Science in Years 5 to 8: Capable and Competent Teaching

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Overview

Science education gives students knowledge about the world and beyond. Through science education, students become more knowledgeable citizens – they are better prepared for higher education and they become informed workers in an increasingly knowledge-rich world.

This Education Review Office report provides examples of good practice in science teaching for Years 5 to 8, in 13 New Zealand state schools. The evaluation included intermediate schools, contributing schools, full primary schools and a Years 7 to 15 secondary school.

In order to help schools make the best use of this evaluation, the report gives detailed descriptions of effective practices found in the schools. It also includes the indicators of good practice used by ERO's review teams, as well as self-review questions that all schools can use to improve the quality of their science teaching.

The Year 5 to 8 age range was chosen for this evaluation because this is when many students make career decisions about science. The New Zealand Council for Education Research (NZCER), citing evidence from an Australian research team, has suggested that most students develop their career aspirations in science before they reach secondary school. In light of this, science teaching in primary years engages students so that they are able to make their future career judgements on the basis of good learning experiences.[1]

The performance of New Zealand primary students in ongoing science testing has indicated concerns in some aspects of science teaching and learning. For example, the National Education Monitoring Project (NEMP) found a small drop in the level of scientific knowledge and understanding of Years 4 and 8 students between 2003 and 2007. The 2007 NEMP science assessment also found that Year 8 students were significantly less engaged in science than they had been in previous years.

This report focuses on capable and competent science teaching, and the importance of school leadership in fostering science education. ERO also found that most schools in this study faced some challenges in developing high quality science education. ERO therefore intends to undertake a large- scale national evaluation of science education, in order to provide a more detailed picture of the overall quality of primary school science across the country, and to identify any system-wide issues that require the attention of policy makers.

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[1] Tytler, R., Osborne, J. F., Williams, G., Tytler, K., & Cripps Clark, J. (2008). *Opening up pathways: Engagement in STEM across the primary–secondary school transition. A review of the literature concerning supports and barriers to Science, Technology, Engineering and Mathematics engagement at primary–secondary transition*. Canberra: Commissioned by the Australian Department of Education, Employment and Workplace Relations, as cited in Bolstad, R. & Hipkins, R. (2008) *Seeing yourself in science*. New Zealand Council for Educational Research. Report prepared for the Royal Society of New Zealand.

Capable science teaching for Years 5 to 8

Capable science teaching in this study was characterised by the following:

- high quality planning, including strategies for identifying and responding to students' prior knowledge, and for teaching students the significant scientific concepts (or big ideas);
- flexible approaches that took advantage of students' curiosity and were able to meet the diverse needs of students;
- an emphasis on the quality of thinking, or conceptual development, undertaken by students;
- high quality investigations, reflection and discussions that helped students develop their understanding of scientific knowledge and scientific processes;
- engaging practical activities that allowed students to investigate their own ideas as well as those of others – these activities were collaborative, relevant, and drew on local context as well the interests of students;
- the use of literacy strategies to support scientific learning and, in some cases, to provide additional context for reinforcing literacy skills;
- the careful integration of numeracy and literacy teaching so that science activities were not lost;
- teachers' sensitivity to the religious and cultural background of students;
- links to careers that directly or indirectly used scientific understanding; and
- high quality assessment and feedback that let students know how well they were achieving in science, that informed classroom teaching and learning, and was used as the basis of meaningful reports to the board and parents.

This evaluation also found that high quality science teaching throughout a school requires effective school leadership and good equipment and resources. If science is to prosper in a school it should be given status by the principal and supported by an effective science leader. Teachers do not need to have a science qualification to be effective science teachers, but they do need to have a good understanding of scientific ideas along with the confidence to teach science well. Principals and science leaders need to provide teachers with professional support so that they develop the knowledge and skills required to sustain high quality science teaching as a regular part of the school programme.

The board of trustees should get information from school leaders about the achievement of students in science as part of their self-review reports. This can lead to the development of particular goals for science learning, reflected in strategic planning and reporting, and in school operations.

Next steps

On the basis of this report, ERO recommends that schools:

- use the self-review questions and science teaching indicators in this report to review the quality of science education for students in Years 5 to 8; and
- review the quality of their assessment of science in Years 5 to 8 and the usefulness of the information for reporting to:

a) the board of trustees to use in making their decisions; and
b) parents about their children's achievement and progress in science.

ERO also recommends that providers of pre-service education for primary school teachers should review the way science and other compulsory areas of the curriculum are taught in their teacher education programmes.

Comments on this report from school personnel and others are welcome. A report feedback form is included as Appendix 3.

Introduction

Science and *The New Zealand Curriculum*

Science helps us know about the world and beyond. It represents what is understood about the universe through methodical observation and investigation.
The New Zealand Curriculum states that science:

> *… is a way of investigating, understanding, and explaining our natural, physical world and the wider universe. It involves generating and testing ideas, gathering evidence – including by making observations, carrying out investigations and modelling, and communicating and debating with others – in order to develop scientific knowledge, understanding, and explanations. Scientific progress comes from logical, systematic work and from creative insight, built on a foundation of respect for evidence.*[2]

Science is also a compulsory learning area of *The New Zealand Curriculum*. As set out in the National Administration Guidelines, New Zealand schools are required to develop and implement teaching and learning programmes:

> *(a) to provide all students in years 1-10 with opportunities to achieve for success in all the essential learning and skill areas of the New Zealand curriculum;*[3]

This evaluation focuses on capable and competent science teaching in Years 5 to 8. The fieldwork for this report was undertaken during Terms 2 and 3 of 2009. During this time New Zealand schools were preparing to fully implement *The New Zealand Curriculum* in 2010, which replaces *Science in the New Zealand Curriculum*, published in 1995. Hence for this period of ERO's evaluation, two national science curriculum statements were in use. It is important to point out that these documents have a similar structure. They are both divided into eight achievement levels. They also have four context strands based on the Living World, the Material World, the Physical World, and Planet Earth and Beyond. While there are some differences in how the context objectives are set out in each of these documents, they reflect similar concepts.

The main differences between *Science in the New Zealand Curriculum* and *The New Zealand Curriculum* are in the integrating strands. These are included in both documents to help teachers to give students ongoing and consistent messages about how science operates. The integrating strands in *Science in the New Zealand Curriculum* are 'Making Sense of the Nature of Science and its Relationship to Technology' and 'Developing Scientific Skills and Attitudes.'

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[2] Ministry of Education (2007) *The New Zealand Curriculum* pp 28.
[3] As downloaded 15 October, 2009 from:
http://www.minedu.govt.nz/NZEducation/EducationPolicies/Schools/PolicyAndStrategy/PlanningReportingRelevantLegislationNEGSAndNAGS/TheNationalAdministrationGuidelinesNAGs.aspx.

In *The New Zealand Curriculum*, the integrating strands have been incorporated into a broader-based *Nature of Science* strand. This strand has four aspects:

- Understanding about Science;
- Investigating in Science;
- Communicating in Science; and
- Participating and Contributing.

The *Nature of Science* strand emphasises the importance of scientific processes or, more simply, how science is carried out. It emphasises investigations and communication in science. This strand helps students understand the way scientific knowledge is developed and how science relates to their lives and the everyday context of wider society.

Studying science

There are many reasons why science is an important area for study. *The New Zealand Curriculum* says that it is important to study science because:

> *Science is able to inform problem solving and decision making in many areas of life. 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.*[4]

Science gives individual students a way of understanding their world. For primary school students it can provide a meaningful way to develop their understanding of how things work and, in some cases, how they might be improved. Science also provides a way to foster creativity, problem-solving and a love of learning.

Science is central to many of the issues facing New Zealand citizens and the wider global community. In recent years concerns such as climate change, genetic modification, pandemics, vaccinations, sustainability and bio-security have been discussed extensively in the media and the community. The public discussion of such issues is vastly improved when we have a good understanding of the relevant scientific concepts.

Science underpins many jobs in the modern economy. While a variety of research careers can be undertaken by scientists, there are also many other jobs that require some level of scientific knowledge. For instance an understanding of scientific ideas is required for work in fields such as communications technology, building, construction, sport, fishing, forestry, farming, childcare, health services and manufacturing. As this list implies, an understanding of scientific knowledge and processes is a common feature of employment in the 21st century.

[4] The New Zealand Curriculum p. 28.

Student achievement and engagement in science

New Zealand's National Education Monitoring Project (NEMP) has found, overall, little change in the performance of primary school students in science from 1995 to 2007. However, NEMP reported a small drop in the level of scientific knowledge and understanding of Years 4 and 8 students between its 2003 and 2007 assessments. Year 4 students were found to have a two percent drop from 2003 to 2007 while Year 8 students had a one percent drop.

More significantly, the 2007 NEMP identified declining levels of engagement in science by primary-aged students. The lower levels of engagement suggest that increasing numbers of students are less inclined towards taking science as a subject at secondary school and as a possible career option.

Science data from *2006/07 Trends in International Mathematics and Science Study* (TIMSS) are broadly consistent with the NEMP findings. In the 2006/07 TIMSS study New Zealand maintained its ranking 22nd out of 37 developed countries.

New Zealand's Year 5 students expressed positive attitudes toward science with eight out of 10 students indicating that they would like to do more science in school. In comparison with other countries, New Zealand students were not as positive about science as many of their international counterparts.

Seeing yourself in science

In 2008 the New Zealand Council for Educational Research (NZCER) prepared a report for the Royal Society of New Zealand and the Ministry of Research Science and Technology (MoRST) on science teaching in upper primary school (Years 5 to 8).

Seeing yourself in science draws on the NEMP data, an Australian-based literature review of science education[5] and NZCER's own research. This report is especially relevant to ERO's evaluation of science teaching in Years 5 to 8. For example:

- the middle years of schooling, from Years 7 to 10, are when the largest drop-off occurs in student 'curiosity';
- evidence suggests that students form strong ideas about their possible careers in upper primary school, which is earlier than previously thought. This emphasises the importance of engaging students in science before they reach secondary school; and
- engaging students in science is considered more difficult in the 21st century due to the development of certain 'late modern' tendencies in youth culture. These include more interest by young people in activities which support self-realisation, creativity, working with people and supporting the environment.

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[5] Tytler, R., Osborne, J. F., Williams, G., Tytler, K., & Cripps Clark, J. (2008). *Opening up pathways: Engagement in STEM across the primary–secondary school transition. A review of the literature concerning supports and barriers to Science, Technology, Engineering and Mathematics engagement at primary–secondary transition*. Canberra: Commissioned by the Australian Department of Education, Employment and Workplace Relations.

For upper primary science teaching the NZCER report suggests that the focus be on engaging students with interesting science activities and building up the sense of achievement in students. It also suggests giving students access to a variety of science and technology career examples and information so that they build important vocational and identity links with science-based jobs.

The quality of teaching in Years 4 and 8: Science (2004)

In 2004 ERO published a report on the quality of teaching in science at Years 4 and Year 8. This study was the first in a series of ERO evaluations examining the quality of teaching for specific learning areas and skills in alignment with the Ministry of Education's National Education Monitoring Project (NEMP).

ERO evaluated the quality of teaching in science in 233 schools and found the following key areas of good performance:

- most science learning programmes had good links to *Science in the New Zealand Curriculum*;
- students were highly engaged in science learning that was based on group work and hands-on activities;
- some schools had effectively integrated local and community resources into science learning programmes;
- teachers used a wide variety of contexts to gather science achievement information; and
- in some cases parents and whānau were given regular opportunities to be involved in science learning programmes.

The following were also identified as areas for improvement:

- consistent coverage of the two integrating strands of *Science in the New Zealand Curriculum* in science learning programmes;[6]
- the linking of professional development priorities for science teaching to performance appraisals or teachers' own reflection on their confidence and knowledge to teach science;
- the gathering of assessment on skills, attitudes and scientific understanding rather than on task completion;
- assessment information used to inform future learning programmes; and
- the identification of school-wide learning expectations and outcomes for science.

[6] The integrating strands of the 1995 *Science in the New Zealand Curriculum* are 'Making sense of the nature of science and its relationship to technology' and 'Developing scientific skills and attitudes.' Under *Science in the New Zealand Curriculum* the integrating strands were to have been interwoven with the four contextual strands when planning and implementing a science programme.

Methodology

Schools in this study

ERO selected 13 schools for this in-depth study. These schools were selected with reference to ERO's recent reviews of schools and in consultation with the Ministry of Education, the School Support Services and university lecturers in science education.

The criteria for selection centred on the extent to which they were likely to contribute evidence of good practice for this report. ERO also sought schools of different deciles, sizes and types to give a range of information about science education in Years 5 to 8.

The final group included a mix of high, middle and low decile schools. Four were rural, while another two were from small towns (minor urban centres). Of the 13 schools, five were contributing, three full primary, four intermediate schools and one Years 7 to 15 secondary school.

Approach to this study

ERO evaluated each school's approach to science education based on a set of good practice indicators (see Appendix 1). The indicators were drawn from the literature on science teaching.[7] The Ministry of Education and representatives from the science education community were also asked to comment and make suggestions on what should be included.

The indicators were used to make judgements about the extent to which good practice was evident in science education at the schools. Reviewers observed science lessons, analysed documents and met with school management, trustees, staff and students.

Findings

The schools in this evaluation had a range of strengths in how they managed science teaching and learning. Similarly each of the schools faced its own challenges in developing improved science education for students in Years 5 to 8.

It should be noted that most of the schools were at the beginning stages in the development of their science programmes. Many staff reported that science had, in recent years, been less of a school priority. They pointed to the emphasis placed on numeracy, literacy, inquiry learning, assessment and ICT initiatives as having had an impact on the quality and quantity of science taught.

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[7] See for instance *Curriculum, Learning and Effective Pedagogy: A Literature Review in Science Education* (2002) Report to the Ministry of Education, University of Waikato and New Zealand Council for Educational Research with Auckland College of Education.

Classroom teaching

Science programme planning

This section discusses the approach the schools are taking to put the science curriculum into practice. During this evaluation ERO considered school plans for implementing the curriculum, science unit plans and individual lesson plans.

Programme planning is important because it shows how a school is seeking to manage the range of complex aspects in science teaching. This could include how students of different abilities are catered for, which key ideas or concepts are to be explored and how student work is to be assessed.

ERO found that the science programmes of most schools were based on a broad yearly or multi-year plan. This set out when objectives were to be met and how the content objectives and *Nature of Science* objectives were to be combined into units of work. Overview plans for science allowed schools to have an understanding of their curriculum coverage. They also provided a framework for more detailed planning for different year levels and syndicates.

Of particular interest was how schools planned to teach the *Nature of Science* strand. In most of the schools science leaders emphasised the importance of teaching students how to investigate and communicate in science. In some cases these schools had embedded *Nature of Science* objectives into their planning formats. This helped to ensure that teachers were teaching scientific processes as well as the content.[8] Some schools also integrated other aspects into their planning formats. These included the key competencies and school-wide priorities for achievement (such as literacy and numeracy priorities).

Some school plans detailed how students' prior knowledge was to be assessed at the beginning of the unit. By understanding what students knew about a science topic, teachers could tailor the class learning activities. In particular it gave teachers an insight into how students were thinking and therefore what was needed to improve understanding of science concepts. Through this, teachers could assess the gains made over a unit of work, and therefore how effective the classroom teaching had been.

Some school plans addressed how teachers would cater for the different abilities of students in the class. Most plans also underlined the key scientific concepts or big ideas that students were expected to understand.

Teachers were beginning to address the challenge of meeting students' interests while also delivering the objectives of the curriculum. This is a complex planning issue because schools need to be able find a balance between the organisation required for

[8] As found in the content strands: Living World, Planet Earth and Beyond, Material World, Physical World.

science teaching and the benefits of following students' interests. One school managed this by surveying students twice a year to find out what their interests were in science topics and activities.

Teachers at one school had developed a flexible approach to science that allowed them to focus on the particular interests of students. While this approach was in lieu of a more detailed yearly plan for science, it gave teachers the opportunity to make science relevant and engaging. The following excerpt is from one teacher's report to the board of trustees in Term 1, 2009.

> *I had planned to start our science topics with "Light" but a chance remark from one of the children about finding that her water bottle was covered in water after she had taken it out of the freezer led to an investigation of what was happening. At the time she remarked that "the water must be leaking out of the plastic" and, as all the children nodded in agreement, I could see that this really was a "teaching moment"! … After much discussion, which included speculation that "the plastic contained holes like the pores in our skin" and that "the bottles became wet from the ice in the freezer," the children increased their [scientific] understanding of condensation.*

Questions for your school – science programme planning

- To what extent does your school-wide plan for science reflect the importance of the Nature of Science strand?
- To what extent does your school-wide plan for science reflect any school-wide priorities, the Key Competencies of *The New Zealand Curriculum* and how student prior knowledge is to be identified and used?
- To what extent does your school-wide plan for science allow teachers to respond to the interests of students?

Professional background of teachers

There are two important domains of knowledge that teachers can draw on to support their teaching of science. The first of these is their knowledge of science. This reflects the qualifications and experience a teacher has in science.

The second domain is that of science teaching or pedagogy. In many ways this is the more important domain of knowledge for teachers. It reflects a teacher's ability to help students learn science. Teachers with good science pedagogy have strategies to identify and respond to the prior knowledge of students. They understand how to develop students' understanding of scientific ideas. They can facilitate scientific investigations and discussions, and know how to create engaging and meaningful lessons.

Having a science background can help teachers develop their confidence in teaching science. An understanding of science allows teachers to put into context the range of ideas that students may develop during a science activity. It gives teachers a background of knowledge to help lead students to more scientific understanding. It provides teachers with a solid foundation for asking questions and facilitating classroom activities. A good understanding of science gives teachers an awareness of what might be a suitable scientific investigation for the classroom as well as helping them to understand some of the specialised safety issues that arise in science.[9]

Most of the primary trained teachers in the evaluation did not have science backgrounds. Low levels of science knowledge and science teaching expertise among primary trained teachers contributed to the variation in the quality of science teaching in and across the schools.

Two schools had a high ratio of staff with science backgrounds. One of these was the secondary school, with a specialist science department, and the other was an intermediate school where five of the staff had degrees in science. Aside from these two, science degrees were rare among the teachers, science leaders and principals.

In general teachers had not learnt about science as part of their pre-service education. Science was not a compulsory aspect of their training, despite being a compulsory part of the school curriculum. In addition, some of the primary teachers who had taken part in the optional science training found it to be of variable quality. This was especially the case for staff who had been trained within the last five years.

> *A review of preparatory teacher education in science is long overdue.* [One of several comments made by personnel at the study schools]

Despite this lack of training, most of the teachers and school science leaders in this evaluation had a high level of enthusiasm for science education. Teachers were willing to try things out in science teaching and to create learning activities that were engaging for students. In some cases their enthusiasm motivated teachers to develop their understanding of science and science education. One principal's efforts at improving his knowledge of science and science teaching had made him an expert in the field, despite not having a science qualification.

The principal has no formal training in science. He recognised early in his teaching career that many teachers lacked confidence in leading and delivering science programmes. He decided, therefore, to increase his own knowledge and expertise in science and science teaching. He did this through personal study and trying new things in the classroom. His interest in science has been sustained and developed over the years. During his career in education he has been a science advisor and science education lecturer.

Questions for your school – the professional knowledge of teachers

- How does your school assist teachers to develop their knowledge of both science and science teaching? How effective is this assistance?

[9] For instance at one school, one syndicate of teachers had students collect a range of bacteria from around the school. These bacteria were then cultured on agar plates. The teachers were unaware of the safety risks associated with students collecting and growing bacteria from bathrooms and similar hazardous areas.

Pedagogy of science

Science teaching requires teachers to find a balance between helping students to develop core scientific knowledge while encouraging them to undertake their own investigations. Teachers also need to be able to identify students' prior knowledge and use this to inform the learning activities they undertake. For many teachers the range of equipment and the extent to which students move around the room during a science activity can be challenging.

Capable and competent teachers of science demonstrate the following pedagogical qualities. They:

- establish students' prior knowledge and use this to develop classroom learning and assessment;
- make connections to the lives of students;
- help students develop core scientific ideas while also encouraging them to investigate their own ideas;
- use a range of engaging and relevant practical activities with students;
- use strategies to engage different groups of students, eg Pacific, Māori, boys and girls;
- use strategies that take into account the religious beliefs of some students; and
- use technology as appropriate to support and extend students' learning.

Teachers who had developed engaging and challenging science teaching had good subject knowledge of the science being studied. Through a variety of methods they gained a good understanding of the relevant scientific ideas being explored in the classroom.

> *Through our class discussions I have come to realise the depth and extent of the children's scientific thinking. Whereas in the past I may have worked through 'my' plan, now I listen to the children and take it from there. And although these discussions are not exactly quiet affairs, I have found them a valuable insight into their thinking*. [Teacher from a contributing school]

These teachers also had experience in helping students to investigate. In many cases teachers had, through their careers, learnt how to manage inquiry processes across a classroom. They used good questioning techniques that helped students reflect on their observations and understanding, and also helped the teachers to reflect on their own thinking.

The highly effective teachers at these schools demonstrated good classroom management. This was based on the relationships they had developed with students and their experience in managing inquiry learning methods and/or scientific investigations. The classroom management shown by these teachers also allowed students to take responsibility for their learning (for instance working on a practical investigation of their own design). They used a range of investigation approaches too, and were not limited to fair testing.[10] Other forms of investigative approaches included exploring a device or phenomenon, as well as classifying groups of animals or materials, in terms of similar characteristics.[11]

As part of the management of inquiry or investigations, capable and competent teachers emphasised to their students which aspects of an integrated unit were science learning. In this way these teachers underlined an aspect of the *Nature of Science* strand of *The New Zealand Curriculum* so that students understood what constituted science. This also enabled students to understand how effective they were at science as well as how much they actually liked 'doing science work.' As discussed in the introduction to this report, this has important implications for how students see science later on in their educational and vocational careers.

Overall, the teachers in this study demonstrated some or most of the above pedagogical qualities, with varying effectiveness. For example, lessons could be superficially engaging lessons for students but not sufficiently challenging. Although several teachers could initiate the first stages of a classroom investigation, or set up a series of individual investigations (such as a science fair), they found it more difficult to manage classroom learning that routinely involved students' asking and answering their own scientific questions.

It was important for teachers to concentrate on student thinking, to take opportunities to address any misconceptions held by students and to challenge them to improve their scientific understanding. Some teachers were effective at identifying the prior knowledge that students had about a topic, and then made good use of this knowledge to shape classroom activities and to assess changes in students' thinking. A few teachers were highly effective at extending the thinking, investigations and conceptual knowledge of students.

An effective Years 7 and 8 teacher at a small rural school

The teacher at this school has a strong background in science. She has a post graduate diploma in Science Education and has taught in the science department at the nearby college of education.

She delivers much of her science teaching through an integrated curriculum. Her planning makes the Nature of Science strand explicit, along with the school's approach to inquiry learning and higher order thinking tools. The study topics are relevant to the local community – stream study/gardening, farming practices and living sustainably.

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[10] A fair test reflects the scientific methods used in controlling all but one of the variables within an experiment.

[11] See http://arb.nzcer.org.nz/supportmaterials/science/investigations.php and also Watson, R., Goldsworthy, A., & Wood-Robinson, V. (1999). *What is not fair with investigations*? School Science Review, 80(292).

The teacher assesses student prior knowledge before fully planning topics. The starting point for a new unit is then identified from this testing. The teacher believes that it is her role to extend student thinking and topic knowledge.

The teacher's subject and pedagogical knowledge is extensive. During ERO's time in her classroom it was evident that students had a well-developed understanding of the 'big ideas' in science. Students are used to spending long periods of time engaged in investigations. These investigations are linked to the students' emerging ideas. Students continually test, modify, discuss and share their thinking.

One of the important management strategies used in the class is based on cooperative learning. The students understand their roles within the cooperative learning groups and work well together. The students are also taught safety and self-management skills for working with equipment in science.

Students perceive themselves as competent scientists. A wide range of assessment data provides valid and reliable information confirming that students have indeed achieved well in science.

A point highlighted by the above example is the place of knowledge in science learning. While many educators emphasise the process of scientific investigation, effective science teaching is also concerned with developing scientific knowledge. However, scientific knowledge is not just about learning facts. Knowledge in this case refers to the development of scientific ideas and concepts and a deep understanding of how things work. Perhaps ironically, in order to develop such knowledge students need to use investigative processes along the way. Both of these components make the learning engaging. As one school principal said during this study:

> *Some schools try to fire up kids on processes but not the knowledge… this often results in a recipe approach to science and produces a structured and repetitive approach that fails to engage students.* [Principal at an intermediate school]

In light of this, teachers need to ensure that the writing, discussion and reflection used in the classroom assists with students' engagement and understanding. Capable teachers try to reduce the amount of low-level writing they expect from students in science, such as note-taking or copying from a whiteboard. Although the documentation of scientific experiments can be important, in terms of conceptual development, discussion and reflection are more important for student thinking and learning.

Questions for your school – the pedagogy of science

- How well do the science lessons at your school connect with the lives of students?
- How engaging are science lessons for students? What data has the school collected to identify what students think of their science lessons?
- How is student thinking, discussion and investigation supported by classroom teaching?

Science competitions

Science competitions complemented the classroom science programme at most of the schools. Some schools avoided science fairs and science examinations, and these schools considered such competitions to be a diversion from the school's efforts in teaching science. In other schools science fairs provided a way for students to extend their individual knowledge of a specific topic or interest.

For example, in a secondary school, students had a successful record in regional science fairs because of the foundation laid for them in the classroom programme. The students had been trained to use a fair test framework for classroom investigations.[12]

This framework was mirrored in the investigations undertaken by the students in their science fair projects. Because students had experience with the investigative approach, they needed no more than one or two classroom lessons in support of their projects. Importantly, there was also a liaison meeting with parents to help them understand how they could support their children with science fair work.

The worth of science fair projects was enhanced when students were given good feedback on their work. This included teachers' feedback on the quality of the investigation undertaken by students as well as the content of their findings.

Learning is consolidated where students are given opportunities to report their findings to their classmates and their parents. For instance, in one school students presented their science fair projects to their classmates. This gave an opportunity for each student to practise his or her speaking skills in the class and also for class members to ask questions about the methods and results of each investigation. In addition, one member of the class prepared a written peer review of another student's work.

Questions for your school – science competitions

- How does any use of science competitions by your school enhance student learning in science?
- What is the quality of feedback that students receive on any science fair projects they complete?

Science, numeracy and literacy

Literacy and numeracy skills are vital for students in developing their abilities in science. A strong grasp of reading, writing and mathematics are needed to comprehend scientific text, diagrams and data. In recent years, governments have focused on the importance of literacy and numeracy. This ongoing emphasis has meant that the schools in this evaluation had some experience in managing the relationship between science, numeracy and literacy.

School leaders and teachers at some of the schools noted that literacy and numeracy activities tended to be tool-based or skill-based activities, whereas science was treated

[12] The fair test framework at this school included an aim; a prediction, the variable to change (test); the variable to measure (and how you will measure it); three variables to keep the same; and a method, results, analysis, conclusions.

more as a contextual (applied) type of activity. While confirming literacy and numeracy as first priorities, this also underlined why science was important too. For the teachers at these schools, science became a way to engage students in meaningful activities that also improved numeracy and literacy skills. Alternatively, some schools were wary of using science as a vehicle to deliver literacy, as teachers had tended to 'drown' hands-on science activity with literacy exercises.

Literacy activities were also used to develop students' understanding of science vocabulary. For instance, staff in one school employed simple strategies to assist students to identify the meanings of technical words. Teachers encouraged students to define words for the rest of the class and provided 'mix and match' cards to put scientific words with their definitions.

Other schools were eager to integrate literacy and numeracy activities into science education. These schools tended to have experience in the more recent approaches to literacy and numeracy. They also understood the importance of the Nature of Science strand of *The New Zealand Curriculum*. This helped ensure that an integrated approach to learning did not exclude science activities.

One school's approach to literacy and science

The principal at this school believed that there was a need for more opportunities to improve students' literacy skills. Science was seen as an area where students could apply and develop literacy skills.

This approach was supported by the findings of a school-wide consultation on student learning needs. The consultation also showed that there were concerns about students' writing, especially that of boys.

As a result of the consultation, the teachers have used science as a context for speaking, reading and writing. They developed planning formats and focused their teaching on developing students' literacy along with their science skills. They have also developed more hands-on science activities, which involve some writing components. This approach has helped to extend boys' engagement in learning as well as their ability in writing.

Questions for your school – science, numeracy and literacy

- How well does your school's science teaching complement student achievement and progress in numeracy and literacy?
- What literacy and numeracy strategies can be applied to improve student learning in science?

Science and diverse learners

There are several dimensions to consider in relation to science teaching and diverse learners. Aside from the various abilities of students, there are also issues to consider about students' culture, the stereotypes associated with science, and the religious beliefs of students. Essentially teachers have to deliver a science curriculum that caters for students with different backgrounds and abilities. Teachers should also emphasise science as an inclusive activity and one that is undertaken by a range of different people, in a range of different contexts.

Students with various abilities

It is important to note that the techniques for teaching students with varying abilities in other parts of the curriculum also apply to science. Teachers in this evaluation used different approaches to teach students with varying abilities in science classes. For example, many teachers were aware of the specific literacy abilities of their students and provided additional help and/or specifically accessible texts for those who needed it.

Group work and/or cooperative learning techniques were used in many science lessons. These helped build leadership and peer support opportunities for students as well as increasing the range of ways students experienced scientific ideas.

Similarly, in those classrooms where teachers encouraged students to investigate their own ideas, there were good opportunities for students to work at a level appropriate for them. This was effective for students who were gifted at science as well as those who were less able.

Student genders, cultures, beliefs and the stereotypes of science

There are issues in science education that can affect the engagement and achievement of boys and girls. For example, anecdotal evidence suggests that some boys are disengaged by large amounts of writing. Similarly, some girls have difficulty engaging with content they perceive as masculine, especially in physical and material science.[13]

Capable teachers had developed strategies aimed at supporting the learning of boys and, to a lesser extent, girls in science. At some schools the practical or hands-on qualities of science were seen as a way to engage some boys in particular. Several teachers also used posters and science texts that showed male and female scientists at work.

In addition to gender-based issues, students bring a variety of cultural and religious backgrounds to their learning about science. ERO found that most teachers were sensitive to the religious beliefs of students. Teachers did this by making themselves aware of the students' backgrounds and emphasising the rights of students to hold their beliefs. Where contentious science topics, such as evolution, were to be covered in class, teachers sent letters home to families so that any potential issues could be managed.

In a few instances where teachers provided a diverse range of models of what science was, and who used science. Some teachers developed activities for Mātāriki and/or discussed Māori navigation and horticulture, but more work was needed to depict, in depth, the diverse cultural frameworks under which scientific knowledge is developed.

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[13] See Bolstad, R. & Hipkins, R. (2008) *Seeing yourself in science*. New Zealand Council for Educational Research. Report prepared for the Royal Society of New Zealand.

Teachers often linked classroom science to the lives of students through discussing the way in which science was demonstrated and applied in everyday contexts. This was usually done in the way a topic was introduced or through the core contexts used to teach a topic. At one school the contexts used for scientific study at Years 7 and 8 included: forensics, cell phones, toys, a mission to Mars and oceans. A teacher at another school talked about her efforts to make links for students between science and everyday contexts:

> *I have used the words 'science', 'scientific thinking' and 'physics'… [in] … identifying what was science related. I want my students to understand how science is connected to our lives in so many ways.* [Teacher at a small school]

In the case of two schools, efforts were also made to supply students with white laboratory coats. The teachers at these schools saw that the laboratory coats were a fun addition to the classroom and, as the teacher stated and made students 'feel like they were doing real science.' The white coats worked at this level, and students appreciated the opportunity to undertake science with such clothing. The challenge for the schools was to ensure that this was not the only representation of science that students received, but that they understood the wider contexts in which science was relevant and important.

Science and Māori – one school's approach

This school has over 200 students, 90 percent of whom are from the local iwi. At the beginning of 2008 the board called for an increased emphasis on science. Trustees noted that, while the local iwi own valuable forestry and fishing industries, these are mainly managed by non-Māori. A lack of academic qualifications and skills in science has impeded Māori from taking on key decision-making positions in industries they own.

As a result, science education has become a charter priority for the school. It was also reflected in the school's strategic goals and principal's performance agreement. The board has required the principal to engage external consultants to help achieve these objectives. The principal does not have a strong background in science but is enthusiastic about the project. A science advisor has helped the school's lead teacher put together the science programme.

Contact has also been made with a scientist at a local Crown Research Institute (CRI). This connection has helped develop a partnership between the CRI and the school. This partnership provides teachers and students with access to an authentic scientific context. The school receives ongoing support from the CRI in developing the science knowledge of teachers and the content of the science programme. As part of this process the CRI has also offered a three-month scholarship for two teachers in 2010 to help build their scientific knowledge and skills.

Questions for your school – science and diverse students

- How do Māori students experience science at your school? What Māori scientific contexts does your school's science programme draw from?
- To what extent is science education responsive to students of different abilities, genders

and cultures?

Careers and science

Careers education in science involves students having an opportunity to:

- investigate scientific careers (eg laboratory technician, conservation worker);
- investigate careers or industries that draw upon science understanding (eg construction, fishing, nursing, forestry, farming); and
- see the relevance of science to their futures.

Career education for Years 7 and 8 students is mandated in the National Administrative Guidelines (NAGs). As NAG 1 part (iv) states: *New Zealand schools are required to "provide appropriate career education and guidance for all students in year 7 and above…."*

Research evidence also suggests that science-based career education is important for all students from Years 5 to 8 given that many young people develop an interest in science as a career during their primary school years.[14]

All the schools in this evaluation used relevant contexts for science education, but only some of the schools had linked their classroom programme to careers. At one school the teacher had asked parents with science-based careers to visit the school to talk to students about their work, with the aim of motivating students to take science at high school. At another school, teachers had students investigate particular careers relevant to the classroom science programme. This investigation helped students see how the world of work was connected to the science learning they had undertaken in the classroom.

Questions for your school – careers education and science

- To what extent do students make links between your school science programme and the different sorts of science and science-based jobs that exist?

Leading and supporting science education

The place of science in the school

Several elements indicate the importance schools place on science education. This includes: the resources invested in classroom programmes; the professional development and support given to staff; the analysis and use of assessment information; the links to school priorities such as numeracy and literacy; the reporting of science achievement to the board; the emphasis placed on science in school strategy documents; and the information about science presented in school publications such as the newsletter and website.

[14] Bolstad, R. & Hipkins, R. (2008) *Seeing yourself in science*. New Zealand Council for Educational Research. Report prepared for the Royal Society of New Zealand.

The focus of this section is on the place of science as outlined in a school's strategic plan. It will discuss how science was presented in school planning, reporting and self-review documentation, and how this emphasis translated into some of the other aspects of school operations, including the number of hours schools allocated to the teaching of science.

> *"Science is the third most important area of the curriculum"* [Principal of a small school]

Most of the schools in this evaluation placed particular emphasis on the teaching of science. As the above quote implies, for most schools science followed numeracy and literacy as an area of importance. These schools had noted the importance of science in their school charter, or their strategic plan, and had developed specific goals for student achievement in science.

In some cases the school-wide emphasis on science had come from the board of trustees. In one school, the community's interest in the natural environment underpinned the school's interest in developing the scientific understanding of students. In another school, the board sought to support iwi interests through developing the scientific knowledge of its students. The wider aim for the board involved helping the children of the local iwi to take greater management control of assets in collective ownership, including forestry and fishing. (See previous example *Science and Māori – one school's approach.*)

Schools' science goals were supported through good levels of resourcing and equipment, support for professional development and school-wide plans for how science was to be taught and assessed in each school. In some cases schools had also developed relationships with specialists in science or science teaching. Other schools had developed science classrooms (laboratories), school-wide celebrations for science achievements and curriculum committees dedicated to the development of science.

These schools placed importance on science in their school curriculum. The place of science in the school was understood by staff and there was cooperation and support for delivering a high quality programme. This culture was independent of the science background of those involved and was led through a combination of senior management and lead teacher knowledge and enthusiasm (see section below *Principals and science leaders*).

Overall, students had between 60 and 180 hours of science teaching a year. Some schools found it difficult to identify the number of hours of science-based learning undertaken because different approaches were used throughout the school, and because science was variously included in the many different integrated units taught in classrooms.[15]

[15] This is more than has been reported on average for New Zealand year 5 students in the Trends in International Mathematics and Science Study (TIMSS). In 2006, teachers reported that they allocated 45 hours a year for science, a drop from 66 hours in 2002.

Some of those principals who could identify the number of hours their school taught science had included only the time that was dedicated to science, and this did not include science content taught, or learnt, in an integrated or inquiry unit. It also tended not to include any classroom time that was used for science competitions and demonstrations.

There was no uniform approach by schools to organising science time for Years 5 to 8 students. Students at the Years 7 to 15 secondary school had science timetabled, much as it would be for Year 9 secondary students. The intermediate schools also tended to timetable science – especially where a specialist science teacher, working out of a laboratory, taught aspects of the school's science programme. Some schools put more emphasis on science in one year and less in another. Some schools delivered one or two science units a term and this meant they delivered between 12 and 24 hours of science per term, on average.

The strategic leadership of science at a large contributing school

Following a successful professional development initiative, science has been a strategic focus for this school since 2002. The school's strategic plan contains goals for numeracy, literacy and science. These are supported by an action plan which sets out the implementation and resources required for these goals.

The deputy principal has led the science curriculum development from 2002 to 2007. During this time a team leader showed an interest in science and this interest has been developed. This teacher was promoted to teacher in charge of science in 2008.

There has been a long-term relationship with an external advisor since 2002. The advisor has appreciated the ongoing commitment and the strategic focus of science in the school. She attends the school on a regular basis to support the school's science programme.

The senior managers provide internal support and professional development in science knowledge and skills. This is supported by professional readings and invitations for experts to visit their professional learning workshops.

The teacher in charge of science has developed the science implementation plan and ensures that the planning of science topics is robust and understood by all teachers. Further support can be requested by individual teachers. This is backed up by the appraisal system through which teachers identify their next steps in professional development, including science.

The principal reports to the board annually, both in his principal's report and in the analysis of variance of student achievement in science for that year, in comparison with progress since 2006.

Questions for your school – strategic place of science

- How is the teaching of science documented in the school's strategic plan? What, if any, goals have been set by your school for learning in science?
- What events, learning experiences or celebrations does your school have to value science and science learning?

Principals and science leaders

During this evaluation ERO examined how school leadership supported the quality of science teaching. The work of the principal was considered along with the work undertaken by those professional leaders with responsibility for science and/or school pedagogy. ERO considered how leaders positioned science in the school and how science was supported in the classroom. It included how science was resourced and the steps taken to give teachers the knowledge and confidence they needed to operate effective science programmes.

ERO's findings underline the research evidence that exists on the importance of school leadership.[16] They indicate that principals did not need to have science qualifications to foster the development of science in their schools. However, it was important for principals to understand and support the development of high quality pedagogy. This included the development of good classroom planning as well as engaging and challenging lessons.

Although most of the principals in this study did not have a strong background in science, they were able to facilitate the development of science teaching at their schools through:

- setting goals for science education in their charter and/or strategic plan;
- having high expectations of teachers and students;
- leading the culture in valuing the role of science in primary school education;
- developing high quality guidelines for science planning and reporting;
- providing useful feedback to staff about the quality of their science teaching (this could include the use of appraisal and/or support for peer-to-peer feedback and other less formal approaches);
- supporting and resourcing the school's science leader to fulfil his/her role;
- providing resources, including classroom resources as well as professional development; and
- being involved in the development of science at the school by taking part in professional development and celebrating effective teaching and learning.

An understanding of science and science education helped some principals lead science education at their schools. Those principals with a good understanding of science teaching were able to provide more direct mentoring to teachers than those without such expertise. In some schools a deputy principal was more directly involved in supporting the development of science because he or she had particular strengths in this area. This worked well where the principal had overseen a school-wide emphasis on science education.

[16] See for example Robinson V. M. J. (2007) School Leadership and Student Outcomes: Identifying What Works and Why *Australian Council For Educational Leaders* Number 41 October 2007 http://www.acel.org.au/fileadmin/user_upload/documents/monographs/Mono_41_online_1_.pdf.

Even where a principal, or a deputy principal, had a good knowledge of science and science teaching, the quality of science teaching also depended on the work of the teacher with responsibility for science education. School science leaders tended to be the people in schools that helped teachers develop the confidence they needed in the classroom.[17] In most instances these teachers had good classroom practice themselves and they were able to model their science teaching for others. As with principals, the science leaders did not need to have a strong science background, although they did need a good understanding of the science content. In particular it was important that the science leaders had effective pedagogy that supported students in investigating and developing scientific concepts and ideas.

As with other forms of professional learning, a challenge for some of the schools was in finding ways teachers could watch each other develop the quality of teaching throughout the school. The section below, *Professional development and support* has more detail on the actions science leaders have taken to support their colleagues.

Leadership and support at a large intermediate

Science has been nurtured at this school over many years by the current and previous principals. The school's emphasis on science has also been reinforced through links with the local community and the high number of parents who have science or science-related careers.

Science is led by the school's deputy principal. She has a degree in science and a passion for science education. As the science leader she oversees the school's planning. She also helps individual teachers to improve their teaching. The deputy principal is assisted by six teachers who make up the science committee. The committee coordinates the planning and assessment of science across the school.

The school has a specialist science teacher who works in the school laboratory. He delivers Physical and Material World science, while classroom teachers deliver Living World and Planet Earth and Beyond. The teacher in charge of the science laboratory works closely with the science curriculum leader to ensure that students experience a range of engaging teaching approaches. This teacher has developed a laboratory learning environment that includes a finch breeding programme and a large variety of tropical fish. There is a wide variety of science resources in the classroom. The teacher's philosophy is that students should focus on practical activities and on participating in learning conversations as opposed to spending long periods of time writing.

The school has a close liaison with a senior science education lecturer from the local university. The lecturer has involved the school in many science-based projects and has recently been leading two teaching teams in the school to enhance the teachers' pedagogical and science knowledge. There have also been whole school learning

[17] There was a slightly different dynamic at the secondary school in the sample. At this school the staff tended to have more confidence about the knowledge needed to teach science. The issues of leadership and support were however, comparable to the other schools, in relation to the need to develop 'science teaching' expertise for Years 7 and 8 students.

opportunities at staff meetings for teachers to prepare their students for the science fair.

Questions for your school – leading school science

- Who is responsible for leading science education at the school? What, if anything, do they need to support the science teaching of other staff?

Professional development and support

The schools in this evaluation had improved the quality of their science teaching through the efforts made in each school. Primarily, the study schools drew on the experience of their school-based science leaders to support the development of science teaching.

Some of the schools had also used external expertise to help mentor, develop and support their science programme. Specific forms of support for science leaders included outlining the nature of good practice in classroom teaching, providing advice for the planning and assessment of science, and introducing staff to useful classroom resources. Science lead-teachers who were given this support could then work more confidently with their colleagues.

In some cases teachers had drawn on their learning from school-wide professional development initiatives in the areas of literacy, numeracy, assessment and inquiry learning (often with ICT) to improve their science teaching.

These development initiatives are consistent with the features of effective professional learning and development. For instance they include:

- a focus on student outcomes and the links to classroom practice;
- the use of assessment information about the performance of teachers and students;
- experts who help teachers develop their own understanding of new ideas; and
- a programme to sustain momentum, where theoretical understanding continues to improve teachers' practice.

These features are discussed in more detail in ERO's 2009 national reports on professional learning and development in schools.[18]

School science resources

The schools generally had good resources for science education. All the schools had drawn on the Ministry of Education's *Building Science Concepts* books and/or the *Making Better Sense* series.[19] These were used in addition to a range of other texts, video and web-based resources.

The types of science equipment used by the schools varied depending on the school. For schools with specialist laboratories ERO found a good selection of glassware,

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[18] ERO (2009) *Managing Professional Learning and Development in Primary Schools* and ERO (2009) *Managing Professional Learning and Development in Secondary Schools* available from http://www.ero.govt.nz/ero/publishing.nsf/Content/Reports%20-%20National%20Reports
[19] http://www.thechair.minedu.govt.nz/.

electrical circuitry, models, measuring equipment (such as rulers, measuring tapes, current meters and thermometers), chemicals and consumables (string, tape, table-tennis balls, balloons etc). These schools tended to be larger than the others and had specific science budgets that were managed by science leaders.

> *The board is extremely supportive of resourcing the school. Good resources help stimulate and provide opportunities for students to voice their opinions and to change them as time goes on.* (Principal of a large contributing school)

Smaller schools tended to collapse their curriculum budgets under one heading such as 'curriculum materials.' These schools, which did not have specialist classrooms or science laboratories, also tended to have more of a focus on less expensive everyday types of equipment. This could include magnifying glasses, large paper, pens, cardboard cutters (instead of scalpels), chopping boards, latex gloves, glass jars (instead of beakers), bicycle pumps, plastic bottles, fish tanks, saucepans and partially disassembled pieces of technology (phones, radios etc). The moist important aspect was the availability and maintenance of these resources so that teachers could easily find and use them when required.

The quality of resources was best maintained when schools had a person responsible for their storage and upkeep. Most schools had developed a specialist space for science resources. This resource area was accessible to staff and well looked after by a teacher aide who also helped teachers in put together the equipment for a unit. Some schools had hired resources from teacher resource centres and some had also borrowed equipment from neighbouring high schools.

One school had developed a series of boxes it used to collect written resources for different science topics. The advantage of this growing collection of resources was that it allowed some flexibility for teachers in putting together a diverse range of written material for students and enabled them to satisfy a variety of abilities and interests.

Questions for your school – science resources

- What science resources does the school have? Is there a list of these resources?
- What assistance do teachers have for accessing, developing and maintaining science resources?
- What science resources could be borrowed from nearby schools or resource centres?

Links with the community

The community provided an important context for some of the schools in their delivery of science. There was considerable variation in the degree to which they used resources and made links with science-based people in the community. Where such relationships were developed, teachers were able to use them to create relevant contexts and authentic tasks for their science programme.

Two schools had developed ongoing relationships with local scientists, which helped to give teachers confidence regarding scientific information and gave an ongoing context for scientific learning. In the case of one school, Year 6 students had helped monitor the quality of a local river over the previous seven years. Students examined the number of invertebrates in the water as well as water clarity.

Other schools had used local environmental contexts and issues as a meaningful science activity. Two schools used the local calf days as a context for science learning. The students at another school had won a prize in the Royal Society's Environmental Monitoring Action Project (EMAP) for the quality of their work in looking at local waterways.[20]

Students in another school had, over the last 20 years, worked on the restoration and reforesting of a scenic lowland rainforest area. The school students, parents, senior managers, environmental group, Department of Conservation (DoC) and local service groups supported this ongoing venture. This school has also worked with DoC to help with efforts to conserve the native kakariki.

At another school, a staff member had used the expertise of a community member to help with their horticultural project. This staff member has contributed many voluntary hours to propagate the resources of the horticulture unit and assist students to grow vegetables and native trees at the school.

Assessment and reporting

The gathering, analysis and use of achievement information

In examining assessment processes for science ERO looked for evidence that teachers were:

- using Te Kete Ipurangi (TKI) science exemplars, matrices[21] and/or the NZCER Assessment Resource Bank (ARB)[22] to assess student achievement in relation to the levels of the curriculum;
- using different forms of assessment to assess scientific process, skills and knowledge (including practical work);
- moderating science assessment tasks and their marking to check that science assessment had been set to the correct standard and could provide accurate information;
- adopting flexible approaches which allowed students to be assessed in terms of their individual goals and investigations;
- establishing the specific criteria students needed to meet to be successful in science activities;
- collating, analysing and using assessment data to inform their teaching; and

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[20] See the project website for more information http://www.emap.rsnz.org/.

[21] See http://www.tki.org.nz/r/assessment/exemplars/sci/index_e.php for information on the exemplars and http://www.tki.org.nz/r/assessment/exemplars/sci/matrices/index_e.php for information on the curriculum matricies.

[22] See http://arb.nzcer.org.nz/ the assessment resource bank provides an extensive range of assessment tasks for teachers in English, Mathematics and Science across Level 1 to 6 of the New Zealand Curriculum. This is a free service for teachers who register.

- providing feedback to students that focused on improving learning.[23]

Science assessment is complicated by the wide range of contexts that are covered in the subject. The different contexts for learning science mean that there may be few knowledge-based links for students from one unit to another. For example, during the course of a year, the contexts a Year 8 student may learn about in science can include:

- the nature of everyday materials (wood, plastic, fabrics);
- electricity and simple electrical circuits;
- the interactions within a biological community; and
- geological landforms and the weather.

The knowledge in each of these does not overlap simply, or reinforce earlier learning. Therefore the feedback a teacher provides a student about the knowledge they have developed throughout a unit of work may not necessarily be reinforced or applied in other scientific studies through the year.

Assessment information about a student's practical skills, or their understanding of scientific processes (through the *Nature of Science* strand) can be reinforced from unit to unit throughout the year. For example, one school had an especially effective approach when it came to assessing students' knowledge of fair test investigations. Based on their school-wide professional development on assessment,[24] the teachers at this school had used assessment tasks from one unit to identify the strengths and development areas for students who were undertaking a fair test. This information was used by students to set goals for subsequent fair test investigations.

Another school used several different brainstorm and quiz-style activities at the beginning of its science units to discover what students understood about a topic. This information was then used as a baseline for teachers to assess students' learning, throughout the unit, not just at the end. Students were also given opportunities to revisit their initial ideas as the class learnt more about a topic. The especially positive quality about this approach was the extent to which it encouraged students to reflect on their thinking and learning.

One small school had made good use of science rubrics to identify students' level of achievement. These rubrics were developed by a team of teachers with the help of the regional science advisor. Rubrics helped to identify how students' knowledge compared with the levels expected in *The New Zealand Curriculum*. Teachers then used these rubrics in their pre- and post-unit assessments. The information from the early use of these rubrics identified that student achievement was low compared to what could be expected nationally. As a result of this information the school made science a priority area for further development and improved its science results.

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[23] ERO also examined the ways in which teachers identified and used the prior knowledge of students in the development of teaching. While this can be considered an issue of assessment, this has been discussed in the planning and pedagogy sections of the chapter on Classroom Teaching.
[24] In this case it was an Assessment to Learn contract (AtoL).

This school also used a regular peer assessment approach to give students feedback on their learning. This assessment occurred at what the school called a science 'hotspot' where students were asked to investigate a scientific idea in pairs or small groups. These tasks were not necessarily related to the current science unit. The investigations were practical but the groups were also asked to discuss and debate the underlying scientific concepts. Only some of the investigations were written down. Students evaluated the quality of their investigation and could, at this point, reflect on the quality of their thinking.

Despite good practice, overall the assessment of science in the schools was not strong. It is interesting to note that although all the study schools had developed effective practices for assessing numeracy and literacy, teachers had not yet extended their assessment strategies into the formal and informal assessment of science.

Assessment practice, at most of the schools, was therefore not sufficient to provide good feedback consistently to students, or to provide reliable information to improve the quality of teaching. Lack of feedback may have contributed to the high proportion of students who told ERO that they either did not think that they were good at science, or did not know if they were good or not.

ERO also found that the teaching in several classrooms was pitched at a curriculum level lower than that expected for the age of the students. Suitable assessment processes would have identified this problem and, ideally, led to a higher level of rigour being applied to science activities.

An effective school-wide approach to science assessment – large urban intermediate

The science programme at this school strongly emphasises the need to build on students' prior knowledge and to learn about science in relevant everyday contexts. The school uses an integrated approach to delivering science, based around broad 'trans-disciplinary' inquiry themes. These include such topics as 'how the world works' and 'sharing the planet.'

Science activities are clearly defined in these inquiry units. Science planning reflects the need for students to learn core scientific ideas, processes and skills, as well as having time to investigate their own ideas. A strong practical focus was also evident in lessons.

Teachers have used the NZCER Assessment Resource Banks (ARBs) to develop detailed rubrics for assessment. These rubrics are often developed with students and they cover several dimensions of the scientific process and core scientific knowledge. The rubrics outline criteria for making judgements about student achievement against curriculum levels 3, 4 and 5, with sub-levels of basic, proficient, and advanced for each of these levels. A high quality moderation process ensures that the assessment information is consistent across the school.

Students reported that they had good information about their achievement in science. All students confirmed that teachers used learning intentions to guide their learning.

Students also talked about how the school's assessment rubrics helped them to understand the quality of their work.

Student achievement is monitored by class teachers and the science leader. Student self assessment and teacher assessment are a strong feature of the process. Students are taught to set and evaluate SMART goals for improvement based on their prior learning. Teachers analyse individual information for reporting to parents about their child's achievement against the national curriculum levels. These reports include specific information about what students have achieved and their next steps for learning.

Data has been aggregated to identify school-wide strengths and weaknesses in science, and to guide target setting for improving student performance in areas of weakness. 2008 data indicated general weaknesses in students' ability to form conclusions about the meaning of experimental findings. Consequently, 2009 targets focused on this area of teaching and learning, with all teachers being given guidance on how to help students formulate conclusions.

Questions for your school – assessment

- How do you know that the science assessment in your school is aligned with the levels in *The New Zealand Curriculum*?
- What information is collected, used and analysed on science achievement at your school?
- What is the quality of feedback that students receive on their work in science?

Self review and reporting to boards of trustees

High quality assessment information is needed for schools to accurately review the quality of their science teaching. As the previous examples demonstrate, analysed achievement information gives a platform for making improvements to science teaching. Subsequently, self review can help a board understand how well a school is performing and provide data to inform their decision making.

Analysed achievement information helps a board to understand how well science education is progressing. About half of the schools in this evaluation included achievement information in their science reports to the board. The information provided by these schools was not always suitably analysed in terms of the achievement of different groups of students, and what the implications were for future classroom teaching. Where schools had specific goals for improving the quality of science teaching it was easier for the board to make decisions about science education.

Most of the other schools reported information about science activities, purchases and professional development to their boards, without achievement information. Two schools did not specifically report on science, but instead included science as part of a wider curriculum report. This sort of information is not useful for a board considering what changes would be needed to support science education.

One school's approach to self review in science provided a range of useful information alongside its analysed achievement data. As part of their science programme, teachers used surveys to collect information on students' attitudes, motivation and perceptions of science (and other areas). This information was then used to confirm the strategic direction of the learning programme while allowing management to identify future learning areas and to make modifications to the learning programme.

Questions for your school – self review of science

- To what extent does the board of trustees receive high quality information about student achievement in science?
- To what extent does the information provided to the board of trustees about science teaching and learning, demonstrate the improvements that have been made to teaching and learning over time?

Reporting to parents

The quality of reporting to parents depends on the quality of assessment undertaken by the school. Schools that analysed student achievement in science well had the evidence that enabled them to report adequately to parents on their child's science achievements in relation to the curriculum objectives (and national expectations).

Where reporting to parents was effective, schools had used their analysed achievement data to give parents reliable information about how well their child was doing in science. In most cases these reports also contained information about what students needed to do to improve on what they had already achieved in science.

For example, one school's approach to reporting on science achievement to parents involved stating whether or not the student was at, above, or below, the expected curriculum level. The school's teachers reported on effort and achievement and also discussed student performance in terms of the school's priority indicators and the integrating strands of *Science in the New Zealand Curriculum*, namely:

- being curious about the world;
- designing and carrying out a scientific investigation;
- using scientific ideas;
- contributing to a scientific conversation; and
- using science knowledge to make connections to the world.

Teachers at this school also prepared a learning journal for each student. This was sent home to parents so that they could see the specific achievements made by their child in science. The learning journals presented a student's achievements clearly and included the teacher's comments for future learning. Senior managers also provided feedback and encouragement in each child's journal. Additionally, senior managers used their reading of the learning journals to appraise the quality of teacher's feedback to students.

Schools also used other ways to report on science at the school. School newsletters gave parents general information about the activities students were undertaking in science. School science fairs were also an opportunity for parents to be an audience for students' work in science. Some schools also held conferences with students and their parents. These report meetings gave an opportunity for parents to see, first hand, the work students were undertaking in science and to discuss with teachers what a student was achieving and how that achievement could be supported.

Questions for your school – reporting to parents

- To what extent do parents receive information on how well their child is achieving in science in terms of the curriculum levels?
- To what extent do the reports to parents make it clear what a child's strengths are in science and what are the key things they can develop?
- Are students at your school able to report to parents what they know about science and what their science learning goals are for the future?

Conclusions

This chapter summarises the range of effective practices used by the schools in their science teaching for Years 5 to 8 students, providing examples for other schools in managing science education.

Capable science teaching for Years 5 to 8

The effective teachers at the schools in this study applied a range of sophisticated strategies in support of science learning. They recognised that the quality of thinking, or conceptual development, shown by students is central to effective science teaching.

It is through high quality investigation, reflection and discussion that students increase their understanding of scientific knowledge and scientific processes. Much of science teaching is also practical or hands-on; it involves students' investigating their own ideas as well as the ideas of others. It is collaborative in that it involves groups of students working together. It is also relevant, drawing on local contexts and ideas, as well the particular interests of students.

Effective teachers observed in this evaluation understood the complex nature of science teaching and used this understanding to plan, deliver, assess and evaluate their teaching. High quality planning included strategies for identifying students' prior knowledge about a topic. This information was used to plan the activities to be undertaken in a unit, as well as to form a baseline for assessing the improvements made in student understanding.

Good planning also focused on the key concepts (or big ideas) students were to explore in a unit. It included the use of strategies to help students develop the key competencies of *The New Zealand Curriculum*, as well as any school-based priorities for learning.

Some schools used science to reinforce literacy and numeracy skills. Often schools drew on an inquiry-based approach that included numeracy and literacy tasks as part of the unit. Where this occurred, teachers were sometimes conscious of the Nature of Science strand of *The New Zealand Curriculum*, and the need to make clear to students when they were learning science, so that science activities were not lost in literacy and or ICT-based investigations.

High quality science lessons were engaging for students. While practical and hands-on aspects of science are appealing to most students, the use of students' ideas, and the ability to have students think about scientific material, can make science lessons highly engaging and effective. This underlines the importance of teachers and students asking questions in science and having class members attempt to understand such natural phenomena as why water forms on the outside of refrigerated bottles, or why it is that some animals are extinct.

In some cases, effective teachers moved away from their initial planning to follow students' interests. Being flexible is an important part of science teaching. It shows the judgement effective teachers need to make the most of opportunities as they arise.

High quality science lessons matched the needs of diverse students. Because students were using collaborative learning techniques, and investigating their own ideas as part of the programme, they were able to be involved in ways that extended their thinking. As a result, different students learnt different things in an effective science class.

Effective teachers were sensitive to the religious and cultural background of students. Such teachers also made links between the science learnt in the classroom and the particular careers that make use of such learning.

Good quality assessment information was important for high quality teaching. Through the use of the ARBs, as well as the curriculum exemplars and matrices, effective teachers knew the level of work expected from Years 5 to 8 students and created opportunities for them to reach and exceed different curriculum levels. They could also, therefore, give high quality feedback to students on their understanding of science knowledge and processes. Good assessment information could also contribute to the quality of teaching by providing evidence about how well students understood particular aspects of a unit.

High quality science teaching across a school depends on effective school leadership and good resources. If science is to prosper in a school it should be given status by the principal and supported by an effective science leader. Teachers need good professional leadership and support so that they develop the knowledge and skills required to sustain good science teaching as a regular part of the school programme. Teachers do not need to have a science qualification to be effective science teachers. To teach science well they do need to have a good understanding of scientific ideas. Understanding and confidence can be developed with the help of principals and lead science teachers.

As part of their self-review reports the board of trustees should get information from the school about the achievement of students in science. In some cases a school may also develop particular goals for science learning, reflected in school planning, reporting and self-review documentation, and translated into some of the other aspects of school operations, including the number of hours schools allocated to the teaching of science.

The resources required for teaching and learning science in Years 5 to 8 need not be technical or expensive. Teachers are, however, well served when there is a person who manages the school's science resources effectively and, where possible, assists teachers to identify and gather the best possible resources for a science unit.

Challenges for science education in Years 5 to 8

This report focuses on capable and competent science teaching, and the importance of school leadership in fostering science education. ERO also found that most schools in this study faced some challenges in developing high quality science education.

ERO therefore intends to undertake a large scale national evaluation of science education, in order to provide a more detailed picture of the overall quality of primary school science across the country, and to identify any system-wide issues that require the attention of policy makers.

Next steps

On the basis of this report, ERO recommends that schools:

- use the self-review questions and science teaching indicators in this report to review the quality of science education for students in Years 5 to 8; and
- review the quality of their assessment of science in Years 5 to 8 and the usefulness of the information for reporting to:
  c) the board of trustees to inform decision making; and
  d) parents about their child's achievement and progress in science.

ERO also recommends that providers of pre-service education for primary school teachers should review the way science and other compulsory areas of the curriculum are taught in pre-service teacher education programmes.

Comments on this report from school personnel and others are welcome. A report feedback form is included as Appendix 3.

Appendix 1: Indicators of capable practice in science

Leading science education

Indicator	Characteristics
The principal provides leadership for the science curriculum	• The principal and board of trustees has clear expectations and/or goals for learning in science (eg in the strategic plan) • The principal, senior management and board of trustees value and promote science teaching across the school • There is a shared understanding about science as an important/necessary area of the curriculum, rather than an add-on • There is a shared understanding about what good practice looks like in science education • Science is suitably resourced in terms of equipment, time and professional development • The principal ensures that there is suitable feedback on the quality of science teaching (eg through performance management or some other less formal approach) • Science is celebrated at the school and community level • Science achievement is reported to the board as part of a self-review process aimed at ongoing improvement in science teaching • The principal ensures that there is professional development, resources and confidence for teachers to teach science
There is a designated lead-teacher of science	• This leader is suitably qualified in terms of the subject and pedagogical knowledge • Is able to manage the planning, assessment, classroom management and resource issues of science education • Is able to work well with other staff members to help build their confidence, planning, assessment, classroom management and overall quality of their science teaching

Planning and assessment

Indicator	Characteristics
Science curriculum planning	• The school has a clear plan for delivering the objectives of the science curriculum, with special emphasis on the Nature of Science strand • The planning shows that students have regular opportunities to undertake science, and know that they are doing science • The planning allows for a range of engaging activities • The school's planning reflects the need for students to learn core scientific ideas, scientific process skills and have time to investigate their own ideas • The science learning attempts to make connections with the lives of students and/or aspects of society • Builds on the existing knowledge and understanding of students and allows students to apply and test their knowledge • Uses relevant practical work to engage students • Has clear learning outcomes and suitable methods for assessing the scientific skills, process and knowledge of students
The assessment of science	• Uses the science exemplars (or some other national/local baseline matrices and/or ARBs) to help analyse individual student achievement in relation to the levels of the curriculum • Different forms of assessment are used to assess scientific process, skills and knowledge (including practical work) • The assessment is flexible to allow for individual students goals and investigations • The assessment information on science is collated, analysed and used to inform professional discussions, planning and teaching • Science achievement information is reported to the board, school community and parents • Students understand the specific criteria they need to meet to be successful in science activities • Parents receive information about student achievement in science • Feedback to students is focused on supporting and improving learning

Classroom teaching of science

Indicator	Characteristics
Teachers	• Teachers are enthusiastic about teaching science • Teachers have a sound pedagogical and subject knowledge base • The teacher has high expectations for student achievement
Teaching strategies	• Teachers establish students' alternative conceptions/prior knowledge as part of teaching • Teachers make connections to the lives of students, aspects of society and the ideas in other subjects • Teachers build on the existing knowledge and understanding of students • Teachers help students develop core scientific ideas while also investigating their own ideas • Teachers use a range of engaging, relevant practical activities with students • Teachers use of a wide range of strategies to engage different groups of students, e.g. Pacific, Māori, boys and girls • Teachers use strategies that take into account the religious ideas of some students • Teachers use technology, as appropriate, to support and extend student's learning
Classroom management	• The classroom management strategies enable students to move safely around the classroom • The learning environment is challenging, but also safe and inclusive • Teachers can give good instructions to ensure that students can safely carry out the lesson
Student achievement	• Students are achieving in line with/or above the curriculum expectations • Students see themselves as successful (high self efficacy)
Student engagement	• Students like doing science at school • Students are motivated by their classroom science activities • Students think they are learning well in science • Students are enthusiastic about doing more science at school

Integration of careers teaching into science (Years 7 and 8 especially)	• Students have an opportunity to investigate scientific careers • Students have an opportunity to hear about, or observe, the work of science-based careers • Students see the relevance of science to their futures

Appendix 2: Self review questions

Science programme planning

- How well does your school plan for teaching science set out how the Nature of Science strand is to be taught?
- To what extent does your school-wide plan for science reflect any school-wide priorities, the Key Competencies of *The New Zealand Curriculum* and how student prior knowledge is to be identified and used?
- To what extent does your school-wide plan for science allow teachers to respond to the interests of students?

The professional knowledge of teachers

- How does your school assist teachers to develop their knowledge of both science and science teaching? How effective is this assistance?

Science pedagogy

- How well do the science lessons at your school connect with the lives of students?
- How engaging are science lessons for students? What data has the school collected to identify what students think of their science lessons?
- How is student thinking, discussion and investigation supported by classroom teaching?

Science competitions

- How does any use of science competitions by your school enhance student learning in science?
- What is the quality of feedback that students receive on any science fair projects they complete?

Science, numeracy and literacy

- How well does your school's science teaching complement student achievement and progress in numeracy and literacy?
- What literacy and numeracy strategies can be applied to improve student learning in science?

Science and diverse students

- How do Māori students experience science at your school? What Māori scientific contexts does your school's science programme draw from?
- To what extent is science education responsive to students of different abilities, genders and cultures?

Careers education and science

- To what extent do students make links between your school science programme and the different sorts of science and science-based jobs that exist?

The strategic place of science

- How is the teaching of science documented in the school's strategic plan? What, if any, goals have been set by your school for learning in science?
- What events, learning experiences or celebrations does your school have to value science and science learning?
- Who is responsible for leading science education at the school? What, if anything, do they need to support the science teaching of other staff?

Science resources

- What science resources does the school have? Is there a list of these resources?
- What assistance do teachers have for accessing, developing and maintaining science resources?
- What science resources could be borrowed from nearby schools or resource centres?

Assessment

- How do you know that the science assessment in your school is aligned with the levels in *The New Zealand Curriculum*?
- What science achievement information is collected, used and analysed, at your school?
- What is the quality of feedback that students receive on their work in science?

Self review of science

- To what extent does the board of trustees receive high quality information about student achievement in science?
- To what extent does the information provided to the board of trustees about science teaching and learning demonstrate the improvements that have been made to teaching and learning over time?

Reporting to parents

- To what extent do parents receive information on how well their child is achieving in science in terms of the curriculum levels?
- To what extent do the reports to parents make it clear what a child's strengths are in science and what are the key things they can develop?
- Are students at your school able to report back to parents what they know about science and what their science learning goals are for the future?

Appendix 3: Report feedback form

Science in Years 5 to 8: Capable and competent teaching

Name: ____

School/Institution: ____

Your role: ____
(for example, Teacher, Parent, Trustee, Researcher, Principal)

Address: ____

*This feedback form has been developed to help ERO evaluate the quality of this report. By sending ERO your views on this report you are contributing to the quality of future national reports. This feedback form can be sent to ERO in the following ways: by email to **info@ero.govt.nz**; by fax to the following number: **0-4-499 2482**; or post to: **Evaluation Services, Education Review Office, Box 2799, Wellington 6140** (Freepost authority number 182612).*

1. How readable was this report? (i.e. was the language, structure and content accessible?) Indicate one of the following:

Highly readable		Fair		Not very readable
5	**4**	**3**	**2**	**1**

2. Were there any aspects or sections of this report that were difficult to understand?

   Yes / No

3. If you indicated yes above, what sections or aspects were difficult to understand?

4. For school personnel: How useful is this report in helping you identify ways to improve science education in Years 5 to 8? Indicate one of the following:

Highly useful		**Moderately**		**Not very useful**
5	**4**	**3**	**2**	**1**

5. Which aspects of this report provided the most useful information about science teaching in Years 5 to 8?

6. What improvements could be made to make future reports more useful for teachers, principals and board members?

7. Any other comments? If you have any other suggestions or comments about the quality of this report, or about how this report has been used by you or your school, please include them below.

Thank you for completing this form. The information you provide will be used to reflect on how future national reports are prepared by the Education Review Office.