, language, and societal aspects are also evident in the learning areas of English, social sciences, and mathematics and statistics. In fact, the 2007 NZC specifically recommends that all learning "make use of the natural

[29] *How NCEA works*, Retrieved 31 July 2012 from http://www.nzqa.govt.nz/qualifications-standards/qualifications/ncea/understanding-ncea/how-ncea-works/

[30] "Crown entities are bodies established by law in which the Government has a controlling interest - for example, by owning a majority of the voting shares or through having the power to appoint and replace a majority of the governing members - but which are legally separate from the Crown." Retrieved 31 July 2012 from http://www.treasury.govt.nz/statesector/crownentities

[31] State Services Commission (2012)

[32] Ibid.

[33] Ministry of Education (2007) p. 17

connections that exist between learning areas and that link learning areas to the values and key competencies.[34]" Many Nature of Science components (communicating and participating, thinking, using language, symbols, and texts) are evident in both the front end and back end of the NZC. With the overarching Nature of Science in place, the vision from the NZC is that students should learn science by experiencing what scientists do. Furthermore, students should understand what makes science a unique approach towards making sense of the world around us.

Implementation of the Curriculum

While the 2007 NZC provides a high degree of flexibility, its holistic, learner-centred approach was initially challenging for many schools when it was released. It took time for schools to understand the new direction of the curriculum. In the latter part of 2009, ERO found that "most schools knew what they needed to do and had made some progress towards implementation.[35]" In addition to the NZC document, the MOE developed support resources and guidance for schools to use in implementation. Schools were more successful in implementing the new curriculum if they had effective leadership, a collaborative staff, and a clear student focus.[36] A subsequent report[37] verified these factors and also identified external support (professional development and print resources) and community engagement as important in the curriculum's success. Barriers to successful implementation were ineffective leadership, staffing issues (turnover, inexperienced teachers, and veteran teachers unwilling to change) and lack of time. Schools that already had a collaborative system for reviewing their practice had an easier time embracing the new curriculum. A key finding from a review of implementation research was that it will take considerable time beyond the February 2010 deadline to achieve the NZC's goal of learner-centred education.[38]

Most schools that successfully implemented the NZC started with the front end of the curriculum (key competencies, principles, and values) and later turned to the learning areas.[39] While there are fewer formal data on the implementation of science, my interviewees pointed to the Nature of Science as the most challenging aspect for teachers to understand. This strand is different in that it is an overarching approach to instruction, not merely a list of content items to be covered. It continues to be an area of focus for professional development and teacher resources, especially at the primary school level. At the secondary school level, there is tension between the NZC science learning objectives and the items that are tested by the NCEA qualifications. Many of the science educators interviewed for this report are concerned that the Nature of Science is not well described and assessed in the NCEA qualification standards. These standards are currently being revised to align with the NZC science learning objectives and provide a more consistent vision for learning.[40]

The Nature of Science was a dominant theme at the 2012 annual meeting of the New

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[34] Ministry of Education (2007) p. 16
[35] Education Review Office (2010b)
[36] Ibid. and Cowie (2009)
[37] Schagen (2011)
[38] Ibid. p. 1
[39] Schagen (2011) and Cowie (2009)
[40] New Zealand Qualifications Authority (2012)

Zealand Association of Science Educators. This biennial conference assembles science teachers from across the country to share and improve their practice. It was clear that five years after the introduction of the 2007 NZC, teachers are still working to implement this strand in their instructional practices. Many acknowledged that they needed to make the Nature of Science strand more explicit to their students.

National Standards

As schools were working to understand and implement the 2007 NZC, the MOE released National Standards for reading and writing[41] and mathematics[42] for English-medium schools. The two documents describe the specific knowledge and skills in literacy and numeracy that students should have at the end of each year of schooling from Years 1 through 8. Published in 2009, they were required to be implemented in 2010. The standards are meant to keep students on track to succeed in secondary school, specifically in attaining the NCEA Level 2 qualification. Schools are required to set achievement targets in their charters. Unlike education standards in other countries, New Zealand's are not linked to a standardised test. Teachers have the freedom to use a variety of assessments, classroom observations, and analysis of student work to show that a child is performing at a specific level.

The National Standards also show parents, whānau (families), and caregivers how well their children are learning and achieving. Schools are required to report to these groups twice a year on a student's progress based on the standards for his/her year level. The impetus was to engage the community in their children's educational progress in obtaining the skills that are essential for success in all of the learning areas. The National Standards are written in plain language and provide a common framework for schools, teachers, and parents to discuss student learning and progress.

While the 2007 NZC was widely accepted by schools, the National Standards have met resistance due, perhaps, to the top-down approach and lack of consultation in their development. Teachers initially saw them as an increased burden to realising the 2007 NZC, although this view diminished as time went on.[43] The release of the National Standards coincided with a wider push on numeracy and literacy in primary schools that led to a reallocation of resources away from the other learning areas. As a result, MOE contracts for school support services in other subject areas were not continued beyond 2009.[44] Within these contracts were the science advisors, the university-based experts in pedagogy and content who supported schools in science instruction. In 2012, MOE re-initiated two-year contracts for external support in science, which are now coordinated through the regional offices.

Teacher Preparation and Licensing

From 2007 to 2010, the curriculum framework in New Zealand saw great changes that shifted the teacher's focus to the learner and away from a prescriptive list of content to be delivered. Initial teacher education is now being examined by the MOE and the

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[41] Ministry of Education (2009b)
[42] Ministry of Education (2009a)
[43] Education Review Office (2010b)
[44] Goodwin (2009)

New Zealand Teachers Council (NZTC). Teachers receive provisional registration after graduating from an accredited teacher education programme. The NZTC accredits programmes based on a set of Graduating Teacher Standards. Teachers are certified in primary education or in a specific subject in secondary education. The Board of Trustees follows guidelines from the NZTC to support new teachers in induction and mentoring programmes.

After two years of teaching practice in a designated school, a teacher may become fully registered if he/she meets a set of Registered Teacher Criteria as determined by the school's principal and supervising teacher. These criteria cover professional relationships and values as well as professional knowledge in practice. Teacher credentials are renewed every three years, based on the principal's judgement that the individual is meeting the Registered Teacher Criteria and participating in appropriate professional development. There are also a set of professional teaching standards that are associated with the collective employment contracts. These are used to set salary levels for teachers. There is a concern that two sets of standards send a mixed signal on what a teacher is expected to know and be able to do at different stages of his/her career.[45]

At the time of this report, most university faculties of education offer a three- or four-year programme of study resulting in a Bachelor's degree and a one-year course of post-graduate study ending with a diploma, such as a Masters. A growing concern is that primary education students are receiving less and less coursework in science and are thus less prepared to teach it as part of the required curriculum.[46] University science educators estimate that some primary teaching students receive as few as eight hours of science instruction during their undergraduate course of study.[47] Post-graduate teaching programmes are even less likely to have a science component. In May 2012, one of New Zealand's largest faculties of education moved towards dropping its multi-year undergraduate teaching programmes in favour of a one-year postgraduate diploma in education.[48] If fully implemented, it remains to be seen how this change may affect the quality of the teachers graduating from the institution. Pre-service science education for teachers was found to be a significant factor in the ability of a school to deliver high-quality science teaching and learning.[49] Furthermore, teachers are required to teach specific learning areas in the curriculum, not merely understand the content. A key component of effective teaching is having the appropriate pedagogical content knowledge for a given subject area.

Policy Actions and Implications

The Tomorrow's Schools reform completely changed the education landscape by reducing bureaucracy and giving schools autonomy. It established a direct connection between the MOE and individual schools under the Education Act of 1989. Within the Act, National Education Guidelines and National Administrative Guidelines are the major policy levers that the MOE uses to enact change at the school level. The 2007

[45] Nusche and others (2012) p. 77
[46] Education Review Office (2010a) and Bull and others (2010)
[47] Author interviews 6 April 2012, 10 April 2012, and 2 July 2012
[48] Duff (2012)
[49] Education Review Office (2010a)

NZC and 2009 National Standards were sweeping policy actions designed to improve the overall education system and provide a vision for learning. To implement these policies, the Ministry developed a significant amount of resources to support the NZC and later, the National Standards, including release time for teachers. Current work is under way to align the NCEA assessments with the learning objectives described in the NZC. The focus of more recent policy action has been on working towards meeting benchmarked criteria, such as the National Standards and attainment of the NCEA Level 2 qualifications. Nationals Standards also articulated expectations for student progress in primary schools. At present there are discussions about going one step further and providing public data on how schools are meeting these targets.

Other policy documents have also targeted specific groups and areas within the education system. Plans to improve the performance of Māori (indigenous) students were formalised and released as *Ka Hikitia – Managing for Success: The Māori Education Strategy 2008 – 2012*. This set out a vision of "stepping up the performance of the education system to ensure Māori are enjoying education success as Māori.[50] There is a similar plan for raising the achievement of Pasifika students, which is now under review.[51] Outside of literacy and numeracy, there has not been a major policy focus on specific learning areas. The last time science was addressed was in 1997 by the Taskforce on Science and Mathematics. This is discussed more at the start of Chapter 5. Lately, teacher quality and preparation have become a policy priority, and the MOE is working with the tertiary education community towards improving initial teacher education.

The autonomous nature of schools in New Zealand presents challenges to designing policies to create positive change across the entire system. The NZC and Māori-medium curriculum provide a unifying vision for schools to work towards in designing their individual programmes of study. These are framework documents, however, and open to a range of interpretations. The MOE will need to provide continued resources and support to enable schools to realise the full potential of their students.

[50] Ministry of Education (2008a) p. 10
[51] Ministry of Education (2011)

2 DATA ON SCIENCE TEACHING AND LEARNING

The New Zealand education system produces some of the top 15-year old science achievers in the world. The Programme on International Student Achievement (PISA) survey from the Organisation for Economic Cooperation and Development (OECD) suggests that these students are on track to tackle the complex science challenges that confront our society, such as global warming and pollution. The survey also points to large disparities in science literacy related to student ethnicity and a school's resources. The picture is still more complex in that there is a higher degree of variation in student ability within schools than between them. The OECD survey and others provide a myriad of data on students, teachers, and schools in New Zealand and other countries. Collectively the data do not identify a 'silver bullet' for raising student achievement in science, only a number of strategic starting points for policy and practice.

Measuring students' knowledge, attitudes, and abilities is a persistent challenge in education. There are a variety of subject-specific assessment tools currently in use at the classroom, school, national, and international level. This report considers five main evaluations that provide rich data on student achievement and engagement in science over time, as well as the context for learning science in the classroom. With the exception of the NCEA, all of the surveys described here use a sampling of students to infer the overall performance of the New Zealand education system. NCEA qualifications data only record the students who chose to participate at that level. The evaluations considered in this report are:

- PISA measures the ability of 15-year olds from across different countries to address real-world issues. PISA assesses knowledge and skills in writing literacy, mathematics literacy, and scientific literacy. It is more than a traditional test of content knowledge and measures how well a student can apply that knowledge in solving problems that are relevant to society. For example, the science literacy survey has had students examine the effects of acid rain on the Acropolis in Athens and the link between carbon emissions and global warming.

  The survey was launched in 2000 and runs every three years with one subject having a major focus each cycle. Science literacy was the major focus in 2006 and helped to better define six levels of proficiency in this area. As a result, only science data from 2006 and 2009 are comparable. New Zealand's scores were largely the same between the 2006 and 2009 surveys. Since science was a focus of 2006 there is a much more detailed set of data. As a point of comparison, most New Zealand students in the PISA 2006 and 2009 groups were in Year 11.
- The Trends in International Mathematics and Science Survey (TIMSS) is another means of comparing students from different countries. In comparison to PISA, TIMSS is oriented more towards a curriculum base and assesses by Year/grade rather than age. It is mainly oriented towards students in the upper-primary and intermediate/lower secondary school levels, Years 5 and 9 in New Zealand, Grades 4 and 8 in the USA. The survey has been conducted since 1994 on a four-year cycle and produces data that are comparable from one round to the next. New Zealand Year 9 students participated in 1994, 1998, and 2002, and Year 5 students participated in all four cycles from 1994 to

2006. Both years participated in the 2010/11 series, and these results will be released in December 2012.

- New Zealand's NEMP looks at Year 4 and 8 students' knowledge, skills, and motivations in all subjects over a four-year cycle. Science was a focus area in 1995, 1999, 2003, and 2007. The year 2007 saw the final round of NEMP for science. The project ceased collecting data in 2010, and a new National Monitoring Study of Student Achievement is currently underway in schools.
- The NCEA qualifications attainment data show how upper secondary school students are achieving. These data are compiled every year and have been made public since 2004. NCEA qualifications serve as a formal measure of students' abilities in secondary school and a predictor of potential success in tertiary studies and the workforce.
- Three national reports from ERO describe "capable and competent" science teaching practices in Years 5 through 8. These qualitative reports complement the student focus of NEMP by examining teachers and their practice.

Each of these evaluations has a unique view on what it assesses in science teaching, and learning. Most of these programmes also provide longitudinal data to highlight trends in the science education system.

Student Achievement in Science

The above surveys provide an enormous amount of data on student performance in science. Rather than dig deeply into complex statistical analysis, this report identifies the major trends and observations that influence policy and practice. The findings are structured as a set of six themes:

Observation 1- New Zealand secondary school students do very well on international achievement comparisons that measure application of science knowledge. Further, there is a high proportion of students at the top level of proficiency. Primary students perform at the international median on surveys that measure more traditional science knowledge.

- The science ability of New Zealand adolescents is very strong compared with their peers in other countries. This performance has been relatively stable over the period of the TIMSS results (1994 – 2002) and the two recent PISA surveys (2006 and 2009).
- TIMSS data show the performance of Year 5 students is at the average of their international peers. There was a steady increase in performance from 1994 to 2002, but this did not continue in 2006.

Observation 2 – New Zealand has one of the widest ranges in scores between high- and low-performing students in the PISA and TIMSS Year 5 surveys. When considering the percentage of students achieving at the high levels of scientific proficiency on PISA, the number not achieving basic proficiency is disproportionally large.[52]

Observation 3 - There are relatively few differences in the performance of boys and

[52] Telford and May (2010) p. 36

girls across the PISA, TIMSS, and NEMP surveys. While there are some differences in performance in specific content areas, gender equity does not appear to be a major issue for science education in New Zealand.

Observation 4 – There are significant differences in the achievement of ethnic groups. Students are assigned into one of six levels of proficiency based on their PISA science literacy scores. Level 6 is the highest and level 1, which is considered "below proficient", is the lowest. While all ethnic groups were represented across all the proficiency levels, the PISA 2009 data highlight this inequity (Table 2). Lower-performing students are more likely to be of Māori or Pasifika descent. Moreover, these students are less likely to be in the highest proficiency levels than Pākehā (New Zealanders of European descent) and Asian students. Māori or Pasifika students are more likely to be lacking a basic proficiency level of science literacy (above level 1).

Table 2 – 2009 PISA Science Literacy Scores by Ethnicity[53]

Group	Mean score	Percent at level 6	Percent at level 5 or higher	Percent at level 4 or higher	Percent at level 1 or below
Pākehā/European	555	4	21	51	7
Asian	530	4	17	41	14
All NZ students	532	4	18	43	13
OECD average	501	2	9	29	18
Māori	487	2	8	24	22
Pasifika	448	1	4	15	38

These differences in achievement are lessened, but do not disappear, when socio-economic factors and confidence in science are taken into account.[54]

Observation 5 - The increase in student achievement seen in the TIMSS Year 5 surveys from 1994 to 2002 was largely due to a rise in achievement among Māori and Pasifika students. This trend did not continue in 2006, when scores fell back to their 1994 level. Asian students were the only group that maintained an increase over the eight-year period (Table 3).

Table 3 – 1994 to 2006 TIMSS Mean Science Achievement Scores by Ethnicity[55]

Group	1994	1998	2002	2006
Pākehā/European	534 (3.9)	541 (4.8)	532 (3.0)	528 (2.3)
Māori	457 (12.0)	478 (8.0)	496 (5.2)	459 (4.9)
Pasifika	441 (14.9)	436 (13.8)	496 (5.2)	431 (5.4)
Asian	493 (16.7)	517 (10.0)	529 (4.2)	529 (6.8)
Other	521 (14.2)	497 (23.0)	536 (9.9)	502 (6.7)

Note: Standardised errors are presented in parentheses.

Observation 6 – While students from high-decile[56] and large, urban schools were

[53] Telford and May (2010)
[54] Caygill (2008) and (2009)
[55] Caygill (2008) p. 29
[56] New Zealand uses the term decile as an indicator of the socio-economic state of the community. Decile 1 schools are in lower socio-economic areas. Decile 10 schools are in higher socio-economic

likely to be higher achievers, the variation in student performance *within* a school was the largest of all OECD countries in the 2006 PISA. However, the variation *between* schools was significantly smaller than the OECD average. Finally, more than 90% of students attended a school where there were top science performers.[57]

Student Engagement in Science

Along with data on knowledge and skills, most of the surveys above also record student attitudes and aspirations towards science. While New Zealand secondary school students are some of highest science achievers in the world, they show average interest in the subject compared with their peers in other OECD countries.[58] They are above the average of their international peers in believing that learning science is generally useful and would improve their career prospects. They are equal to the OECD average in terms of science career aspirations. Similar data are found in the TIMSS surveys. Not surprisingly, students with a positive attitude towards science and confidence in their abilities perform better in achievement tests. In the PISA 2006, 90% of New Zealand student participants were taking a science class. Students who were enrolled in a science class far outperformed those who were not, regardless of gender or ethnicity.[59] The NEMP 2007 data showed a trend that Year 8 students were significantly less engaged in science than in the previous years.[60]

As one of the eight learning areas in the NZC, science is a compulsory subject for students until the end of Year 10. NCEA data on participation and engagement are thus a measure of student interest when science is no longer a required subject. The past three years of NCEA data (2007 to 2009) are consistent, and 81% of candidates were in a science course, usually general science or biology, at Year 11. Participation drops to 48% at Year 12 and 37% at Year 13. A closer look at participation and attainment of 14 or more credits in a Year 11 general science class highlights inequities correlated with ethnicity. Māori and Pasifika students are slightly less likely to participate in a Year 11 general science class and much less likely to attain NCEA credit in that class than their Pākehā and Asian peers. Participation and attainment disparities by ethnicity are more pronounced in Years 12 and 13.[61]

The School Environment for Science

A number of studies point to changes in the primary school classroom that have implications for science instruction. The picture is more stable at the secondary school level. Both the NEMP and TIMSS report a significant reduction in the amount of time spent on science instruction in the primary classroom over the past decade. Interestingly, 71% of Year 4 students and almost half of Year 8 students reported that they wanted to do more science at school.[62] The NEMP 2007 data also point towards a trend away from hands-on experiments and towards more book work. At the primary level, the TIMSS 2006 survey found teachers to be less likely to have a pre-

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areas.
[57] Telford (2010)
[58] Ibid.
[59] Ibid. p. 43
[60] Crooks, Smith and Flockton (2008)
[61] Education Counts (2010)
[62] Crooks, Smith and Flockton (2008)

service specialisation in science and receive less professional development as in-service teachers compared with their international peers.[63] Finally, a 2007 survey of primary principals found that very few (2%) indicated that improving science instruction was a curricular priority for their school during that year.[64]

The most in-depth picture of science teaching in New Zealand schools comes from a series of reports released by the ERO. In 2004, *The Quality of Teaching in Years 4 and 8: Science* examined practices at 233 schools and was designed to complement the student data from NEMP. At this time, 48% of the 233 schools sampled were found to have effective practices in science teaching; this was based on six factors, including student engagement and achievement, teacher pedagogical knowledge and application, and assessment.[65] A further 40% of schools showed adequate practice. There was a strong correlation between teacher effectiveness and recent professional development. Accessing the expertise of science advisors was the most common form of external support teachers received.[66] However, less than half of the teachers reported receiving professional development in science in the past year. Many teachers said they had greater confidence in delivering instruction in other learning areas, such as literacy. Effective assessment of student learning in science was also identified as an area in need of improvement.

The 2010 *Science in Years 5 to 8: Capable and Competent Teaching* report defined effective practice based on observations at 13 exemplary schools. This report ends with a long list of indicators of capable practice in science[67]. The indicators are divided into the headings of leadership, planning and assessment, and classroom teaching of science. A set of self-review questions based on the indicators is provided to guide schools as they review and improve their science programmes. While schools surveyed in the report showed exemplary practice, all faced significant challenges to developing and maintaining their science programmes. These challenges were summarised as[68]:

- Teachers' lack of confidence and ability in teaching science
- The lack of science preparation in initial teacher education
- Developing teaching strategies that constantly improve student understanding and thinking,
- The assessment and reporting of science achievement, and
- Accessing effective professional development opportunities in science

ERO's third report on science education in Years 5 through 8, released in May 2012, points to a system greatly in need of improvement if New Zealand is to continue to maintain its performance in international studies. In a survey of 100 schools from across the country, only three were found to be engaged in highly effective science practice and 24 had science programmes that were deemed generally effective. The

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63 Caygill, Lang and Cowles (2010)
64 Schagen and Hipkins (2008)
65 Education Review Office (2004) discusses the criteria in greater detail
66 Education Review Office (2004) p. 14: The MOE provided subject-specific curriculum advisors to schools through recurring Student Support Services contracts, which were typically with university faculties of education.
67 Education Review Office (2010a) Appendix 1
68 Education Review Office (2012) p. 5

report identifies nine components that the effective schools shared, and 12 characteristics of the lower performing schools, which comprised 73% of the total sample. The characteristics of schools practising effective science instruction are[69]:

- School leaders who were very actively promoting science teaching and learning, working in partnership with a curriculum leader with a passion for science
- Support provided for staff to raise their confidence and competence in science teaching through ongoing professional learning and development opportunities
- Clear expectations and guidelines for teacher planning with opportunities for students to experience all curriculum strands within an agreed timeframe, with a regular focus on the Nature of Science strand, particularly on the investigative process and the language of science
- Flexible and responsive programmes clearly connected to students' interests and daily lives
- Science-specific lessons, directly related to an identified science concept
- Hands-on, cooperative learning activities that engaged students with teachers acting as facilitators as students influenced the direction of their own learning
- The successful integration of science with literacy and mathematics learning, and with an inquiry learning approach
- Clearly defined, expected learning outcomes outlined for students, with progress assessed through science-appropriate assessment tools
- Regular evaluation of science programmes through well-developed school self-review.

Policy Actions and Implications Centred on Student and Teacher Data

International and national surveys provide the foundation for policy decisions on student learning in science. The PISA, TIMSS, and NEMP studies all present, analyse, and draw inferences from their data. More importantly, they are all designed to show trends over time. These surveys provide the raw data for informing new or revised policies. The ERO reports extend their data analyses with specific policy recommendations. The results from the TIMSS 1994 survey spurred the Minister of Education to form a Mathematics and Science Taskforce to raise student achievement in these subject areas – this is discussed in more detail in the concluding chapter. At the present time, the NCEA data also serve as a specific benchmark for success of the education system.

As one of the top 10 priorities of their government in 2012, Prime Minister John Key and Education Minister Hekia Parata have set the goal of 85% of 18-year olds attaining NCEA Level 2 qualification by the end of 2017. This will be a significant increase from the 2010 mark of 67%.[70] Secondary schools are required to report their NCEA attainment data annually and make them publicly available. There is no science-specific requirement within this NCEA Level 2 goal; rather, it is used as an

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[69] Education Review Office (2012) p. 8 and following examines these characteristics in detail.
[70] State Services Commission (2012)

overall measure for student success. A further point for secondary school science comes from the PISA data. New Zealand secondary students do extremely well in science when they continue to study it until the end of Year 11. If science is important, this has implications on the compulsory requirements of the NZC ending at the conclusion of Year 10.

The results from the PISA, TIMSS, NEMP, and NCEA data point to ethnic inequities in science achievement. These inequities are seen throughout the New Zealand education system and strategic documents such as *Ka Hikitia* and the Pasifika Education Plan are seeking to address this. These plans work to ensure an effective and respectful learning environment where Māori and Pasifika children may flourish. Neither have subject specific goals or requirements. Interestingly, the OECD used PISA data to examine "resilient" students, those who thrive academically despite coming from disadvantaged backgrounds. *The Against the Odds* report raises the notion that taking more science courses benefits disadvantaged students more than their advantaged peers.[71]

Statistical analysis of the TIMSS 2006/7 results of Year 5 students points to strategies that may help to lessen the inequities in performance of Māori and Pasifika students compared to their Pākehā and Asian peers.[72] There was a positive correlation between leisure time spent reading and achievement in science (and maths as well). Students who are self-confident in science also show higher achievement. It could be worth considering strategies that raise student confidence and promote reading. These are two areas where teachers and parents may help increase Year 5 student achievement in science.

It is important to stress that all ethnicities were represented in the highest-performing groups of all assessments. As well, students from all ethnic groups were found at the lowest levels of achievement. The 1997 Mathematics and Science Taskforce makes the point that "for a great many complex reasons, teachers, parents/caregivers, the wider community, and the students themselves appear to have low expectations of success in mathematics and science for Māori and Pacific Island students. There is no reliable evidence to support this claim.[73]" The Taskforce stressed that the expectations of teachers and parents need to be raised so that all children can succeed in mathematics and science.

The observation that these studies found more variation in student achievement within schools that between schools identifies strategic areas for policy actions. A 2009 MOE report notes that the within-school variability "reinforces the notion that there is a diverse range of student ability within schools, emphasising that students start schools with different knowledge and skills, and learn at different paces. [74]" It thus falls on the classroom teacher to move all children forward in their learning. As such, teacher preparation and quality are a strategic area of focus. This is not the only consideration, the report goes on to point out the "clear link between school decile (as an indicator of the extent to which schools draw students from low socio-economic

[71] Organisation for Economic Cooperation and Development (2011) p. 11
[72] Caygill (2009)
[73] Mathematics and Science Taskforce (1997) p. 3
[74] Ministry of Education (2009a) p. 4

communities) and science achievement, with students in higher-decile schools having higher achievement, on average, than those in lower-decile schools." School resources, including their staff, are one of the issues here. Taken together, these data support the need to focus on teachers (within schools, not between) and students who need the most help. Most of the studies show a weakening of science instruction and achievement at the primary level over the past fifteen years. While there has not been a corresponding drop in student science achievement, it has many educators concerned.

The differences in achievement between the PISA and TIMSS data also have implications for the goals of science instruction in New Zealand. PISA measures students' ability at solving science problems in a societal context. The TIMSS items are more content- and curriculum-based. The differing performance on these two instruments raises a discussion point for examining the purposes for teaching science in primary and secondary schools. The Chief Science Advisor to the Prime Minister recently started a conversation on the purposes of science education in New Zealand schools. This topic is explored more deeply in the following chapter.

3 SCIENCE EDUCATION AND PROFESSIONAL COMMUNITIES

The New Zealand professional science community has a history of engaging with schools, teachers, and students in programmes aimed at enriching and improving science learning. The Royal Society of New Zealand, an organisation that promotes science, technology and the humanities, conducts such programmes and commissions studies and policy reports on science education. A number of these programmes have been supported by government funding from the Ministry of Science and Innovation and its precursor the Ministry of Research, Science and Technology. With the establishment of a Prime Minister's Chief Science Advisor in 2009, the professional community gained a more prominent role in advising national policy. Science education was quickly set as one of six issue areas. In April 2011, Professor Sir Peter Gluckman used his platform as the Chief Science Advisor to release a report that lays out a vision for science education in the twenty-first century.

The Science Community and Education Policy

The 2011 Gluckman Report, *Looking Ahead: Science Education for the Twenty-First Century,* takes a careful look at science instruction in primary and secondary schools and considers the future needs of New Zealand society. Sir Peter sees a smart, innovation-minded population as the key to the country's future prosperity. The title section of the report is a forward-thinking piece that suggests purposes for science instruction in primary and secondary schools. Sir Peter argues that "a well prepared primary teacher will integrate excitement about the natural world and scientific forms of thinking into literacy and numeracy teaching, and into general educational purposes.[75]" He acknowledges that many primary teachers do not have the confidence to do this and calls on "science champions" to provide support. In secondary schools, he identifies two outcomes that need to be attended to – one that enables students to continue in further study and science careers (pre-professionals) and another that produces citizens who have a "clear understanding of the complex world of science that they will confront as citizens over the next 60 years of their lives.[76]" Sir Peter points out the inequities that need to be addresses to raise the achievement of Māori and Pasifika students. Finally, he concludes that policy makers, teachers, and the scientific community must work together to improve science education from a system that is promising to one that is outstanding.

Prior to releasing *Looking Ahead*, Sir Peter and the Royal Society commissioned *Inspired by Science*[77], a report that looks at the 2010 state of science education in New Zealand. The report identifies four purposes for science education:

1. Preparing students for a career in science (pre-professional training)
2. Equipping students with practical knowledge of how things work (utilitarian purpose)

[75] Gluckman (2011) p. 4
[76] Ibid. p. 5
[77] Bull and others (2010)

3. Building students' science literacy to enable informed participation in science-related debates and issues (democratic/citizenship purpose)
4. Developing students' skills in scientific thinking and their knowledge of science as part of their intellectual enculturation (cultural/intellectual purpose)[78]

Inspired by Science also notes that "while the practice of science research has changed over the last century or so this is not evident in how science is taught in schools.[79]" The report details a concrete scenario for how the difference aspects of science education could be addressed across the primary, middle, and senior secondary years. It notes that this scenario is compatible with the 2007 NZC.

Inspired by Science was the catalyst for a discussion paper from the Science Advisory Committee of the Office of the Prime Minister entitled *Engaging Young New Zealanders with Science.*[80] The Committee identified five key challenges and actions towards improving school science education:

1. Create opportunities for communities to discuss the purposes of science education at different levels during schooling.
2. Develop alliances between teachers and scientists to understand the impact of the changing nature of science research on science education.
3. Enable effective science education in primary schools by identifying the needs of primary teachers around science instruction and how to meet them.
4. Understand the diverse needs of upper secondary students and engage secondary and tertiary groups toward this goal.
5. Address the challenge of raising the performance of low-achieving students, many of whom are Māori and Pasifika.

The report stresses that these challenges will be met by engaging all stakeholders and using evidence to make decisions. As a whole, these three reports stress the need for the science and education communities to come together to work toward a system that will be outstanding in the 21st century. A forthcoming report from the Royal Society of New Zealand echoes this call and suggests similar ways forward.[81]

The MOE recently responded to the Gluckman report with a set of five initiatives aimed at raising student achievement in science at the primary and secondary level.[82] The Ministry has commissioned three studies on science in the curriculum. One examines the resources around teaching the Nature of Science, the overarching strand in the NZC science learning area. The second looks at the extent of engagement between the science community and teachers. Connecting schools with an ultra-fast broadband network is a current priority at the MOE. A third study looks at the use of e-learning and online tools to enhance instruction. There will also be a summary report on the findings from all of these studies. This work is currently under way at

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[78] Bull and others (2010) p. 7
[79] Ibid. p. 31
[80] Office of the Prime Minister's Science Advisory Committee (2010)
[81] Author interview 5 March 2012
[82] These are described in a 02 July 2012 circular to principals and all teachers of science, New Zealand Qualifications Authority (2012)

the New Zealand Council for Educational Research.[83] The Gluckman report also spurred the Ministry to provide professional learning development opportunities in science for primary and secondary teachers.

Finally, *Inspired by Science* initiated the internal review of NCEA qualifications structure in light of the observation that progressively fewer students continue with science classes as they progress through Years 11 to 13.[84] The NZQA also extended the expiry date of NCEA Level 1 science qualifications that many saw as necessary to engaging lower-performing students in science. The announcement of this extension was made in the middle of the 2012 biennial meeting of the New Zealand Association for Science Educators and received a mixed response among the science teachers present. Many felt that these standards are too low and do not adequately prepare students to succeed at the Level 2 qualifications, which are seen as the basic qualification for completion of secondary school. Others felt that they could not design a science course for students to attain the Level 1 qualification without these standards. The NZQA circular acknowledges this and states that "schools that continue to use these unit standards would need to give priority to developing new and meaningful pathways in science.[85]"

Education Programmes from the Science Community

The above policy reports call for a closer association between the professional science community and schools. There are presently numerous examples of such programmes from the science community in schools across New Zealand. This section highlights a few of these partnerships and their approaches. It is by no means an exhaustive list but a sampling to illustrate ways that the science community engages with primary and secondary schools.

The Royal Society of New Zealand is one of the oldest organisations representing professional science. The Society has a wide array of initiatives that target students and teachers for the purposes of improving science education. The Society website lists programme offerings and other resources, including funding, aimed at science teachers and students.[86] The most prominent programmes are:

> **Advancing Primary Science** is a recent initiative designed to strengthen educators' confidence and ability in teaching science. It does this through teacher education activities, encouraging the science community to engage in primary science, and highlighting science resources that support numeracy and literacy. The second annual Primary Science Week, held 7 to 11 May 2012 in collaboration with the New Zealand Association of Science Educators, brought together numerous partner organisations to provide after-school professional development opportunities for teachers in 10 regions across New Zealand and online.
>
> The **Teacher Fellowships Programme** engages primary and secondary

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[83] Further information on these projects is at http://www.nzcer.org.nz/research/science-curriculum, retrieved 30 June 2012.
[84] Author interview 24 Feb 2012
[85] New Zealand Qualifications Authority (2012)
[86] http://www.royalsociety.org.nz/teaching-learning/, retrieved 30 July 2012

school science teachers in a 20-week (two school terms) research experience. Teachers are placed in science and technology research settings at universities, Crown research institutes, museums, and businesses. The primary teacher programme includes professional development on the nature of science and leadership with an aim to develop the Fellows as science champions once they return to their schools.

Science Competitions for Students – the Society coordinates the BP Challenge, the CREST Awards, and Realise the Dream, all of which are competitions for students that encourage and award innovative and creative thinking in science.

Science departments in universities often have an education and outreach programme aimed at improving primary and secondary school science education. These can provide opportunities for students and teachers. Three representative examples are:

LENScience from the Liggins Institute at the University of Auckland provides life sciences experiences for schools at Years 7 through 13. Students come to the Institute to engage in structured science activities using state-of-art laboratory equipment. Support is also provided to teachers to extend the experience in their classrooms. The activities are aligned with the NZC, emphasise the nature of science, and are based on the research activities at the Institute. During the summer, Year 13 students have the opportunity to work alongside scientists and gain an understanding of research at the university setting. LENScience has a focus of providing these opportunities to students and schools most in need.

Te Rōpū Āwhina at Victoria University of Wellington is an on-campus whānau that supports Māori and Pasifika students in studies at the faculties of science, engineering, architecture, and design. While the focus of the programme is the success of Māori and Pasifika students, all ethnicities can be part of the whānau. Āwhina started as a peer-to-peer mentor programme to support Māori and Pasifika tertiary students and has expanded to reach out to students in Years 9 through 13 in the Wellington area. Āwhina graduate and undergraduate students visit schools on a regular basis to guide secondary students in science. Events throughout the year bring students in Years 7 through 13 to Victoria University to engage in research activities and celebrations of science. Notably, the programme is run on a nearly entirely voluntary basis with Āwhina members donating their time to enable the growth of others.

The **Science Learning Hub**[87] from University of Waikato is a free online resource for science teaching at Years 5 to 10. It features web-based articles, videos, and interactive activities that are aligned to the NZC. It also presents science research in a manner that is accessible to students and teachers. This online resource was initiated with funding from the Ministry of Research, Science and Technology (MoRST). It received continued support from the Ministry of Science and Innovation (MSI), which replaced MoRST.

[87] http://www.sciencelearn.org.nz, retrieved 30 July 2012

Science- and engineering-based organisations across New Zealand support a variety of partnership programmes with schools. These include:

Futureintech Ambassadors is an initiative of the Institute of Professional Engineers New Zealand that promotes education and careers around science, technology, and engineering. Ambassadors are young science and engineering professionals who visit classrooms to engage students in a technology or science-based activity and discuss careers in these fields. There are eight regional coordinators across New Zealand who facilitate this partnership between schools and industry.

The **Enviroschools** Foundation promotes sustainability and environmental sciences by partnering with individual schools to engage in school-wide and community-based projects. The Enviroschools programme typically engages a group of students within a school on implementing sustainable practices such as recycling and composting. Schools are awarded for their commitment to sustainability. Currently 28% of New Zealand schools participate in this programme.[88] **Schoolgen** is a similar sustainability-focused programme from Genesis Energy Company that outfits a school with solar panels and engages students in energy conservation and green building practices.

NIWA Science and Technology Fairs - Science fairs are a common approach to engaging students in an authentic process of discovery. The National Institute on Water and Atmospheric Research (NIWA), one of the Crown research institutes, is a major sponsor of regional science fairs across the New Zealand north island. NIWA's aim in this endeavour is to promote science careers and enhance science and technology education.

The Science Roadshow is a travelling programme sponsored by the dairy industry giant, Fonterra, that brings engaging and interactive science experiences to schools and communities. The roadshow website provides schools and teachers with resources on how to incorporate a visit with their regular course of study.[89] The experience is aimed at students in Years 5 through 9.

The Greater Wellington Regional Council, a local government authority, developed a **Take Action for Water Curriculum**. This is an in-depth unit on ecology that schools implement in the classroom for up to a 10 week period, one school term. In addition to the curricular materials, the programme provides professional development for teachers and facilitators who work with students in the classroom and on field trips. The lessons are specifically designed to meet the NZC for Years 5 through 8. Many other regional councils across New Zealand have similar programmes.

LEARNZ is a virtual field-trip programme[90] that is free to all schools in New Zealand. It began with a focus on science research in Antarctica and now

[88] http://www.enviroschools.org.nz/our_organisation/about-enviroschools/enviroschools-stats, retrieved 29 June 2012.
[89] http://roadshow.org/index.php, retrieved 30 July 2012
[90] http://www.learnz.org.nz/index.php, retrieved 30 July 2012

offers students the ability to participate via the internet on a wider range of real-life experiences. Students interact with researchers and a lead teacher online during the trips, which last from a few days to a few weeks and are scheduled across the school year. Topics include whale migrations along the coast, wetland biodiversity projects, and the rebuilding of Christchurch after the earthquakes of 2011/12. The focus of LEARNZ is predominantly science, but also includes a few offerings in the areas of social studies and the arts. The New Zealand Department of Conservation, the Earthquake Commission, and other science-focused organisations enable this project as well.

One unique programme, in that it was not initiated from the science community, is the **Matakokiri Science Initiative**, which brings together Māori youth ages 7 to 15 with nearby science professionals and facilities. In 2011 Ngati Whakaue, an iwi (tribe) around Rotorua, started this school-break science camp to provide their children with a week-long, hands-on experience in different sciences. The initiative is driven by the iwi management officials, who are not scientists. The iwi sees achievement and training in science as a critical area for their prosperity and is actively promoting its study among its tamariki (children) and rangatahi (adolescents) through this camp. Matakokiri is the name of an asteroid and refers to the Ngati Whakaue rangatahi "lighting up the night sky with their knowledge.[91]"

Not all collaborations between the science community and schools are on-going like the programmes above. The Transit of Venus in early June 2012 brought scientists and schools together to celebrate an astronomical event of special relevance to New Zealand. Captain Cook's 1769 voyage to the South Pacific was to observe the planet Venus move across the Sun so that astronomers in England could use the measurements to estimate the distances between objects in our solar system. After observing the transit in Tahiti, Capitan Cook continued his voyage and arrived in New Zealand later that year. The 2012 Transit of Venus provided schools with a rich and relevant topic to discuss science. The Royal Society of New Zealand, the Royal Astronomical Society of New Zealand, and four planetariums across the country offered programmes for children and resources for teachers centred on the transit. Despite cloudy conditions over most of New Zealand on the day of the transit, 6 June 2012, many students watched the transit streaming live over the internet. With the expansion of ultra-fast broadband, more schools will have the opportunity to integrate real-time science exploration into their classrooms. These organisations also provide similar resources every year around Matariki, the Māori New Year, which occurs on the first new moon after the rise of the Matariki (Pleiades star cluster) constellation in the night sky. In 2012 this day was 21 June.

Policy Actions and Implications from the Science Community and Others

With the appointment of a Chief Science Advisor to the Prime Minister, the science community has a more direct voice in national policy. The Gluckman report on science education initiated policy actions at the MOE in late 2011 and continues to do so today. The science community itself is engaged in education activities aimed at primary and secondary schools. While these programmes collectively provide a wide

[91] Ngati Whakaue (2011)

variety of experiences for teachers and students to engage with real-world science, there is little coordination among them. There are also few rigorous evaluations that measure the effectiveness of these programmes in meeting their science education goals. A number of educators interviewed for this report describe this as a patchwork of resources for schools from the science community. The implications of this observation are further explored in the final chapter.

While there are many programmes and resources available from the science community, teachers and schools that need assistance in science are often unable to find or utilise appropriate resources.[92] The Primary Science Week initiative from the Royal Society of New Zealand and the New Zealand Association of Science Educators is starting to address this concern at the primary level. Through 2009, the MOE-contracted science advisors helped to match science resources, including programmes from the professional community, with the needs of schools. At present there is not a consistent system to do this, although there is a clear need. The New Zealand Council for Educational Research is undertaking a survey to assess the utilisation of resources from the science community.[93] Data from this study should also inform strategies to enable teachers to find and effectively use appropriate science resources in the classroom.

Many of the above initiatives have been funded by MSI and its predecessor MoRST. MSI also initiated research and policy studies on science education. In July 2012, four government ministries were consolidated into the Ministry of Business, Innovation and Employment (MBIE), which is meant "to be a catalyst for a high-performing economy to ensure New Zealand's lasting prosperity and wellbeing.[94]" Science is at the core of this initiative, and MSI is one of the ministries that are now part of MBIE. It is presently unclear how much of a priority, or even a component, primary and secondary science education will be in this fledgling agency's agenda.

During the past decade in the USA, the business community has become a major driver for policies to strengthen science education in primary and secondary schools. Business leaders voiced the concern that the current American education system is not producing the skilled workforce they need to remain competitive. While the New Zealand business community has been vocal about science and innovation being important to the country's prosperity, there has not been the same engagement towards improving science education. These conversations may be beginning to take place. In June 2012, the Royal Society convened a conference looking at the role of science in the future prosperity of New Zealand. Participants from the business sector, iwi, and the science and education communities all talked about developing an innovation economy as the future to New Zealand's success. These stakeholders agreed on the importance of doing this in a way that is inclusive and community-based, so that all see themselves in the future of New Zealand. Primary and secondary school science education has not, yet, become a full part of these discussions.

None of the professional community's programmes will have maximal impact if they

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92 Education Review Office (2012)
93 http://www.nzcer.org.nz/research/science-community-engagement, retrieved 31 July 2012
94 Ministry of Business, Innovation and Employment website, http://www.mbie.govt.nz/, retrieved 1 July 2012

do not support the science instruction that students experience in schools. There is a danger that an engaging science activity away from school will only heighten the sense among students that classroom science is boring. Scientists and educators must work together to integrate real-life science experiences across a child's years at school. It is thus critically important to understand the context for science in today's classrooms. The next chapter describes how six schools are able to engage students with highly-effective science instruction at a time when too many others struggle to do the same.

4 LESSONS FROM THE CLASSROOM

In order to balance the policies that guide science instruction with classroom realities, I undertook a case study analysis of six schools engaged in "highly-effective" science instruction at the late primary level.[95] These schools are giving science a balanced and relevant place in their curriculum among the other seven learning areas. They are implementing the guidance of the NZC with the Nature of Science strand infused throughout the four science content strands (the Living World, Planet Earth and Beyond, the Physical World, and the Material World). Through this study I sought to identify the common policies and practices that give rise to their success in science instruction at a time when too many other schools struggle to do the same.

The 2012 ERO report on science instruction in Years 5 through 8 found only three schools out of 100 surveyed engaging in "highly-effective" practice. Twenty-four schools showed "generally-effective" practice. A 2010 ERO report studied 13 exemplary schools to identify capable and competent practices in science instruction in Years 5 through 8. ERO's characteristics of effective practice are described here in Chapter Two and in greater detail in their 2010 report.[96] At my request, ERO officials contacted principals at six of these top 16 schools to gauge their interest in participating as a case study school. With consent from the principal, ERO provided me with the school contact information. I explained the details of my study to each principal and, with their consent to participate, scheduled two-day visits to examine their science programmes.

This report generally considers science instruction across Years 1 through 13 but specifically focuses on Years 5 to 8 for the school case studies. The environment for teaching science at the primary level is very different from secondary school, especially in Years 11 – 13. To make the most of my time and resources, I limited my observations to Years 5 to 8. Education researchers[97] and MOE officials[98] view these intermediate years as a critical period to engage students in science for later success. A focus on these years allowed me to use one protocol to look at a number of variables within a common set of curricular guidelines. In Years 5 to 8 there are:

- various school organisational structures (Primary with Years 1 - 6, Primary with Years 1 to 8, Intermediate/Middle with Years 7 and 8, Area with 1 through 13, etc.),
- various educational backgrounds and qualifications requirements for teachers (primary educators versus science specialists at secondary level),
- common guidelines in the NZC where science is compulsory for all students, and
- relevant data from ERO, NEMP, and TIMSS reports.

During a two-day visit to each school, I interviewed the principal, the staff responsible for science, and the teachers of Year 5 to 8 students (see Appendix 1 and 2 for survey protocols). I reviewed documents relevant to the planning and implementation of

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[95] Education Review Office (2010a) and (2012) describe highly-effective science practice
[96] ERO (2010a) Appendix 1
[97] Summarised in Bolstad and Hipkins (2008)
[98] Author interviews 1 and 4 February 2012

science instruction, such as strategic plans and timetables. I examined recent science lesson plans and student work. If possible, I observed science instruction in the classrooms. My visits occurred during May and June 2012 (Term 2 of the four-term school year) and not all schools were engaged in science with Years 5 through 8 students at this time. In contrast, students receive instruction in literacy and numeracy nearly every day across the entire academic year. In most schools, I also had informal conversations with students on their experiences with science. None of the schools, teachers, or principals was compensated to participate in this study. On the contrary, schools generously absorbed the cost of release teachers so that I could interview the regular teachers during the school day. All participants and schools in the study were assured that they would be anonymous in this report.

Profiles of Case-Study Schools

The six schools in this case study collectively represented a range of geographic localities and organisational structures. They were not as socioeconomically or ethnically diverse as the array of schools in New Zealand. From the TIMSS and NEMP surveys, it is not surprising that the schools found to be succeeding in science are predominantly Pākehā and mid- to upper-decile. All of the schools had recently examined their science programmes and were actively working to improve them. A brief description of each school follows in random order:

School 1 is a large primary with Years 1 through 6 located in a major urban area. The school has a philosophy of student-centred inquiry that goes across all instructional areas. Students are organised into a number of single-year classrooms where teachers work in teams to coordinate instruction. Science instruction lasts two to three weeks (typically alternating with social studies) and focuses on big ideas, such as adaptation. The principal is a strong leader for inquiry and for science across the school. The teams of teachers review their plans to be sure that all four science learning areas receive coverage across the school year.

School 2 is a large primary with Years 1 to 8 in a major urban area. It also has a school-wide philosophy of student-centred inquiry, although it is different from the model above. Students are organised in blended classrooms with two years present, and teachers plan together to coordinate instruction. In the past five years, the school examined its science programme and made changes towards improvement. After this planning period, the whole school engaged in a year-long science topic to celebrate their environment and community. Now students experience science in periods of less than 10 weeks. All learning areas for science at a given NZC level are covered over a two-year period. The culmination of science for students in Years 7 and 8 is a project designing and conducting their own inquiries for a science fair that is presented to the entire school.

School 3 is a rural school with approximately 50 students in Years 1 through 8 split into three classrooms. The half-dozen full- and part-time teachers, including the teaching principal, plan instruction together. In 2009 the school began to examine its science programme, but the introduction of National Standards delayed the completion of this action until last year. Students experience science in term-long topics and short, 20-minute investigations. These short investigations are sometimes used as a common experience for a literacy or numeracy exercise. The teachers are concerned, however, that science that is too integrated with other subjects risks getting lost to the students. As with School 1, science and other subjects are scheduled in the afternoon after numeracy and literacy. This school sometimes uses the short hands-on investigations as a reward for good student behaviour, especially at the lower primary level. Students here enjoy science and this strategy works well.

School 4 is a large intermediate with students in Years 7 and 8. It is located in a major urban area and had the most ethnically diverse student population of the schools profiled. The principal is the key proponent of the school's strong vision for student-centred inquiry that runs across and integrates all subject areas. The school has a technology focus and subject-specialty staff, but only has a dedicated science teacher every other year. Regular classroom teachers handle science instruction and work in teams for planning. On one of the days of my visit, four classes of Year 8 students were rotating to different classrooms each set up with a unique science investigation. Each teacher conducted the investigation four times, rather than running through four different sessions with their home class.

School 5 is a mid-sized, single-sex integrated school with students in Years 7 to 13. It is located in a large town. There are two mixed Year 7 and 8 classes led by primary-trained teachers. The intermediate students' schedule follows that of the secondary school, and science instruction is blocked for three times every six days. The science department and intermediate syndicate recently came together to improve the alignment of their instruction from Years 7 through 13. Science at the intermediate level is now planned and taught by a primary-trained teacher and a secondary science specialist. This has been a collaborative process where the intermediate teacher gained science knowledge and confidence while the secondary teacher improved her knowledge of student-centred pedagogy. The heads of the science and intermediate departments were the main drivers of this collaborative reform.

School 6 is a large primary located in a major town with students in Years 1 through 6. At nearly 30%, this school has the largest population of Māori students of all those that I visited. Students are organised in mixed-year classes (Years 1 to 2, 3 to 4, and 5 to 6). Literacy and numeracy instruction occurs in the morning and inquiry instruction, which includes science, is scheduled in the afternoon. Teachers work in year-level teams to plan and coordinate instruction, which has recently focused on implementing a system for students to assess their level of thinking and understanding in a given topic. The school also recently placed a year-long instructional emphasis on science because there was concern that science was not being fully covered as described in the NZC. During this time all teachers participated in science planning and professional development. A whole-school focus on a learning area is not unique. What is unique is that the focus was science.[99]

Throughout the school visits, common policies, circumstances and practices were evident that contributed to the success of the science programmes.

Commonalities of Successful Schools

The ERO 2010 report provides a detailed (three-page) description of the components of successful science instruction. It also contains a 28-point self-review checklist for

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[99] Schagen and Hipkins (2008)

schools to use in examining and improving their science programme. While this is a useful resource, it is seen by some as daunting to implement. My case study analysis sought to identify a smaller set of components that seemed to be crucial to the success of schools in science and to provide more description on what these components look like in a school. Not surprisingly, my findings are consistent with a recent report on effective STEM (Science, Technology, Engineering, and Mathematics) education practices in the USA[100] and with the Schagen report on factors influencing the implementation of the NZC.[101]

Strong leadership centred on a school-wide vision for the student

> *[We] start with a clear vision of science in the school and what students will get out of it.*[102]
>
> *The key to [our success in] science is working together...with shared values and a philosophy of learning.*[103]

The case-study schools each had a strong and consistent vision for success with their students. They were clear on what they want their students to know and be able to do when they leave the school. This vision was usually incorporated into an inquiry-based, student-centred approach to education that the staff and leadership had spent time developing. There were differences in the schools' educational philosophies, but all of the approaches were in line with the NZC. A shared vision also provided the staff with a common language to discuss student learning and how to measure it. The principals supported the staff in being innovative and taking risks in providing students with a range of learning opportunities. Science was a natural fit and an important component of this vision. The common visions for student learning, which incorporated all subjects, also helped to ease the pressures of the National Standards among the principals and teachers.

Science was a recent focus in curriculum planning

> *We were only able to [improve] by making science a priority in 2011. We had to do that because on reviewing our implementation of the 2007 curriculum we realised that the science strands had not been adequately addressed. Despite the aim of the revised NZC to reduce the content load of the curriculum – we are still feeling very pressured.*[104]
>
> *We're bringing science back to interest children and teachers and get everyone excited about learning.*[105]

All but one of these schools had recently re-examined their science programmes and were placing a greater emphasis on engaging students and teachers in science. Programme improvements also sought to make instruction more responsive to

[100] National Research Council (2011)
[101] Schagen (2011)
[102] Case-study teacher, author interview 22 May 2012
[103] Case-study teacher, author interview 29 May 2012
[104] Case-study principal, author interview 8 June 2012
[105] Case-study principal, author interview 22 May 2012

students' interests and to ensure coverage of all areas of science in the NZC. In some cases this was in a natural cycle of curriculum review, which typically occurred every three years. Other times this was because of specific concerns that they had not been adequately covering science or that it was not preparing students to succeed in secondary school. Typically the review was initiated by the principal or the teacher responsible for science and carried out in collaboration with one or two other teachers. These teachers did not necessarily have a specific training in science, but they all were enthusiastic about science and the possibilities it has for better engaging their students. In fact, an enthusiasm for science was cultivated in many of the case-study schools:

> *Discover with the children – if you don't have all the answers they are more likely to find them or other answers on the way. Scientific discovery is not about answers but the discovery – make it [science] part of your language/reading and maths programmes.*[106]

> *The key ingredient [to our success] is the disposition of the teacher towards inquiry. [We work on] developing a perspective that embraces inquiry as a state of mind. [We also work on enabling teachers in] organising learning experiences that they can't help but engage with...and are as practical as possible.*[107]

Schools started by putting science within the existing vision for student education at that school. This period of review was usually a year long and in many cases was done in collaboration with an external science advisor. The MOE-funded science advisors were utilised by more than half of the schools before the positions were eliminated in 2009. After the planning period, two of the schools dedicated an entire year to science topics. All of the schools continued to pay closer attention to science after the changes were made, but not in a way that took their focus off other priority areas.

> *[We] take a look at what is sustainable in science and what is reasonable for a primary school teacher to deliver.*[108]

This underscores the observation that doing science well is a challenge, even with highly resourced schools.[109] Most of the schools planned to revisit their science programmes in three year cycles. Many also saw the benefits of science extend into other learning areas:

> *There is a constant pressure to get students to the next step and no time to celebrate learning. We use science to let children celebrate their learning...especially those who struggle in numeracy or literacy.*[110]

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[106] Case-study teacher, author interview 11 June 2012
[107] Case-study principal, author interview 21 May 2012
[108] Case-study principal, author interview 29 May 2012
[109] Education Review Office (2012)
[110] Case-study principal, author interview 21 May 2012

Schools had a collaborative staff and team-based approach

> *Organise to support teaching; just focusing on science won't do it.*[111]

> *Teachers have a shared responsibility for all of the students at our school. We do our planning in teams. This helps spread leadership and support teachers who need more assistance.*[112]

> *Our school is very team focused now, but it took years of practice to get like this.*[113]

In every school, teachers planned in teams that were collaborative and supportive. The teams were usually set by year levels, but they could also be set by subject areas. In the rural school, the entire staff planned together. With this team-based system, teachers who were strong in science supported their less confident peers. Each school had a strong collaborative spirit and teachers frequently remarked that they knew they could rely on their colleagues for support and resources in any subject area.

> *Our principal brings teachers together to work on specific projects [like science or assessment]. He creates leadership opportunities for us and team support across the school.*[114]

The team-based approached not only worked in planning but also in the implementation of science activities in the classroom. Each lesson or topic and its outcomes were discussed in planning teams and decisions were made on how to do it differently, if at all, again. Individual staff brought new ideas for science instruction to their teams. The teams worked together to plan the activities, outcomes, and assessments for students. Teachers met frequently for brief sessions to discuss how the lesson was working, and more so at the end to tell how it worked in meeting their learning objectives. This iterative process kept science fresh and exciting for teachers and for the students. Enthusiasm spread across the team when the lessons were working well with the students. The principals made the most of their staff's knowledge and worked to have a balance of subject expertise across the schools.

Science had dedicated time

> *We wanted to move away from a long [six to ten week] topic study that gets played to death. Science can get lost. We're now specific and explicit [with students] that you are doing science.*[115]

> *We use short and snappy science experiences. Science shouldn't be a huge series of questions followed by heaps of writing. It should be hands on and exciting – followed up with asking why and [drawing] connections to other things in the world.*[116]

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[111] Case-study principal, author interview 21 May 2012
[112] Case-study principal, author interview 30 May 2012
[113] Case-study teacher, author interview 21 May 2012
[114] Case-study teacher, author interview 29 May 2012
[115] Case-study principal, author interview 22 May 2012
[116] Case-study teacher, author interview 21 May 2012

Each school had dedicated time for science as part of the academic year timetable. This did not mean that science was specifically addressed every day, every week, or even every term. While most schools had a term-long focus on a science topic, students also experienced science in much smaller increments. One school examined science topics in two- or three-week sessions. Another had a regular series of 20-minute investigations designed to engage students in hands-on activities. These shorter science periods kept the interest of the students high as well as that of the teachers. It also enabled the teachers to be more nimble in responding to the needs and interests of the students.

> *[We use] science as a way of fun to make literacy and maths enjoyable and related to real life. It helped us with our older boys who we needed to hook in and keep engaged.*[117]

> *Science gives a purpose to reading.*[118]

While the schools had dedicated time for science, they also integrated it into literacy and numeracy. This provided more time for the subject, but teachers acknowledged that they needed to be explicit on when a topic, such as the rocky shore, was science and when it was literacy, maths, or social studies. In many cases there had been specific professional development on the nature of science. Teachers agreed that making the nature of science explicit to students is a challenge, but crucially important if students are to understand the role of science and its limitations in helping us understand the world. There was also an issue of distinguishing science activities from technology activities, especially when it came to students brainstorming on projects for a science fair. A number of teachers noted that the annual science fair generated interest and helped keep science "on their radar":

> *The science fair helps us reflect on science every year and on how we can make sure all kids do well. We're always thinking about how to do better next year.*[119]

Teachers and principals were creative and persistent in supporting science instruction

> *[Our principal] is inspirational and fires us up. He walks the talk and models [science inquiry] with us in our PD sessions.*[120]

The leadership in each of the schools agreed that science was an important part of their students' education and were continuously looking for resources and opportunities to improve it. Teachers were also constantly scanning for science resources to bring into the classroom and share with their colleagues. The science programme review in one school started with a survey to parents and whānau. This resulted in engaging the community around science instruction and in identifying local resources and professionals who could help. Beyond science, the leadership were also persistent in negotiating with the MOE to make the most of their staffing

[117] Case-study principal, author interview 11 June 2012
[118] Case-study teacher, author interview 11 June 2012
[119] Case-study teacher, author interview 29 May 2012
[120] Case-study teacher, author interview 21 May 2012

allocations and access professional development opportunities for their teachers.

While some of the schools were very well resourced, all took advantage of the materials they had. Many of these science materials were developed through funding from the MOE, such as the *Connected* series[121] and the *Making Better Sense* series,[122] and the NZC exemplars in science.[123] For the most part, students engaged in science activities using common, household items. Teachers and principal did not cite the lack of science-specific equipment as a barrier to instruction. Their real need was a means to enable less-experienced teachers to effectively use science resources in the classroom. Most of the cases schools used lead teachers (or the principal) to modelling instructional practices.

> *The "Making Better Sense" books are a good resource, but I would rather see a teacher in action [in the classroom].*[124]

Many also cited the difficulty in accessing external expertise as a key concern towards improving their science programmes:

> *We need a lot of specialised assistance with learning the big science concepts ourselves. Accessing effective PD for staff in science is not easy or cheap. We have purchased specialised resources and equipment for science – but in truth we desperately need more PD about how to use it effectively.*[125]

Policy Implications and Actions from School Case Studies

The case-study analysis found five commonalities among the schools succeeding in science instruction that seemed to be most important. Policies that promote the above attributes are thus likely to be successful in improving science instruction. These attributes stood out because they directly addressed many of the common challenges to effective science instruction.[126] Strong leadership and team-based staff support improved the confidence, knowledge, and abilities of all teachers in science instruction. The dedication to the on-going improvement of science resulted in the development of instructional practices and assessments with a focus on student understanding and ability. School staff worked as one to deliver effective science instruction that engaged both the students and teachers.

With the exception of the first point above, none of the attributes are necessarily specific to science. Engaging in these practices should help schools succeed in all educational areas. The reason that these strategies enabled the case-study schools to have highly-effective practices in science instruction is that they applied them towards improving their science programmes.

Each school had policies and practices in place that enabled staff collaboration. Through the use of specialty teachers scheduled in blocks during regular periods,

[121] http://www.tki.org.nz/r/technology/connected/2009/index_e.php, retrieved 31 July 2012
[122] http://arb.nzcer.org.nz/resources/science/bettersense/, retrieved 31 July 2012
[123] http://www.tki.org.nz/r/assessment/exemplars/sci/index_e.php, retrieved 31 July 2012
[124] Case-study teacher, author interview 19 June 2012
[125] Case-study principal, author interview 20 June 2012
[126] Most recently described in Education Review Office (2012)

classroom teachers were able to meet during the school day to plan lessons. During periods of review of the science programme, lead teachers were often assigned management units and occasional release time. Teams were organised so that teachers could assume different leadership roles depending on their areas of interest and expertise.

One of the current aims of the MOE is to raise the achievement of Māori and Pasifika students. While none of the schools had predominantly Māori or Pasifika student populations, I asked each how they engaged these students in science. The common response from teachers was that they seek to engage each of their students in science that is meaningful to them. This may be by studying a topic that is relevant to the community or by allowing the students to design an investigation of their choosing. The teachers also had high expectations for each student, and all of the schools provided support and resources for any child who was having difficulty in a given subject area. Māori themes were integrated where relevant. For example, a focus on the New Zealand long-finned eel was supported by a trip to a nearby Marae (meeting house) to learn about Māori fishing techniques and eel traps. The use of shorter investigations was also a common way to quickly respond to areas of student interest. The teachers were very mindful of knowing their students and establishing a positive bond with them. A strong school vision for learning was explicit to the students and helped maintain a sense of community and inclusiveness.

The collaborative, community spirit within the schools was undoubtedly one of the keys to their success. At the present time, there is a focus a teacher preparation and quality from the MOE. Rewarding individual teachers for exemplary practice is one strategy that is being explored towards improving education. There is a feeling among the teachers and principals interviewed here, that such strategies could switch the focus within a school from collaboration to competition. Any system-wide policies towards rewarding an individual teacher's achievement will thus need to be conducted in a manner that all agree is fair. Policies that facilitate and reward collaboration, such as use of management units and release time, should also be explored as a promising lever to raise student achievement.

As the schools were focused at the primary or intermediate level, much of their instructional emphasis and time was on literacy and numeracy. Perhaps the most important characteristic common to the schools was that they all recognised that science is also an important component of a child's education. They had systems in place to revisit their science instructional practices regularly among other cyclical reviews of curriculum areas. The schools were dedicated to the on-going, but not overwhelming, improvement of science instruction.

RECOMMENDATIONS AND CONCLUSION

In the mid 1990s there was a sense of urgency to improve science and mathematics instruction in New Zealand. Teachers were having difficulty implementing the 1993 curriculum, and students did not perform well in the TIMSS 1994/95 survey.[127] There was a consensus that something needed to be done. The Minister of Education convened a Mathematics and Science Taskforce comprising university-based educators, primary and secondary teachers, and principals to address the problem. The taskforce presented recommendations in its 1997 report that centred on five overriding issues:

1. Raising the expectations of teachers and parents that all students can achieve in science and mathematics
2. Addressing the underachievement of Māori and Pasifika students
3. Increasing teachers' confidence, skills, and knowledge in science and mathematics instruction – recommendations were for pre-service education and practicing teachers
4. Producing and disseminating curricular materials that translate mathematics and science concepts into practical, hands-on activities
5. Accompanying the curricular materials with teacher professional development that is school based and sustained over time.

As long-term strategies, the Taskforce also recommended supporting research on science and mathematics education and raising the profile of science among parents and the community.

During the mid 1990s, mathematics instruction in New Zealand also underwent a change from a traditional, memorisation-based approach to a focus on enabling students to understand the concepts behind mathematical thinking. The last decade saw an increase in investments in mathematics instruction and the release of national standards for numeracy. This sustained emphasis showed positive results in the TIMSS surveys. There was significant overall improvement in student achievement in mathematics between 1994/95 cycle and 2002/03, although the results remained the same in the 2006/07 survey.[128]

The Taskforce's recommendations resulted in the development of curricular materials for mathematics and science. As evidenced in the case-study schools, many of these resources continue to be used effectively today. While mathematics was receiving sustained support from MOE, science did not see the same emphasis over time. The increased attention to numeracy and literacy drew further resources away from science and the other NZC subject areas over the first decade of the 21st Century. The curricular materials that support science remain in schools. The professional support that enabled teachers to find and effectively use these materials has diminished over the past three years.

Of course, it is not possible for schools or an entire agency to have a sustained focus on all of the components of the NZC all the time. The case-study schools had recently

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[127] Mathematics and Science Taskforce (1997)
[128] Caygill and Kirkham (2008)

made time to examine and improve their science programmes. They also have systems in place to sustain these changes. Many of the schools have a cyclical review system where subject areas or other components of the NZC were revisited every three years for more intensive examination and improvement. In most cases this was a flexible schedule that could adjust to unexpected circumstances but also balance priorities in a thoughtful way so that no subject went unattended for too long.

With the release of the Gluckman report in 2011 and the ERO 2012 findings, there is a new call to improve science instruction in primary and secondary schools. The present economic situation presents a challenge: How do we improve science instruction at a time when budgets are being cut and there are many other competing priorities?

Professor Sir Peter Gluckman and the *Inspired by Science* report spurred a number of actions at the MOE on improving science education. In 2012, the following policy actions specifically address science:

- MOE initiated two-year contracts for professional learning and development (PLD) services to provide support in science to primary schools. These services are coordinated through the regional Ministry offices. Secondary science was already being addressed through a larger contract related to NCEA success.
- NZCER began the MOE-funded Science in the Curriculum projects to better understand the resources that teachers are using for supporting their science instruction. These findings will be summarised in a report that will provide the Ministry on measures to improve science instruction
- Although the contracts for the university-based science advisors were not renewed beyond 2009, there are now two part-time National Science Coordinators who assist schools in their science needs. The coordinators each have access to a few facilitators to liaise with schools and are on independent contracts from the PLD services.
- The assessment items on the NCEA are being revised to improve their alignment with the 2007 NZC and to better reflect the overarching Nature of Science strand.

The MOE is currently seeking to improve teacher education and preparation and is in the process of formulating new policy. While there is not a science focus to this work, it is likely to result in policies to improve the ability of teachers to address all NZC subject areas, especially at the primary level. This may address the concern that university students seeking primary education degrees are receiving fewer and fewer hours of instruction in science and science pedagogy. It may also revisit the concerns raised in the 1997 Taskforce report. The recurrence of themes between the mid 1990s and today underscores the need for constant attention in improving science education.

New Zealand and the USA see science and innovation as a key to securing a better economic future. There is a push in both countries to improve science instruction for all students, especially those in traditionally low-performing groups. At the same time, we are in the midst of worldwide financial crises where governments are showing little interest in funding new sweeping initiatives. It is critically important that all stakeholders come together to improve instruction for all students. These stakeholders include students, teachers, principals, administrators, scientists, business leaders, whānau, iwi, and other community members. The recommendations below strike a balance between these tensions and point to a number of strategies towards moving forward.

Recommendations

Agree that science education is important and requires attention – First and foremost, all stakeholders must agree on the importance of science in primary and secondary schools. The 2012 establishment of the Ministry of Business, Innovation, and Employment put science in a visible and prominent place in the economic future of New Zealand. To be fully realised and sustainable, the vision of New Zealand as a smart country needs to include the education system, too. All stakeholders – iwi, businesses, educators, scientists, and other community members – need to come together in sustained partnerships to make this a reality. This includes all of the education-related agencies within the government. Improving science education requires dedicated attention and nurturing – there is no quick fix. In an address to the 2012 meeting of the Secondary Principals' Association of New Zealand in Wellington, American educator John Pisapia made the analogy that education needs gardeners, not mechanics, to improve.[129] This dedication to on-going nurturing of science instruction was also evident in successes at the case-study schools.

Recommendations for the Ministry of Education

Provide schools with consistent, tailored support for science – In order to improve, schools require support and guidance that specifically meet their needs in science instruction. MOE provided a consistent source of support with the university-based science advisors until 2009, when the student support services contracts were discontinued. Many of the case-study schools successfully engaged with the science advisors. There are now two part-time national coordinators and fewer contracted professional development providers. The current support system is designed to work with individual schools to address their specific needs in improving science instruction. This is a smart approach, but many schools are not aware of these resources, and it is not clear if the contracts will meet demand.[130] Access to this support must also be consistently implemented across the regional offices. Science advisors served to identify resources and link schools together by sharing best practices. As the science advisors were a continuous item in the MOE budget through 2009, this sent the message to schools that science was important. At present, it is not clear how the current science PLD contracts will be revised or renewed when they expire at the end of 2013.

Enable collaboration and strong leadership within schools – The case-study schools all had collaborative environments where teachers frequently came together to improve instruction. Within these teams, individual teachers had the opportunity to take leadership roles in areas of interest, such as revising the science programme. The leadership had placed a priority on establishing and maintaining an effective team-

[129] Keynote address at 2012 Symposium of the Secondary Principals' Association of New Zealand, Intercontinental Hotel, Wellington, 19 March 2012
[130] Author interviews 2 and 17 July 2012

based system within the schools. Policies that promote and enable collaboration should be explored. These include staffing arrangements to provide release time for teachers to meet together, management units to compensate those who take on leadership roles, credit for teachers who improve content knowledge (papers in science education) and bring this back to the school. These findings are consistent with other implementation studies.[131] The establishment of groups of schools coming together (as both face-to-face and virtual clusters) to improve instruction on specific topics is a current strategy. There should also be mechanisms to compensate teachers who take on a leadership role in bringing groups of schools together on improving science. Policies that enable collaboration and leadership will likely act to improve instruction in science and overall.

Include science in formulating current policies on teacher preparation – Teacher preparation is a recent area of policy interest. This should include attention to subject-specific knowledge and pedagogy. Teachers must be confident and knowledgeable to be successful. There is also subject-specific pedagogical knowledge to teaching science that is beyond merely understanding the content. Pedagogical content knowledge is typically addressed in a science methods class in universities. With decreasing time spent on science in tertiary teacher-preparation programmes, it is not clear where teachers will gain the knowledge and confidence to be successful in science instruction. One of the major universities is moving closer to eliminating their multi-year undergraduate teacher programmes in favour of a one-year post-graduate diploma in education. If the teacher preparation system becomes more streamlined, subject-specific pedagogical knowledge will have to be picked up on the job. Again this points to the need for continued professional development opportunities to make this happen.

Recommendations for the science community

Engage all stakeholders with focus on science education – The professional science community has been engaged and active in promoting science in primary and secondary schools. Typically, this is through programmes that engage teachers and students in the professional's specific area of science. These professionals do not often come together to discuss common needs and goals. The 2012 Transit of Venus conference assembled a wide array of stakeholders to discuss the role of science in New Zealand's future prosperity. These connections could be used to broaden the discussion to schools. MoRST and its later incarnation MSI both invested in science instruction at the primary and secondary level. The MBIE should consider how much of an interest area this will be. Business leaders in the USA see science education as a crucial part of workforce development, not just for science professionals, but for all. Engaging more sectors also helps spread the cost of science education programmes so that they are not reliant on one funding source.

Continually review primary and secondary education programmes for effectiveness – There is an array of programmes from the science community that engage students and teachers in the professional realm of science. Many of these programmes highlight science in the real world and its connections to everyday life. Such efforts have the potential to significantly improve science interest and

[131] Education Review Office (2010b) and National Research Council (2011)

understanding across the country. To be more effective in supporting schools, programmes should work to better align the science experiences they provide with the NZC and classroom demands. The case-study schools continually worked to improve their science programmes so that they met their expectations for students and were engaging and relevant to students and staff. This approach holds true for science education programmes from the professional community, too. All providers of science education programmes must have rigorous, on-going evaluation mechanisms in place to ensure continued improvement.

Conclusion

The New Zealand education system with its highly-autonomous schools presents challenges and opportunities for improving science instruction. There is a tension for government policies to respect this autonomy while guiding and enabling positive actions in schools towards common goals. All stakeholders interviewed for this study agree with the educational vision for developing young New Zealanders as confident, connected, actively-involved, life-long learners who will succeed in tomorrow's society.[132] However, the 2007 NZC is a framework document, and each school must interpret and implement this vision. Principals and other school leaders play a critical role in carrying out the NZC by the emphasis they place on learning areas and the professional opportunities that they seek for their staff. The relationship between principals and MOE officials, including the Minister of Education, is an important element in the realisation of policies. To avoid confusion in this relationship, there is a need for principals to receive consistent messages and equitable actions from regional and central MOE staff. Another source of complexity is that principals must also respond to requirements from ERO, NZQA, and NZTC. These four entities should work together for educational policies to be most effective. A number of the case-study principals commented on receiving mixed signals on instructional priorities from the different agencies.

While this system of autonomy is challenging to oversee, it empowers schools to create unique learning experiences that engage students in ways that resonate with their community. The power to be innovative and respond to the specific interests of students is one of the strengths of the New Zealand system. Indeed, the PISA 2009 survey suggests that "most successful school systems granted greater autonomy to individual schools to design curriculum and establish policies...[133]" The devolved system also underscores the importance for all to agree on the need to improve science instruction for every student.

Despite the autonomy of schools, principals do not make decisions in a vacuum. This is apparent in the survey of primary school principals that found science to be at the bottom of their areas of curriculum emphasis in 2007.[134] Accordingly, maths, reading, and writing were at the top of their lists. The impact of the new draft NZC was evident in many of the areas of emphasis: "using more inquiry-based learning", "getting to grips with the [NZC]", and "the new key competencies" were all

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[132] Ministry of Education (2007) p. 8
[133] Organisation for Economic and Cooperative Development (2010) p. 14
[134] Schagen and Hipkins (2008)

prominent.[135] When asked about prospective areas of curriculum emphasis, nearly half responded they would include a focus on the then newly released MOE guidelines on food and nutrition.[136] It should be noted that these MOE priorities are also the ones that ERO officials measure when they conduct school reviews.

The complexity of autonomous entities in science education extends beyond the primary and secondary school system. New Zealand universities have freedom in designing their own studies, degree offerings, and directions. The NZTC guidelines for teacher-preparation programmes allow universities great latitude in design. University-based education faculty engage with schools in the context of their research interests. The professional science community also has great freedom in carrying out education programmes, provided that they can maintain funding. Scientists are not traditionally rewarded for engaging in primary and secondary education activities. Those who do are passionate about their work and feel that they are making a difference. Science educators in both university and professional setting thus engage in education activities on their own terms and are not coordinated in any overarching manner.

The autonomy of the players in the science education arena creates what many describe as a patchwork of programmes. Programme providers focus on their area of interest and expertise, such as biomedicine or agricultural science. However, all agree that science is an important part of a child's education. By law, all children are entitled to the same high-quality education to prepare them for the future. The patchwork system runs the risk of fostering inequities and unequal access to science education opportunities. It is a challenge to formulate policies that promote excellence across this system of diverse opportunities without squashing the passion and innovation of those involved. As well, many of the science education entities, schools, universities, and scientists, respond negatively to heavy regulation. A strong, common vision of the 21st century science learner is a key step to enabling these programmes to improve and developing consistency across the country. Teachers and principals are the ones who know their students the best and can judge which programmes will be most beneficial. While this report seeks to make sense of the complex New Zealand science education system, the findings and recommendations are not specific to one country.

There are calls across New Zealand from different sectors on the importance of science to future prosperity. The role of science education here is eloquently captured by the Ngati Whakaue iwi in its reasoning behind starting a science camp for Māori youth:

> "Our aspirations for our rangatahi [young adults] are that they will be global citizens, with the ability to walk tall anywhere in the world; that their knowledge and understanding of tikanga and kawa [our customs and lore] is strong; and that they will eventually take their turn to contributing to the growth and development of future generations.
>
> As such, [we] believe that cultivating curiosity-driven science amongst our

[135] Schagen and Hipkins (2008) p. 8
[136] Ibid. p. 9

> tamariki and rangatahi, supporting the linkages of science back to our tikanga, our whakapapa [lineage] and our stories, and reaffirming an ethos of "the enquiring mind" as a core value will help us achieve our aspirations.[137]"

If we all embrace this vision of science education as a crucial component of our society's prosperity, we will be on our way to a better future.

[137] Ngati Whakaue (2011) p. 5

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APPENDIX 1: INTERVIEW PROTOCOL FOR PRINCIPALS FOR SCHOOL CASE STUDY

The purpose of each interview is to understand 1) the school's science programme, 2) how it is planned and integrated into the overall school curriculum, 3) the people, resources and support that enable it to happen, and 4) the challenges that need to be met to keep it relevant, effective and engaging.

The following questions will guide my conversation with the principal:

- If I were to observe a half-dozen science sessions at your school, what would I see? What do you want to see in the science classroom?
- How is it that your school delivers balanced and effective instruction in science when too many other schools struggle to do so? How has the heightened emphasis on literacy and numeracy affected your science programme?
- How do you (or your designee) provide leadership in science instruction? What is your vision for science and how it fits into the whole school curriculum? Do you see any challenges on the horizon that may affect science?
- Teachers I met at a recent PLD session lamented that their colleagues are often reluctant to move beyond their "comfort zones" to address science issues and investigations that truly engage students. How do you help your teachers engage students in relevant science investigations?
- The Ministry of Education has a big emphasis on addressing the needs of Māori and Pasifika learners in a culturally appropriate manner. Some see this as especially challenging in science. Do you see this as a challenge in your school, and if so, how do you address it?
- Are there particular experiences that helped you in giving science a more prominent place in your school's curriculum? Are there other people and resources that are key enablers of science in your school?
- What suggestions do you have for principals at other schools who are struggling with science instruction? What suggestions do you have for the MOE to enable effective science instruction in all schools in New Zealand?

During the interview I will also ask to see planning documents (strategic plans, timetables, etc.) that show how science is managed within the school year and the overall curriculum. These questions are meant to guide the conversation around the success of the school in science education.

APPENDIX 2: INTERVIEW PROTOCOL FOR TEACHERS FOR SCHOOL CASE STUDY

The purpose of each interview is to understand the teacher's views on 1) the school's science programme, 2) how it is planned and integrated into the overall school curriculum, 3) the people, resources and support that enable it to happen, and 4) the challenges that need to be met to keep it relevant, effective and engaging.

The following questions will guide my conversation with the teacher:

- If I were to observe a half-dozen science sessions in your classroom, what would I see? What do you expect to see?
- How do you plan your science instruction? Who else inside or outside your school is involved? How do you find time for science with the huge emphasis on literacy and numeracy? Many teachers find it difficult to incorporate the Nature of Science strand throughout their lessons. How do you address this?
- Are there some students that you have trouble engaging in science? What support do you have/need to address this? Are there some students who are particularly engaged with science? Why do you think that is?
- Are there particular experiences that have helped you in keeping your science instruction engaging and relevant to students? Are there opportunities you'd like to have to help you in science?
- If you are developing a new science lesson or having trouble with a current one, where do you turn for help? Do teachers at other schools have access to these people/resources?
- The Ministry of Education has a big emphasis on addressing the needs of Māori and Pasifika learners in a culturally appropriate manner. Some see this as especially challenging in science. Is this a challenge in your classroom, and if so, how do you address it?
- What suggestions do you have for teachers at other schools who are struggling with science? What could the MOE and other agencies do to help teachers across New Zealand engage their students in effective science instruction?

These questions are meant to guide the conversation around the success of the school in science education.