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Te Tāhuhu o te Mātauranga

e-in-science: Scoping the possibilities

Cathy Buntting

Science in the New Zealand Curriculum

This report is one in a series written for the Ministry of Education by The New Zealand Council for Educational Research in collaboration with Learning Media and The University of Waikato. The work was divided into three strands: Curriculum support for science, science community engagement, and e-learning in science.

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Report prepared for the Ministry of Education

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EXECUTIVE SUMMARY

This report explores the possibilities that exist for e-in-science to enhance student engagement and learning in science. It uses as a framework three interconnecting purposes for using ICT in science education; that is, to support students to: work as scientists, work with scientists and work with one another to co-construct scientific knowledge and understanding.

Key findings from the literature suggest:

- A range of examples exist in the academic literature of New Zealand teachers using ICTs to support the collection and analysis of scientific data ("working as scientists"), to interact with scientists ("working with scientists") and to collaborate with one another as part of their scientific learning ("peer collaboration").
- It is much more common for teachers (and students) to use ICTs for retrieving information relevant to their science education programmes.
- The effective incorporation of ICTs in science pedagogy requires significant expertise. A useful framework for considering this is "technological pedagogical content knowledge" (TPACK) (Koehler & Mishra, 2009).
- Sustained and sustainable teacher professional learning is needed to support teachers in their efforts to expand their pedagogical repertoire to include ICTs in ways that enhance students' engagement and learning in science.
- Related to sustained professional learning opportunities is the need for supportive school infrastructure (hardware, software, technical support) and leadership.

Key findings from a teacher survey suggest:

- Teachers are far more likely to use ICTs for retrieving and sharing scientific information than for collaborating or creating knowledge. However, many would *like* to use ICTs for supporting students to collaborate and/or creating knowledge.
- Secondary teachers are more likely to use resources fully embedded within a digital environment, such as the Science and Biotechnology Learning Hubs and TVNZ learning hub. They are also more likely than their primary colleagues to use these resources to support student learning as opposed to teacher learning. Science learning objects in TKI's digistore were used equally by primary and secondary teachers.
- Web-based portals where teachers can share ideas offer valuable opportunities for teacher professional learning.
- Teachers in rural schools or decile 1 or 2 teachers tend to be overrepresented among those reporting little or no access to online resources. Less than half of all respondents reported easy access to "e-tools that support science inquiries (e.g., data loggers, science databases)".
- Teachers reporting ready access to online resources (and other resources, such as community resources) are more likely to have students use ICTs during class to collect and/or analyse scientific data, to collaborate/share their learning with their peers and to communicate with a science expert.
- Teachers who are most confident in their ability to implement the various strands within the science learning area of the New Zealand Curriculum (NZC) are more likely than others to use ICT resources to update their own knowledge, find student activities, have students collect and analyse scientific data and have students communicate with a science expert.
- Sound curriculum knowledge and strong professional support are likely to precede innovative ICT use.

1. INTRODUCTION

This report explores e-learning in science education, or "e-in-science" for short. The project is one of three strands in a combined programme of work being led by the New Zealand Council for Educational Research, with the University of Waikato and CWA New Media as partnering organisations.[1]

The aims of the e-in-science strand are to:

1. identify teachers' views of possible e-in-science practices, including the opportunities and constraints
2. work with students and teachers to explore innovative possibilities for e-in-science practice to enhance teacher capability and increase student engagement and achievement
3. make recommendations about a sustainable, scalable model for e-in-science.

The focus of the first phase of the project (March–May 2012), detailed in this report, was to identify teachers' views of possible e-in-science practices, including opportunities and constraints. This was accomplished through an online teacher survey which integrated the aims of the e-in-science project with the aims of the other two projects that are part of the combined work programme. A comprehensive analysis of the findings from the survey is provided by Hipkins and Hodgen (2012). A summary of salient findings related to teachers' views of e-in-science are presented in this report in Section 3. First, Section 2 introduces current and potential e-in-science practices as reported in the education literature. The purpose is to offer insights into opportunities offered by ICTs for enhancing teacher capability and increasing student engagement and achievement in science education. The survey findings are then analysed with respect to these opportunities. Finally, the next steps in terms of phase 2 of the project are outlined in Section 4.

[1] The first milestone report was for the combined projects and was provided on 28 February 2012, soon after the signing of the contract.

2. SCOPING POSSIBILITIES FOR E-IN-SCIENCE PRACTICES

2.1 INTRODUCTION

The New Zealand Curriculum suggests that e-learning has considerable potential to support teaching by: introducing new and supportive learning environments; enhancing opportunities for learning through virtual experiences and tools; and facilitating shared learning (Ministry of Education, 2007). A range of Ministry of Education programmes are aligned with this vision and encourage and support the adoption of e-learning in schools, including New Zealand's laptops for teachers (TELA) scheme, funding for school ICT infrastructure and teacher professional development, and the Ultrafast Broadband in Schools (UFBiS) and Network for Learning projects. However, the pursuit of pedagogical innovation and implementation is not straightforward. For this reason, our approach to this project is premised on four key assumptions:

1. e-Learning encompasses ICT in its broadest sense.
2. e-Learning involves more than simply using e-resources in a "20th century" way.[2]
3. Teachers need support to effectively incorporate e-opportunities into teaching and learning.
4. A developing culture of e-in-science is shaped by the interplay between teacher professional development, school technological infrastructure and school organisation and leadership.

In order to identify New Zealand teachers' views of possible e-in-science practices, including opportunities and constraints, it is necessary to first consider what might be possible. To this end, considerable effort was made to identify examples of e-in-science practice reported in the academic and nonacademic literature. This included a comprehensive literature search using multiple databases, and approaching fellow science education researchers for leads about innovative practices. We also took account of relevant findings from the international literature.

As already indicated, the affordances of an ICT resource, or the opportunities it offers to users, depend not only on the resource but also on the activity in which it is used and the nature of the classroom interactions. In other words, while ICTs offer new possibilities for learning, the affordances must be appropriated and crafted to support pedagogical strategies that can bring about successful learning experiences (Webb, 2005). The role of the teacher's knowledge, and specifically "how *this* technology can be used with *these* students to accomplish *this* purpose" (Wallace, 2004, p. 450, emphasis in the original) is thus critical. Pertinent here is the concept of "technological pedagogical content knowledge" (TPACK) (Koehler & Mishra, 2009). Even when the incorporation of ICT in a lesson appears relatively simple, assuming the infrastructure is available to support it, a range of important pedagogical decisions need to be made. For example, Otrel-Cass, Cowie and Khoo (2011) worked with two Years 7/8 teachers to investigate how ICT use can structure activities that offer enhanced opportunities for students to actively participate in science. One of the examples they provide is a vignette in which the students observe condensation forming on the outside of a cooled glass, after which the teacher shows a time-lapsed YouTube video of a similar demonstration. Otrel-Cass et al. report: "The use of time-lapse videos is not novel in science classrooms, but Tina's timing of its use and her connecting the video with a real experience made this episode significant" (p. 28).

In the context of more recent collaborative technologies, such as Web 2.0, decision making about when, how and why to incorporate a specific ICT tool in a teaching and learning

[2] A "20th century" way is taken here to mean using ICT in a similar way to using a textbook or other traditional classroom resource; a "21st century" way requires using ICT in ways that go beyond merely accessing content.

programme needs to take into consideration not only students' (and teachers') information literacy, but also their participatory literacy (Haythornthwaite & Andrews, 2011). This requires skills not only in retrieving and evaluating information, but also in writing blog posts for collaborative learning purposes. However, assessing these skills and taking them into account introduces additional complexity for teachers.

Presented below is a series of examples reflecting small pockets of innovation with respect to the use of ICT in science education in New Zealand. These are offered with the purposes of providing insights into what might be possible. A number of interactive Web-based resources also support students' understanding of science, including *StudyIt* on TKI,[3] The University of Auckland's *BestChoice* portal for chemistry education[4] (Adam, Salter, & Woodgate, 2011; Woodgate & Titheridge, 2008) and the ethics and future thinking tools on the Science and Biotechnology Learning Hubs (Buntting & Saunders, 2011). In addition, an online course comprising three astronomy unit standards was developed by the Carter Observatory (Shaw, 2007) and was offered until recently. While these resources represent an important part of the ICT landscape, a detailed analysis of how they might be used to support science learning is not presented here. Also not presented are examples of teachers using ICT for information retrieval and sharing; for example, showing images, video clips, animations or simulations.

As already pointed out, teacher knowledge and care in identifying such resources and incorporating them in appropriate and effective ways is not unproblematic. However, the focus of this project is to explore even more innovative approaches regarding what might be possible in the e-in-science space. In particular, Web 2.0 technologies supported by reliable software and hardware as well as Ultrafast Broadband (UFB) provide enhanced opportunities for synchronous online interactions and collaboration and co-construction of knowledge (McLoughlin & Lee, 2008). The multiple affordances of such mobile technology to transform learning are eloquently captured by Cochrane (2010):

> It is the potential for mobile learning to bridge pedagogically designed learning contexts, facilitate learner-generated contexts, and content (both personal and collaborative), while providing personalization and ubiquitous social connectedness, that sets it apart from more traditional learning environments. (p. 134)

2.2 POCKETS OF INNOVATION

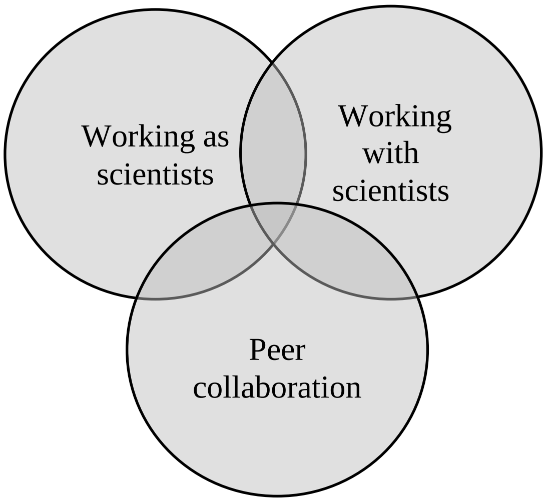
The examples of innovative New Zealand practice reported below suggest that ICTs have an important role to play in contemporary science education. Three interconnecting purposes were identified: ICTs to enable students to work as scientists; ICTs to support students to communicate and work with scientists; and ICTs to facilitate peer collaboration and co-construction of knowledge (see Figure 1). For example, ICTs such as infrared cameras and mobile sensors can enable students to collect and analyse data in ways that mirror authentic scientific inquiry. Secondly, ICTs offer increased opportunities for school students to connect to and communicate with scientists (for example, through videoconferencing), although logistical constraints and costs in terms of scientists' time remain significant considerations. A third way in which ICTs can support science learning in new ways is through facilitating peer

[3] In May 2012, *StudyIt* recorded over 35,700 registered users. Feedback from students and the annual increases in unique visitors suggest that *StudyIt* makes a significant contribution to student success in NCEA (K. Norton, pers.comm.).

[4] In 2011, *BestChoice* recorded 340 Report users. These are high school teachers who are registered to view how their students are doing on the site. 7,418 students were enrolled in classes with a further 3,483 not enrolled in classes. In total these two groups entered 3,450,000 correct answers. On average the number of responses from students enrolled in classes was 2.5 times higher than those not enrolled in classes (S. Woodgate, pers. comm.).

collaboration in an "anywhere, any time" mobile environment. Often these purposes are integrated to a greater or lesser extent, as depicted in Figure 1. For each of the examples that follow, careful and thoughtful planning and pedagogy—drawing on the teacher's technological pedagogical content knowledge—was needed for the ICT to meaningfully enhance opportunities for student engagement and learning.

Figure 1: Interconnecting purposes for using ICTs in science education



2.2.1 Working as scientists

To demonstrate the potential for ICTs to support scientific inquiry and enable students to "work as scientists", four vignettes are presented. The first involves a Years 7/8 class using digital photography, digital microscopy and Google maps to study rocks as part of an erosion unit. In the second, a Years 5/6 composite class used digital cameras, digital microscopy and an infrared camera to investigate the ecology of a local gully. The third example illustrates secondary students using real data and the fourth shows students using mobile sensors.

Vignette 1: The need for sophisticated technological pedagogical content knowledge

In "Science classroom investigations of the affordances in teaching with ICT" (SCIAnTICT), Otrel-Cass, Cowie and Khoo (2010) worked with two Years 7/8 teachers to investigate how ICT use can structure activities that offer enhanced opportunities for students to actively participate in science. The teachers incorporated a range of ICTs into an earth science unit about erosion and landforms. As part of the unit the students visited a local riverbank. Before the trip, the teachers showed the students photographs that they had previously taken at the riverbank, using an interactive whiteboard to annotate the photographs during the discussion and enabling the students to "virtually" visit the location. During the field trip, students took digital photographs of selected rocks *in situ* (the rocks were then taken back to the classroom for further analysis) and recorded a narrated video about the location, which required careful observation and articulation. In class, students referred back to these artefacts when studying their rocks. They also used a digital microscope to study the rocks' internal structure. Internet-based animations were used to help explain how rocks are formed and weathered, and then the students used Google Earth and other Internet-based maps, including geological maps, to further investigate the likely sources of their rocks. They also matched the photographs of their rocks with those found on the Internet. Significantly, the Years 7/8 students were responsible for using and manipulating each of the ICTs used through the unit. However, this required careful preparation by the teachers, and a sophisticated blend of content knowledge, pedagogical content knowledge (PCK) and TPACK:

> Just as usual, the teachers had to plan their teaching carefully, with a clear structure and purpose, and to consider the learning objectives for the science unit. However, in addition they had to think about what the various ICTs could offer to their students, and the skills that the students needed so they could use these tools and resources. The effectiveness of the ICTs the teachers used to support learning about landforms and erosion of rocks depended on more than teachers knowing how to use technology; *it also required them knowing how to use it to support the specific learning required for earth science*. (Otrel-Cass et al., 2010, p. 21, emphasis added)

Vignette 2: The potential of ICTs to broaden students' scientific inquiry

Primary students have also been shown to interact competently with a range of ICTs in the context of a science education programme. For example, Falloon (2011) reports on a school–scientist partnership between Scion and a Years 5/6 composite class (9- and 10-year-olds) in a school over 100 km away. Through the partnership, the teacher was supported to plan an ecological investigation situated in the gully bordering the school grounds. A key aspect of the programme was that Scion provided the class with a resource kit comprising four laptop computers, four digital microscopes, an infrared night vision camera and three digital cameras. This equipment not only broadened the inquiries students were able to undertake, but it also enabled a greater number of inquiries to be pursued depending on student groups' interests. Even increasing the number of classroom computers from two to six was significant. As the teacher reported:

> ... having access to the laptops was brilliant. I could have all the children in groups on a computer, answering specific questions ... there was no point in going down to the gully and putting food in the traps when we didn't know what the predators like to eat! I couldn't have done it without the technology, a lot of it, and having the night camera and being able to get real footage ... that was huge. (p. 43)

Access to the technology was also highly significant to the teacher in terms of her own professional learning:

> She viewed the chance to learn about and use a range of new technologies such as the infrared night vision camera and the digital microscopes as unique, and developed significant technical and problem-solving skills as a result. Because help from Scion was over 100 km away, she generally had to solve any issues herself. (p. 45)

The recent Education Review Office (2012) report on science teaching in Years 5–8 points out that in schools where science was identified as a priority, leadership teams:

> ... fostered the notion that you don't have to be a science expert, rather you need to be a learner along with the students. Teachers had permission to be creative and were willing to 'give things a go'. They gained confidence through collegial support. (p. 10)

This highlights the role of school leadership in promoting e-in-science (indeed, e-learning in any curriculum area), a theme that will be returned to later.

Vignette 3: Using real data to enhance student engagement

The PROBLIT (PROblem-Based Learning in Teams) initiative run in the Waikato and Coromandel from 2006–11 offers another example of ICTs being used to provide students with authentic scientific data. The full-year programme included gifted and talented Year 10 students from seven schools, and took the place of the students' school-based science classes. Students used email and videoconferencing to communicate with the teacher and each other, and learning centred around a series of problems designed to offer powerful learning experiences (Lowe, Taylor, & Buntting, 2011). Several of these problems were supported by weekend camps during which a range of ICTs were incorporated into the tasks. For example, to help students explore force and motion they addressed the problem "How do glider pilots use the principles of the conservation of energy to enjoy long extended flights?" During a weekend camp, held at the Piako Gliding Club, students each experienced two glider flights, one launched with a winch tow and the other released from a tow plane at a given height. In both cases the glider carried a GPS unit to record data that were later downloaded and each flight could be watched in animated 3D from any angle; data such as speed, height and position could be obtained from any point on the flight path; and plots such as altitude over time could be generated. These data were then used in a series of physics calculations, the students using their own data. The example therefore exemplifies the use of ICTs in offering students opportunities to record and analyse real data collected in the field (so to speak).

Vignette 4: Using real data to support authentic learning

RIGEL is a mobile sensor unit invented by a teacher and past e-learning fellow, who trialled its use with a Years 7/8 science class (Fenton, 2008). The inquiry took place during the lead up to the Beijing Olympics, which formed the focus for student groups to design and then run sporting events that incorporated the RIGEL sensor units. This first involved familiarising the students with the RIGEL units and the types of sensors that might be attached. Next, students brainstormed ideas for events that would use the sensor units, developed a specific event,[5] tested and modified the event where necessary and ran the event for two other classes. The lesson sequence was highly motivating to students, and stimulated their thinking about other uses for sensor technologies. For example, Fenton reports that in interviews 21 out of the 26 students (81 percent) could list four types of sensor and discuss at least one example of how a sensor might be useful in everyday life. Students were also observed expressing curiosity about surprising or unexpected findings, and at the end of the unit were able to generate a wide range of interesting questions to investigate using the sensor units for the upcoming science fair.

Teacher direction versus student agency

The first three vignettes—from earth science, biology and physics—suggest a strong teacher-directed component in that it was the teachers who acted as gatekeepers on the types of ICTs that were used during the scientific investigations. Perhaps this is inevitable to a certain degree, since choice is in part dictated by resources. In the fourth vignette, RIGEL's open-ended architecture and connectivity with other applications offered a wider range of choice for students, as did the inquiry in which they were engaged. The agency of students in selecting which ICTs to use as part of their learning, and when to use them, seems worthy of further investigation.

[5] Examples of the events included: a BMX race (the sensor detected which team finished first); infrared spotlight (the infrared sensor detected which team found the sensor unit first); treasure hunt (finding a hidden radio in the quickest time using the sensor unit to track the treasure); and cyber cycle (a stationary cycle had sensors attached that controlled a flight game projected on the whiteboard).

2.2.2 Connecting with scientists

Another opportunity ICT offers science education is the opportunity for students (and their teachers) to access scientists or science experts. As pointed out by Gluckman (2011) in his report *Looking Ahead: Science education for the twenty-first century*, such access to scientists and contemporary science is an important mechanism for enhancing the relevance and value that students place in their science learning.

In a study investigating the use of videoconferencing for connecting school students with scientists, Falloon (2012) reports on a 6-month school–scientist partnership in which 29 Year 13 biology students in Wellington used videoconferencing tools to virtually access scientists at a Crown Research Institute (CRI) over 500 km away. The project comprised three seminars via videoconferencing and three virtual labs. Face-to-face school-based laboratory sessions were also run by the scientists during the initial phases, and the teacher visited the research institute. The seminars typically were led by a scientist who made a presentation on a predetermined topic, followed by opportunities for questions. The virtual labs took place in a laboratory in the research institute, with the scientist demonstrating a variety of relevant laboratory procedures. Students' responses to a short questionnaire indicated strong support for the teaching seminars, and slightly less support for the labs. Interviews with some of the students suggested this was likely because they felt the content of the seminars was more useful and relevant to their assessment task than the content of the labs. As one student commented:

> I thought the labs were great. It was good seeing how scientists really do this stuff, and that it's happening here [in New Zealand] ... but I'm not sure how useful it will be for the exam.

However, 18 of the 29 students (62 percent) considered that the videoconferences enhanced the relevance and authenticity of their school studies, and interview data generally linked this more with the virtual labs than the seminars.

As Falloon (2012) notes, "best practice" models for the use of videoconferencing in education are still developing. The case study he details highlights some of the challenges associated with fostering genuine dialogue between the students and the scientists. These included issues associated with the tightly bounded time frame for each videoconference, student confidence, limited opportunities to form relationships and students' need for time to reflect. The teacher, while surprised about the lack of interaction between the students and the scientists, did not consider that this lessened the value of the experience:

> We got some really good stuff out of it though, after it had finished! We talked for about half an hour on the techniques and how they're being used in Liz's research. It's really good for the students to see and hear it first hand.

For scientists, the time involved in preparing for the interactions was considerable. Logistics related to accessing the videoconferencing equipment and, in the case of the virtual labs, setting the videoconferencing equipment up and then manoeuvring it around the lab as necessary, was also a significant constraint that involved forward planning, time and technician support.

The above example represents one of several initiatives in which the New Zealand Government sought to explore how the resources of the CRIs could be combined to support science teaching. As part of this broader programme of work, Falloon (in press) interviewed each Institute's CEO, who also completed an online questionnaire. Of particular relevance to this report on e-in-science possibilities is the finding that the Institutes were committed to school engagement, primarily to improve general literacy and address negative stereotypes, but that they considered improving the knowledge of teachers to be the best way that they could support school science. There were also "concerns about the sustainability of more direct participation models—either scientists working in classrooms or students working in labs—and the probable impact such models would have on scientists' work" (p. 9). However, six out of eight CEOs indicated that they agreed or strongly agreed with the statement "My CRI would prefer to provide technology-facilitated support to schools". The roll-out of UFB in particular offers exciting opportunities for synchronous online communication, which Falloon postulates is more likely to "support relationship establishment and dialogue, perhaps better promoting positive perceptions of scientists and their work" (p. 13).

2.2.3 Peer collaboration

A third purpose for integrating ICT into science pedagogy is for supporting the online collaboration of students with each other, either within a class or beyond. Four examples of the collaborative opportunities offered by ICTs are presented below.

Vignette 1: Moodle

"Networked inquiry learning in secondary science classrooms" (NILSS) is a 2-year project being led by the University of Waikato to investigate ways in which electronic networking tools such as the Internet or mobile technologies can support authentic science inquiries in junior secondary science classrooms. e-Networking tools are defined as those that afford: communication and sharing of information and ideas; the collaborative production of knowledge; and a reaching beyond the school's resources in order to experience other spaces for collaboration and communication (Morgan, Williamson, Lee, & Facer, 2008, as cited in Otrel-Cass, Ballard et al., 2011). Examples include using Moodle-based discussion forums to explore and share ideas, mobile devices to record experiments and identify possible relationships, and Skype or other videoconferencing platforms to access a science expert.

Preliminary findings, based on the experiences of six teachers from three high schools, suggest that these tools provide multimodal opportunities for students to expand their observational skills and share ideas; and to see, reflect and talk science (Otrel-Cass, Ballard et al., 2011). In particular, the online learning platform Moodle was considered by teachers and their Years 9 and 10 students (13- and 14-year-olds) to provide a new space for learning that incorporates permanency and time to think, space for ideas to be clarified and/or summarised and opportunities for formative assessment and the determination of next steps. One student reflected:

> I was confused because I didn't really understand how energy was put into matter cause our teacher said that matter was everything but I sort of thought that not everything has energy but has the potential to have energy, so I got a bit confused with that one but then after reading a few of them [discussion posts] it helped me to understand a bit better and that way I was learning from my other class mates that were in the same classroom with me hearing what the teacher had said. So we were learning from each other without asking the teacher. (Otrel-Cass, Ballard et al., 2011)

Vignette 2: Class wikis

Another example of peer collaboration is provided by Falloon (2011) in his account of a CRI–school partnership between Scion and a Years 5/6 composite class, also introduced above. As well as using the ICT equipment provided by Scion to search the Internet and collect data (e.g., using the digital microscopes and infrared night camera), the students contributed to a class wiki. Groups of students were responsible for different aspects of its development, and as the teacher or students learnt new skills, they demonstrated them to the rest of the class.

Importantly, the wiki space became a crucial communication nexus between the students, the scientists and parents and the wider community. The feedback that was posted from beyond the classroom "was fundamental to sustaining interest in the unit" (p. 47) and offered a forum not only for enhancing students' science understandings, but also their literacy skills. The teacher reported, for example, that both the volume and quality of students' written language improved significantly during the study.

Vignette 3: Sharing digital data

The Ministry of Education's *mLearning Capability Pilot Project at Howick College* (Wright, 2010) provides an example of Year 11 geography students using their mobile devices to create photographic and video records during a field trip to Tarawera (not unlike the SCIAnTICT Years 7/8 students who visited a local river, described above) and then shared these with the whole class so that each student had ample footage to work from. Each student then created a narrated or annotated set of slides and these were again shared, enabling self-critique, ideas for revision and social learning. Finally, the revised products were exported to the students' mobile devices from where they could be reviewed, or shared with others. Unlike the SCIAnTICT project, therefore, the focus here was on using the mobile devices for collecting data that could be shared as part of the learning process. Students reported that they "liked having their class work in their pockets" (p. 4), and also that they were more likely to show their parents files on their mobile devices than they were to share their other schoolwork. As well as offering examples of mlearning possibilities in enhancing student engagement and learning, the project highlighted the importance of: appropriate technological infrastructure, including wireless as a key enabler of student-centric learning because it allows ubiquitous access on campus, and pedagogically aware IT support staff; effective and proactive leadership; and carefully planned lessons incorporating deliberate acts of teaching where pedagogy was adjusted to suit the affordances of the mobile devices. Teachers more likely to engage in innovations of this kind were identified as: being experienced; being risk-takers who are able to cope with uncertainty; having high levels of professional energy; highly self-reflective; and willing to learn alongside their students.

Vignette 4: Google Wave

At the preservice level, Heap (2011) reports using Google Wave as an e-learning tool to facilitate students' individual and collaborative reflections on the nature of science. Google Wave[6] allows real-time online collaboration between multiple participants, who can reply any time and anywhere in a wave. As part of their course participation, the preservice teachers used laptops loaded with the program to record all references to the nature of science (explicit and implicit) during course lectures. With the wave displayed on the lecture wall, other students and the lecturer were able to read the comments as the lecture progressed, and to add their own responses. This provided the lecturer with immediate feedback about how individuals were making sense of concepts related to the nature of science, and offered students "access to the ideas of other students, and attempts to consolidate these ideas in order to improve their own understanding, which builds the knowledge of the community of which they are a part" (p. 630). After-class reflection was possible, and students could also make further comments or include additional media. This meant that the interaction via Google Wave went beyond "being merely a discussion platform, to building a communal resource for learning" (p. 631) where the students were responsible for their own learning in collaboration with others.

[6] Google Wave is unfortunately no longer available as a stand-alone product, although alternatives like Shareflow exist.

Summary

Social networking technologies have potential to place students in the collaborative and creative position of co-constructors and critical consumers of scientific knowledge. However, this is likely to require both teachers and students to view the co-construction of scientific knowledge from a community-based, distributed perspective (Luehmann & Frink, 2009). As pointed out above, teachers more likely to engage in innovations of this kind were identified by Wright (2010) as: being experienced; being risk-takers who are able to cope with uncertainty; having high levels of professional energy; highly self-reflective; and willing to learn alongside their students.

2.3 DISCUSSION

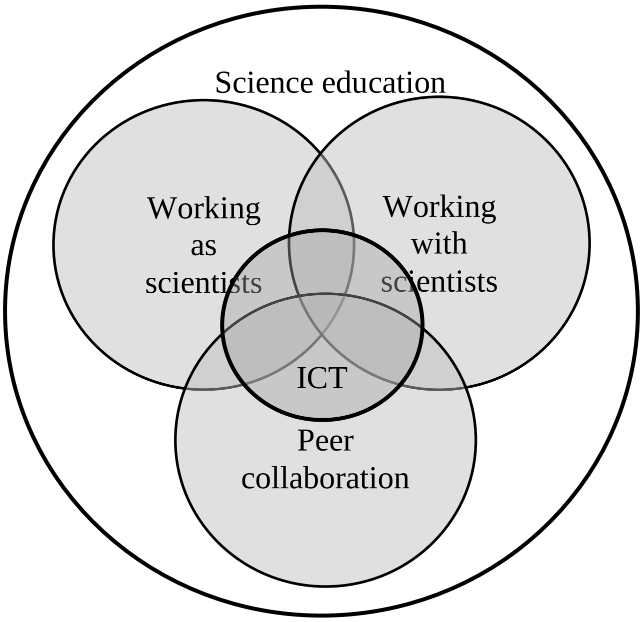
There is a growing body of national and international research evidence suggesting positive effects of specific websites, software packages and e-learning platforms and tools on student attitudes and/or conceptual development in science education at both primary and secondary level (e.g., Buntting & Saunders, 2011; Chen, Cowie, & Oliver, 2011; Harlow, Cowie, & Heazlewood, 2010; Jones & Buntting, 2012; Lowe et al., 2011; Otrel-Cass et al., 2010). The challenge, however, is for teachers to incorporate e-learning into their science pedagogy in ways that are meaningful and relevant to students, and that enhance the learning beyond that which could be achieved in their absence. As Garrison and Anderson (2003) counsel, "For e-learning to have a significant place in education it must prove that it is more than a medium to conveniently access content" (p. 54). In addition, Haythornthwaite and Andrews (2011) warn against using e-opportunities for convenience rather than pedagogically sound reasons.

The Education Review Office (2012) report described effective science education for Years 5–8 as classroom practice where:

> Students made predictions and were familiar with the investigative process, including fair testing. They used structured thinking process in lessons and ICT (including 'Skyping' in the classroom with local and overseas 'experts'), where appropriate. Students' predication and descriptions of their observations included their own ideas. They blogged about their thinking, problems and their solutions. (p. 17)

In line with this vision, and even broadening it, the examples presented earlier in this report demonstrate innovative ways in which ICTs might contribute to students' experiences of and learning in school science at both primary and secondary level. In particular, they move beyond more conventional uses of ICTs to retrieve information. This does not deny the valuable contribution that can be made to science education by information-based resources that offer, for example, insights into up-to-date scientific endeavours (e.g., the Science and Biotechnology Learning Hubs) or clarity about abstract scientific concepts (e.g., animations, simulations, time-lapse photography, etc.). However, the focus of this project is to expand our understanding of what might be possible when ICTs become integrated in science education in ways that transform the teaching and learning interaction. In this sense, the model depicting the interconnecting purposes for using ICTs in innovative science education, presented in Figure 1, could be expanded as shown in Figure 2.

Figure 2: Interconnecting purposes for using ICTs as part of a transformed approach to science education



Within this expanded model, core components of innovative science education include students having opportunities to participate in scientific inquiry (students working as scientists), students connecting with the science community (students working with scientists)[7] and students collaborating with one another as an integral part of their learning. ICTs have potential to play a significant part in each of these by offering new opportunities for data collection and analysis, and for mediating interactions between people. They also offer a unique means for drawing each of these purposes together: students working with each other and scientists to undertake authentic scientific inquiry.

Of the examples reported above, the one that perhaps comes closest is the school–scientist partnership between Scion and the Years 5/6 class who carried out an ecological investigation in their local gully. In this case, learning was extended well beyond what would have likely occurred had the school–CRI partnership not existed. For example, the teacher was supported through the partnership to facilitate a student-led ecological inquiry. Her self-efficacy was enhanced particularly by her ready access to expertise, available through synchronous and asynchronous communication tools. As Falloon (2011) reports: "... without the support of scientists and other partnership resources 'on tap', Helen would have been in a far weaker position to implement the unit using an inquiry model" (p. 41). The students, too, had access to digital equipment that enabled them to carry out a range of inquiries (working as scientists) that would have been practically much more difficult for the teacher to make possible without the CRI's support. In the class wiki, the students worked together to co-construct their developing understandings about the ecology of their gully. The wiki also formed a crucial communication nexus between the students, the scientists and the parents and wider community. While Falloon's report did not offer insights into student learning, it seems likely that the integration of ICT would have increased the opportunities for learning compared with what this teacher might have done without the ICTs.

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[7] School engagement with the science community is another of the three projects being carried out under this programme of work.

Another important role for ICTs only alluded to up to this point is their ability to support teacher professional learning, as they did with the teacher referred to in the above example.

2.3.1 Teacher professional learning

As well as enabling interactions between teachers and scientists, ICTs also have potential to enable collaborative learning among teachers. For example, the Central North Shore ICT PD cluster created a wiki to share and record their learning from 2006 to 2008 (http://centralnorthshore.wikispaces.com/). The site was jointly edited by teachers and offered participants "access to the work of people doing exciting things ... you're sharing ideas with a wider range of people ... we've found it useful for teachers to be able to talk to other teachers at the same level" (Education Gazette, 2008). Most of the other professional development offered through the Ministry of Education's ICT PD initiative appears to have been facilitated via face-to-face meetings and workshops, with "opportunities to share ideas and problems and reflect and produce solutions together on their use of ICTs for teaching and learning purposes ... among the most appreciated aspects of the programme" (Sahin & Ham, 2010, p. 2).

The *National School Sampling Study* found that science teachers wanted resources that would stimulate students and maintain motivation, as well as guidance on how to use available material in their teaching (McGee et al., 2003). Similarly, in a project evaluating the New Zealand's laptops for teachers (TELA) scheme (Cowie, Jones, & Harlow, 2005) science teachers were identified as being particularly amenable to using Internet-based resources in their lessons. However, access to formal and informal professional development opportunities significantly influenced whether and how teachers continued to develop their use of ICTs to support student learning.

One aim for teacher professional learning in relation to e-learning is to identify and address some of the challenges teachers face when incorporating a new approach, with affordances and constraints that have not previously been encountered. For example, Wallace (2004) points out that whereas with a textbook teachers can see what page students are on and what they are likely to be looking at, this is a lot more difficult to do when students are using a Web-based environment: "Student work can be located anywhere in a nearly limitless information space, with the physical manifestation (what appears on the screen) varying with each page change" (p. 476). One way to address this is using Web 2.0 technologies to create a visual record of students' explorations—and to use this record to enhance student learning. For example, students can collaborate with each other synchronously and asynchronously via the digital record. They can also review their own and others' contributions at crucial points in their learning. In addition, teachers are provided with insights that they can use to develop timely and appropriate formative commentary (e.g., Heap, 2011, see above).

Another challenge of e-learning environments is changes in power relations between teacher and student and student and student, and a reconstruction of who holds what expertise. Wallace (2004), for example, highlights the additional demands placed on the teacher's subject knowledge when students have open-ended assignments and access resources or websites that teachers are not familiar with. In contrast, researchers such as van Zee and Minstrell (1997) show positive gains in learning that come about when the authority for classroom conversations shifts from the teacher to the students. Web 2.0 technologies potentially shift the centre of control even further in the direction of students, with contributions able to be made simultaneously, at any time, from anywhere and in response to anyone. Wright (2010) suggests that teachers willing to engage in these pedagogies incorporating ICTs in this kind of way are likely to be experienced, secure in their pedagogical practices, astute about what students' responses mean for learning and self-motivated to seek out further knowledge.

School organisation and leadership also have a critical role to play in facilitating and supporting teachers' professional learning, and indeed in providing an environment where risk-taking is not only possible, but actively fostered.

2.3.2 School infrastructure and leadership

The national evaluation of the laptops for teachers scheme carried out by the University of Waikato highlighted the interplay between teacher knowledge, confidence and professional development; school technological infrastructure; and school organisation and leadership (e.g., Cowie, Jones, & Harlow, 2011). This concurs with Selwyn and Facer's (2007) position that ICT use is not just based on the individual being able to understand the potential benefits, but also on how well the ICT-based activity fits with the wider context. In other words, school-level factors influence teacher utilisation of ICT, and a system-wide approach is needed to support any change.

In analysing the findings from the TELA evaluation, Cowie et al. (2011) draw on Engelbart's (1992) three-tiered improvement infrastructure: core capability, enabling the core work of the organisation; infrastructure enabling the improvement of core work; and infrastructure enabling ongoing improvement of the improvement process. Using this model, Cowie et al. demonstrate the ways in which professional development opportunities, school technological infrastructure and school organisation and leadership acted together to influence the ways in which teachers were using their laptops in and out of their classrooms. They also point out the different roles each of these aspects might play at different times in the improvement cycle. For example, in schools with well-established ICT infrastructures, professional development led to increased demand for hardware and software so that professional learning could be enacted within the teaching programmes. In contrast, teachers in schools with less well-developed ICT infrastructures focused on the more immediate infrastructural needs, and professional development was not as prioritised.

A cycle of need was also identified by Cowie et al. (2011) at the level of individual teachers, where professional development led to changes in classroom practice, which in turn led to changed infrastructure needs; when these were met, additional professional development resulted in more changes to classroom practice and new infrastructural needs. In line with this, Frank, Zhao, Penuel, Ellefson and Porter (2011) found that teachers need different sources of professional knowledge depending on their current level of implementation. At a whole-school level, Owston (2006), analysing 59 cases of technological pedagogical innovation across 28 countries, found a complex interplay between:

> Essential conditions for the sustainability of classroom innovation were teacher and student support for innovation, teacher perceived value of the innovation, teacher professional development, and principal approval. Contributing factors for sustainability were supportive plans and policies, funding, innovation champions, and internal and external recognition and support. (p. 61)

The advent of the Ultrafast Broadband in Schools and the Network for Learning programmes will offer schools "affordable, safe, ultra-fast Internet access as well as a range of online content and centrally-procured services" (http://www.minedu.govt.nz/theMinistry /EducationInitiatives/UFBInSchools/ANetworkForLearning.aspx). While a necessary step if New Zealand education is to keep pace with the 21st century needs of its students, the concomitant changes that will need to be negotiated by teachers, principals and schools need to be approached with a system-wide view and with sensitivity.

The next section presents pertinent findings with respect to science teachers' views and uses of ICTs in science education. These offer valuable insights into how e-in-science might develop within the New Zealand landscape, and who might participate as key innovators in the area.

3. TEACHER SURVEY

3.1 SURVEY QUESTIONS

As indicated in the introduction above, an online survey was constructed to seek teachers' views of e-in-science, as well as information related to the other two project strands. In order to provide a context in which teachers could frame their responses to the item focusing on how students use ICTs in their science programmes, the survey stated that ICTs include, but are not limited to, using: the Internet, learning platforms like Moodle, videoconferencing or Skype, blogging, data loggers and Web 2.0 technologies. The survey item then listed a series of tasks and asked teachers to indicate how often they used ICTs to support student learning through these tasks (never, don't but would like to, sometimes—every couple of weeks, or often—at least once a week).[8] The listed activities included a set of common-place approaches where ICTs are used to retrieve or disseminate information (e.g., teachers updating their own knowledge, finding resources like images or articles, finding student activities, demonstrating a concept or providing an example or having students use computers to search for information), as well as more innovative approaches involving creating knowledge and/or collaborating (collecting or analysing scientific data, communicating with peers or experts and publishing on the Internet). No open-ended questions were included, with the expectation that focus group discussions in the next phase of the project would be more useful at providing insights into how ICTs are being used to support students' science learning and engagement.

Teachers were also asked as part of another question to indicate their level of agreement with the statement "It is important to use ICTs as part of a 21st century science education programme". In addition, several survey items related indirectly to ICT use. For example, the question bank focusing on teacher use of named curriculum support materials included several online resources in the list. Also presented in Hipkins and Hodgen's (2012) report are the findings from correspondence analyses of the data, highlighting significant patterns that emerged, including those relating to teachers' use of ICTs. The findings relevant to the e-in-science project are summarised.

3.2 SURVEY FINDINGS

Of the 343 teachers who completed the survey, nearly all agreed or strongly agreed that it is important to use ICTs as part of a 21st century science education programme (91 percent of primary teachers, with 34 percent strongly agreeing; and 95 percent of secondary teachers, with 54 percent strongly agreeing).[9] Of course, the sample is likely to be skewed in favour of teachers who feel comfortable using an online medium given that the survey was online and advertised via online networks.

While it is positive that so many respondents support the use of ICT in science education, particularly given NZC's emphasis on e-learning and the considerable resource allocated to up-scaling the electronic infrastructure available to schools,[10] the insights into teachers' actual ICT use offered by the survey are more useful. These insights relate to the following aspects: how teachers use ICTs; use of online curriculum support materials; resource access; and characteristics of ICT innovators.

[8] See Figure 3.

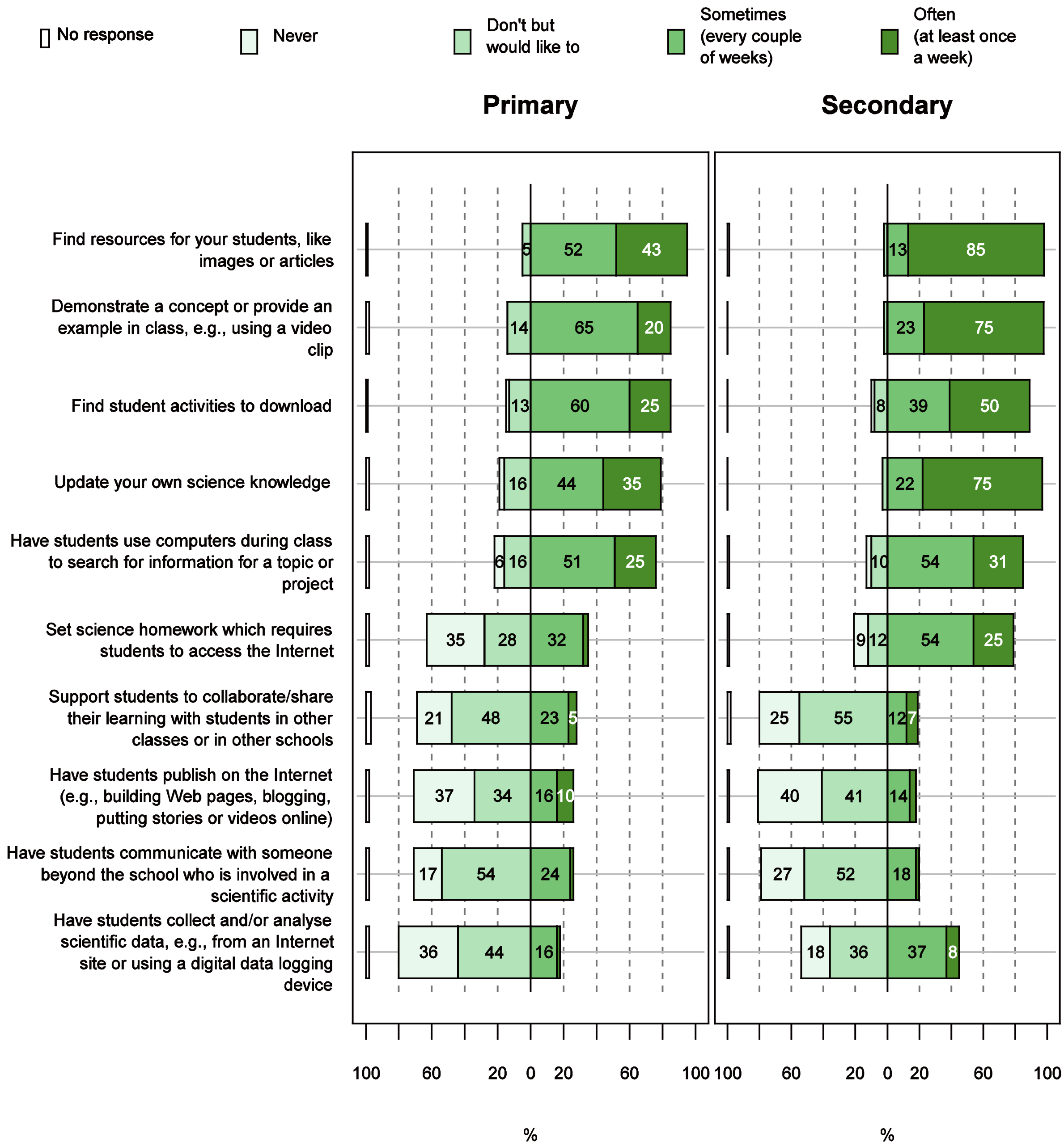
[9] Of the 343 respondents, 36 percent taught at primary level, 52 percent at secondary level and 12 percent did not respond to this item.

[10] These include the teacher laptop scheme, the ICT PD and school network upgrade (SNUP) programmes and the imminent rollout of Ultrafast Broadband in Schools and the Network for Learning project.

3.2.1 How teachers use ICTs

Figure 3 outlines teacher responses to the survey item seeking information about how they use ICTs in their science programmes.

Figure 3: How secondary (n=179) and primary (n=122) teachers use ICTs in their science classes (Hipkins & Hodgen, 2012, p. 26)



As can be seen, teachers were far more likely to use ICTs for retrieving and sharing information than for collaborating or creating knowledge (see Figure 3).[11] Importantly, for the

[11] The difference in use of ICTs for retrieval and collaborating/creating may be related to the asynchronous versus synchronous nature of these activities: retrieval generally occurs asynchronously, content being downloaded after it has been created; collaborating and creating, while possible to do asynchronously, is arguably enhanced by

latter category of activities (collaborating and/or creating knowledge), there were large groups of teachers who indicated that they would like to use ICTs for these purposes. This suggests that teachers would like to move into the collaborative/creative space, but need support. As indicated earlier, a likely fruitful direction may be to support them in shifting from what they may perceive to be their role as "subject expert" to learning alongside and with their students. In other words, it is not the teacher's responsibility to "create the knowledge", but rather to create the opportunities for students to collaborate and co-construct knowledge.

We cannot tell from the general statements used in this survey item the extent to which the task the teacher had in mind when responding to each item engages students in critical thinking. For example, searching for information or downloading scientific data may or may not open up opportunities for rigorous, critical evaluation and synthesis. Similarly, activities that require students to use ICT to communicate with peers or an expert have potential to broaden understandings by both parties when shaped by meaningful and shared purpose. Creating "busy work" is not equivalent to creating opportunities for meaningful learning, and the skill of the teacher in constructing and managing appropriate and relevant ICT-based activities is central.

Finally, it seems noteworthy that while 79 percent of primary teachers reported using ICTs to update their own science knowledge, only 35 percent did so often (at least once a week). Hipkins and Hodgen (2012) suggest this is likely associated with the lower frequency of science teaching in many primary classrooms. However, it seems an important observation in light of the Education Review Office (2012) report highlighting the lack of science content knowledge of many primary school teachers, and the subsequent impacts on their confidence and efficacy with respect to science teaching. How are such teachers to be supported to enhance their content knowledge, their PCK *and* their TPACK?

3.2.2 Use of online curriculum support materials

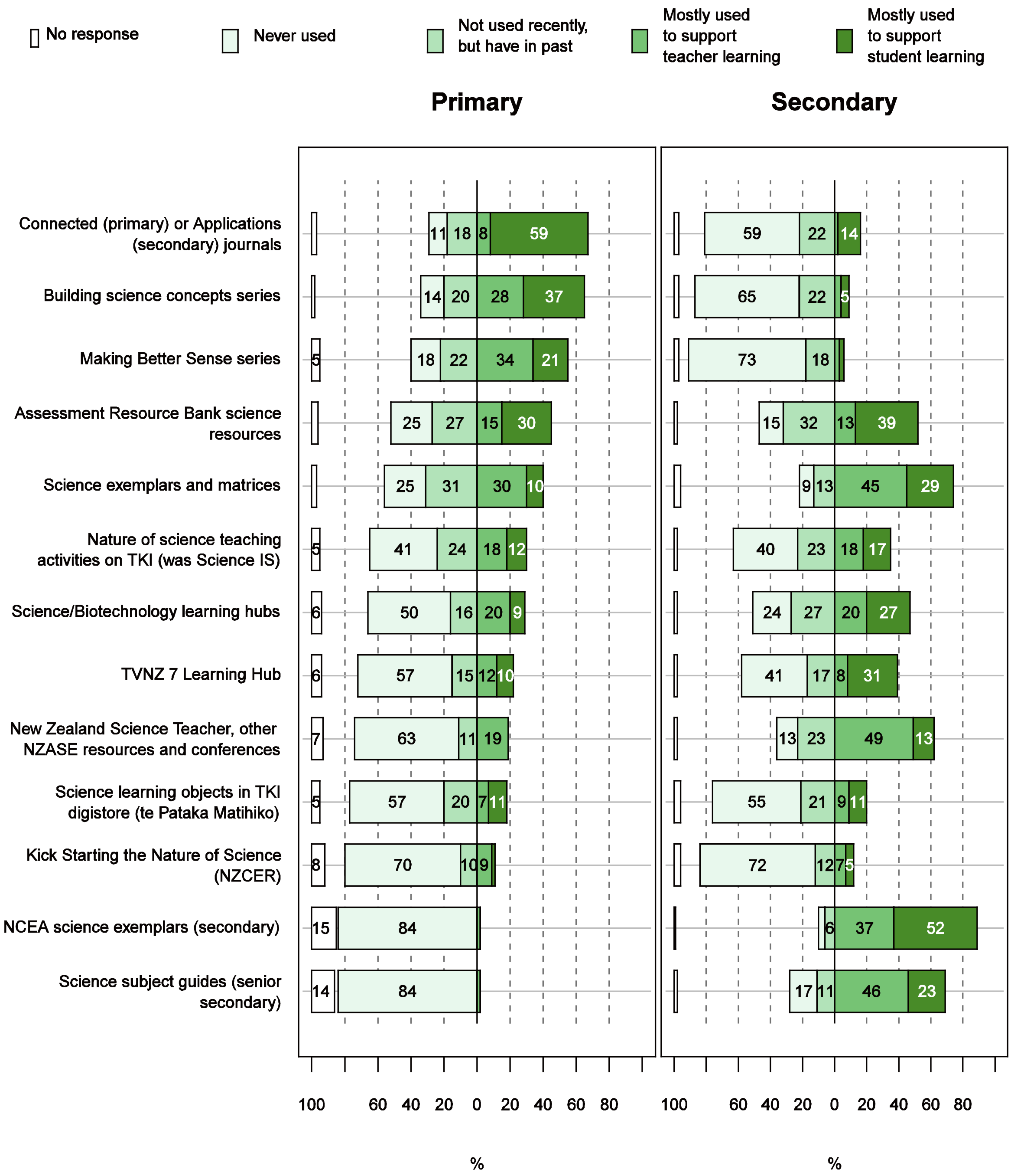
As part of the broader research programme, the survey sought to identify the purposes for which teachers used specific curriculum support materials.[12] A range of examples was provided (see Figure 4 below) followed by space for respondents to list additional resources. Of the ones provided, the majority are delivered online (e.g., Assessment Resource Bank [ARB] science resources, Science exemplars and matrices) but only three of the 13 resources listed are fully embedded within a digital environment. These are: the Science and Biotechnology Learning Hubs, TVNZ learning hub and science learning objects in TKI's digistore (see Figure 4).

Of the 13 listed resources, 11 are relevant to primary school teachers and the three fully embedded online were ranked 7th, 8th and 10th respectively in terms of use during the previous year. In addition, half or more than half of primary teacher respondents indicated that they had never used these three online resources (50 percent, 57 percent and 57 percent respectively). The picture is more positive for secondary school teachers' use of these digital learning resources, which ranked 6th, 7th and 9th out of 13 (NCEA exemplars and science subject guides—not included in the primary teachers' ranking—here placed first and third respectively). Secondary school teachers were also significantly more likely to use these digitised resources mostly to support student learning (as opposed to their own learning). However, there was still a large group who had never used them (24 percent, 41 percent and 55 percent respectively).

opportunities for synchronous interactions. Such synchronous interaction is likely one of the key affordances (opportunities) offered by Ultrafast Broadband.

[12] This part of the survey was focused on the second project within the three-project work programme: curriculum support for science.

Figure 4: Patterns of use of various curriculum support materials by secondary (n=179) and primary (n=122) teachers



In the open-ended section related to resources for supporting science teachers, primary teachers listed a range of Web-based resources, although these were each mentioned only once or twice, and several primary teachers referred to sites where teachers could share ideas. Their use of these sites—when, how and why—will be an interesting question to pursue during the next phase. In particular, the potential role of these websites for supporting the teaching of the Nature of Science strand of the science curriculum will be investigated. Secondary teachers similarly referred to a wide range of e-resources. In addition, Hipkins and Hodgen (2012) point out that secondary teachers appeared to stress the value of resources that were clearly linked to student learning needs, and there was some criticism of local (New Zealand) resources that they felt did not meet this criterion. Favourable mention was made of onsite (rather than online) programmes like LENS, funded by Auckland University's Liggins Institute, for students to access up-to-date science information. A later survey item probing teachers' use of community resources suggested that issues of access (such as funding or school location) as well as school organisational structures (such as timetabling) could act as barriers. As Hipkins and Hodgen (2012) point out, however, “some barriers can be transcended with determination and creative thinking” (p. 24). Here, they refer to an online solution proposed by one respondent, who indicated, “We will be Skyping experts.” A balanced view regarding infrastructural constraints and innovative possibilities therefore needs to be sought.

3.2.3 Resource access

Access to resources did not appear to be the dominant barrier for those not using ICTs in their science education programmes, as evidenced in the survey item asking teachers about their ease of access to a set of listed resources. For example, 46 percent of primary teachers reported “ready access” to online science resources during class, with a further 38 percent reporting access “with time to plan”. Of the secondary teachers, 58 percent reported “ready access” and 25 percent reported access “with time to plan”. However, this still leaves more than 10 percent of the respondents reporting either no access or limited access. Perceptions about access to “e-tools that support science inquiries (e.g., data loggers, science databases)” were not as positive, with only 36 percent of primary teachers and 46 percent of secondary teachers reporting “ready access” or access “with time to plan”. This seems a significant issue to pursue during the next phases of the study, particularly since it is the use of such e-tools that is likely to influence how ICTs can be used to enhance (or even transform) education in science, as opposed to other curriculum areas.

Another salient finding from the survey item on resource access is the high level of coherence between individuals’ responses across the range of resources. For example, factor analysis suggested that “teachers who are well-connected to resources are able to access and use a whole range of these, while those who perceive access issues cannot or do not access resources of all different types” (Hipkins & Hodgen, 2012, p. 45). Teachers in rural schools or decile 1 or 2 schools tended to be overrepresented in the “no access/little access” quartiles, as did secondary teachers (as opposed to their primary colleagues). Teachers in these quartiles were, perhaps not surprisingly, less likely to use the three fully digitised resources: the Science/Biotechnology Learning Hubs, TVNZ 7 Learning Hub and the science learning objects in TKI’s digistore. However, there were no overall differences by resource-access quartile for the more conventional uses of ICT for learning. In addition, “no access/little access” teachers indicated they used other resources that are delivered electronically (e.g., ARBs). This suggests, as Hipkins and Hodgen point out, that access is not straightforwardly about online capacity. Again, this is worthy of further investigation. For example, it is possible for the ARBs to be downloaded by the teacher at home and then used as paper-based resources; this would not require school IT infrastructure support. In addition, teachers in the readiest-access and planned access quartiles were more likely to have students use ICTs to collect and/or analyse scientific data, to collaborate/share their learning with their peers and to communicate with an expert.

3.2.4 Characteristics of ICT innovators

In pursuit of a more nuanced understanding of teachers’ use of ICTs, it is interesting to note that those who were most confident in their ability to implement the various strands of NZC, including the Nature of Science (NOS) strands, were:

> more likely than all other respondents to often (at least once a week) access ICT resources to: update their own science knowledge; find student activities to download; have students collect and analyse scientific data; and have students

> communicate with someone beyond the school who is involved in a scientific activity. (Hipkins & Hodgen, 2012, p. 47)

They were also more likely to say they had ready access to e-tools that support science inquiries. However, once again, there was no statistically significant correlation between confidence implementing the strands and online access to science resources during class. This appears to reinforce the notion that whether—and how—ICTs are used in class is not straightforwardly about physical access.

Correspondence analysis carried out by Hipkins and Hodgen (2012) offers evidence of a relationship between ICT use and teacher outlook. For example, correspondence groupings based on teacher responses to a range of curriculum support materials (see Figure 4) were described as follows:

- non-users (17 percent; had never used a combination of the listed resources)
- primary teachers (22 percent; had used a combination of the print-based resources, but no NCEA resources)
- NCEA-focused teachers (20 percent; had only used NCEA science exemplars with their students)
- innovators (11 percent; had used a combination of the listed resources during the last year, and were all secondary teachers).

Of these, it was the "innovators" and "NCEA-focused teachers" who were:

> more likely to be the most active (weekly) users of ICTs to: update their own science knowledge; find resources for students; find students activities to download; demonstrate a concept in class; set science homework that required students to access the Internet; and have students collect and analyse scientific data. Innovators were also more likely to often have students use ICTs to: do research during class time; collaborate with students in other classes or schools; and to sometimes communicate with people outside the school about a science activity. Teachers in the NCEA cluster, along with non-users, were more likely to say they never had students use ICTs to communicate with other students, or with people beyond the school. (Hipkins & Hodgen, 2012, p. 62)

Those who use a range of curriculum resources are therefore also likely to use a range of ICT-based tasks in their teaching programmes. That these teachers were a subgroup of secondary teachers rather than primary teachers is likely linked to the specialist nature of science teaching in secondary schools. However, the Education Review Office (2012) report on science teaching in primary schools highlights the need for passionate science curriculum leaders at this level as well.

Perhaps more heartening with regards to primary school science teaching is the survey finding that it was teachers in the innovator and primary teacher clusters who reported accessing a wide range of community resources, and being most confident in their ability to implement the NOS strand of the NZC. As Hipkins and Hodgen (2012) point out:

> Again, there is a clear association between use of a range of resources and a confident understanding of the broader intent of the curriculum (i.e., not just the content strands). (p. 44)

Correspondence analysis for responses to the survey item focused on ICT use (see Figure 3) resulted in four quadrants described as follows:

- non-users (19 percent)—do not use some combination of the activities listed, and although they did want to use ICTs to update their own knowledge, they were not currently doing so

- ICT as a teaching resource (13 percent)—the focus of ICT use was more likely to be their teaching rather than the direct use of ICT by their students for learning purposes
- cautious e-learning innovators (27 percent)—occasionally require students to use ICTs to collect/analyse scientific data, or set homework requiring Internet access; they would like to have students collaborate with their peers and publish on the Internet
- e-learning innovators (12 percent)—use ICT to do some combination of all the listed activities on a regular basis (at least weekly).

Not surprisingly, the "innovators" were the only group likely to have used the Science or Biotechnology Learning Hubs. They were also more likely to have accessed all of the community resources in a given list, and were more likely to strongly agree that they had good access to personal networks for teaching ideas and support. They were most likely to strongly disagree with the statement, "There is too much emphasis on student voice and similar ideas nowadays". Along with teachers in the "ICT as a teaching resource" cluster, innovators had the highest confidence with regards to their confidence implementing all strands of NZC. These two clusters were also the most likely to strongly agree with the statement, "The NOS strand of NZC is changing the way I teach science".

The link between innovative ICT use and strong access to professional learning networks is important to note. It is also interesting that teachers who reported ready or planned access to a range of resources also reported that they had good access to personal networks for science ideas and support; their school had good processes for learning and changing pedagogy together; and the NOS strand was changing the way they teach science. The positive association between perceptions of resource access and ICT use has already been pointed out. Taken together, these findings suggest a strong association between professional support and ICT use in science education programmes. This concurs with several other studies that have highlighted the importance of school support and leadership in fostering a school climate of innovation in e-learning (e.g., Cowie et al., 2011; Education Review Office, 2012; Wright, 2010).

3.3 SUMMARY AND DISCUSSION

A key aim of the e-in-science project is to develop scalable, sustainable models of e-in-science practice. With this in mind, it is encouraging that 91 percent of primary teachers and 95 percent of secondary teachers who responded to the survey agree or strongly agree with the statement "It is important to use ICT as part of a 21st century science education programme". However, the picture of how ICTs are currently actually being *used* in science education is more cautionary.

While a large majority of respondents (more than three-quarters) reported using ICTs for more conventional purposes related to retrieving and disseminating information, less than a third require students to use ICTs to communicate or collaborate with peers or an expert, or to publish on the Internet. Secondary teachers (45 percent) are more likely than primary teachers (18 percent) to have students collect and/or analyse scientific data (e.g., from an Internet site or using a digital data logging device). Only 12 percent of the respondents were identified through correspondence analysis as being "e-learning innovators", using ICT to do some combination of all these activities on a regular (weekly) basis. However, a large proportion of teachers (more than a third) indicated that they wanted to do many of the listed activities.

Analysis between survey items suggests that perceptions about access are only a small part of why teachers actually use—or don't use—e-resources. For example, strong associations were found between ICT innovation and confidence implementing all science strands of NZC; and between ICT innovation and professional support. This suggests that, where there is the perception of strong professional support and high levels of confidence implementing all of the science strands in NZC, there is likely also innovative use of ICT in science pedagogy. Given the "newness" of many of the innovative ICTs (e.g., social networking sites and Web 2.0 technologies) it seems possible that sound curriculum knowledge and strong professional support precede innovative ICT use.

While teachers showed generally strong support of an e-in-science approach to science education and a desire to provide online opportunities with a clear purpose for learning, the survey results highlight the varying capability and efficacy teachers have with regards to embedding more innovative ICT approaches in their science pedagogy. School infrastructural and leadership support also needs to be considered. For instance, the importance of ongoing, sustained professional learning opportunities is highlighted by Sahin and Ham's (2010) finding that the greatest persisting concerns for 2,674 teachers who were part of the 2006–8 School Cluster cohort and completed a survey were: "lack of student access to equipment, a perceived lack of time to keep up to date with the range of ICTs available, technical reliability, and some concern about their continuing need for PD after the programme's formal end point" (p. 2).

The challenge of this project is therefore multifaceted. In order to encourage discussion about what the future of e-in-science could look like and why, we need to ask how the constraints perceived by teachers might be addressed. In addition, we need greater clarity on how teachers can be supported to develop their PCK and TPACK in order to provide meaningful experiences for students to engage collaboratively in science learning and inquiry.

4. NEXT STEPS

4.1 E-IN-SCIENCE: PROJECT PHASE 2

The aim of the e-in-science project is ultimately to identify sustainable, scalable models for e-in-science in New Zealand. As part of this project, we will seek to identify factors that enhance or constrain the incorporation of effective e-learning in science education, including teacher knowledges (i.e., knowledge of e-learning, knowledge of e-resources and e-tools that are available and how these might be used to enhance student engagement and learning in science, and knowledge of the diverse needs of their students); teacher professional development; and school context, including leadership and infrastructural support. The design we have developed takes as its starting point our understanding of the needs of diverse learners, with a particular focus on Māori and Pasifika students.

During the second phase (July–December 2012), the project team will convene four to five focus group meetings with teachers identified as being innovative and enthusiastic about what might be possible in e-in-science. These teachers will be identified from the survey (a large number of respondents indicated a willingness to participate in follow-up conversations) and from our personal and professional networks.

The aim of the focus groups will be to identify and explore:

1. examples of actual or possible e-in-science practice where teachers and students have used ICT to collect and/or analyse their own scientific data (working as scientists), interact or collaborate with scientists or science experts (working with scientists) and/or collaborate with each other in the co-construction of scientific understanding (peer collaboration)
2. teacher versus student-directed use of ICT, and what this might mean for the classroom dynamic
3. possibilities for sustainable professional learning of teachers, particularly with regards to their PCK and TPCK
4. how Web 2.0 platforms might be used to support teachers to share resources and ideas, particularly regarding the NOS strand of the science curriculum
5. the role of school leadership in enabling successful e-in-science practice
6. values and principles of a future-focused approach to e-in-science.

It is anticipated that at least two participants from the focus groups will be invited to work with the research team to plan and implement a science unit in which ICT is embedded for the purpose of enabling students to work as scientists, work with scientists and/or work with each other to develop their scientific understanding. Ideally the ICT will be some way linked to online access, since the genesis of the project was in part the rollout of Ultrafast Broadband to schools. With the permission of the teacher participants, the research team will construct a case study of each initiative, detailing insights about: the affordances offered by the ICT; student engagement and achievement; teacher PCK and TPCK; and constraining and supporting factors at the level of the school system.

The findings from phase 2 will be used to further refine our approach for phase 3, in which we will consider ways forward in establishing sustainable, scalable models for e-in-science.

REFERENCES

Adam, J., Salter, D., & Woodgate, S. (2011, November). *Analysing the mistakes made by New Zealand year 13 students using Bestchoice chemistry tutorial website*. Oral presentation at the Science Education Research Symposium (SERS), Auckland.

Buntting, C., & Saunders, K. (2011, July). *Scaffolding ethical reasoning using a digital learning object.* Paper presented at the 42nd annual ASERA conference, Adelaide.

Chen, J., Cowie, B., & Oliver, K. (2011). Reading to learn about birds and their conservation. *New Zealand Science Teacher, 127*, 31–33.

Cochrane, T. D. (2010). Exploring mobile learning success factors. *ALT-J: Research in Learning Technology*, *18*(2), 133–148.

Cowie, B., Jones, A., & Harlow, A. (2005). The digital horizons: Laptops for teachers policy initiative: Impacts and consequences. *New Zealand Annual Review of Education*, *15*, 111–132.

Cowie, B, Jones, A, & Harlow, A. (2011). Technological infrastructure and implementation environments: The case of laptops for New Zealand teachers. In S. D'Agustino (Ed.), *Adaptation, resistance and access to instructional technologies: Assessing future trends in education* (pp. 40–52). Hershey, PA: Information Science Reference.

Education Gazette. (2008). The online ideas pool. *Education Gazette*, *27 October*. Retrieved 18 April 2012, from http://www.edgazette.govt.nz/Articles/Article.aspx?ArticleId=7709&Title=The online ideas pool

Education Review Office. (2012). *Science in the New Zealand curriculum: Years 5 to 8*. Retrieved 10 May 2012, from http://www.ero.govt.nz/National-Reports/Science-in-The-New-Zealand-Curriculum-Years-5-to-8-May-2012

Engelbart, D. (1992). *Toward high-performance organizations: A strategic role for groupware*. Freemont, CA: The Bootstrap Institute.

Falloon, G. (2011). The science-for-life partnerships: Does size *really* matter, and can ICT help? *Waikato Journal of Education*, *16*(1), 35–50.

Falloon, G. (2012). School–scientist partnerships through videoconferencing: Students' perceptions and scientists' challenges. *Research in Learning Technology*, 20*(*3). doi. 10.3402/rlt.v20i0.17194

Falloon, G. (in press). e-science partnerships: Towards a sustainable framework for school–scientist engagement. *Journal of Science Education and Technology*.

Fenton, M. (2008). *Authentic learning using mobile sensor technology with reflections on the state of science education in New Zealand*. Retrieved 18 April 2012, from http://www.nexusresearchgroup.com/downloads/eLearning-eFellow-Report.pdf

Frank, K. A., Zhao, Y., Penuel, W. R., Ellefson, N., & Porter, S. (2011). Focus, fiddle, and friends: Experiences that transform knowledge for the implementation of innovations. *Sociology of Education, 84*(2), 137–156.

Garrison, D. R., & Anderson, T. (2003). E*-learning in the 21st century: A framework for research and practice*. New York: Routledge/Falmer.

Gluckman, P. (2011). *Looking ahead: Science education for the twenty-first century: A report from the Prime Minister's chief science advisor.* Auckland: Office of the Prime Minister's Science Advisory Committee.

Harlow, A., Cowie, B., & Heazlewood, M. (2010). Keeping in touch with learning: The use of an interactive whiteboard in the junior school. *Teaching, Pedagogy and Education*, *19*(2), 237–243.

Haythornthwaite, C., & Andrews, R. (2011). *E-learning theory and practice*. London: Sage.

Heap, R. (2011). Riding the wave: Using Web 2.0 technology to develop nature of science understanding among preservice teachers. In J. Parr, H. Hedges, & S. May (Eds.), *Changing trajectories of teaching and learning* (pp. 601–647). Wellington: New Zealand Council for Educational Research.

Hipkins, R., & Hodgen, E. (2012). *Curriculum support in science: Patterns in teachers' use of resources.* Wellington: Ministry of Education.

Jones, A., & Buntting, C. (2012). Conceptual change through information and communication technologies in Australasia. In C. B. Lee & D. Jonassen (Eds.), *Fostering conceptual change with technologies: Asian perspectives* (pp. 3–25). Melbourne, Australia: Cengage Learning.

Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education (CITE), 9*(1), 60–70.

Lowe, P., Taylor, S., & Buntting, C. (2011). Problem based learning in science. *New Zealand Science Teacher, 127*, 28–30.

Luehmann, A. L., & Frink, J. (2009). How can blogging help teachers realize the goals of reform-based science instruction? A study of nine classroom blogs. *Journal of Science Education and Technology, 18*, 275–290.

McGee, C. J. A., Cowie, B., Hill, M., Miller, T., Harlow, A., & MacKenzie, K. (2003). *Curriculum stocktake: National school sampling study: Teachers' experiences in curriculum implementation: English, languages, science and social studies*. Wellington: Ministry of Education.

McLoughlin, C., & Lee, M. J. W. (2008). Future learning landscapes: Transforming pedagogy through social software. *Innovate: Journal of Online Education, 4*(5).

Ministry of Education. (2007). *The New Zealand curriculum*. Wellington: Learning Media.

Otrel-Cass, K., Ballard, M., Andrews, S., Cutler, D., Cowie, B., Khoo, E., & Taylor, S. (2011, November). *E-networking tools in support of secondary science inquiry*. Paper presented at the Science Education Research symposium, The University of Auckland, Auckland.

Otrel-Cass, K, Cowie, B., & Khoo, E. (2010). ICT in support of science teaching and learning: Teaching landforms and erosion. *set: Research Information for Teachers*, *3*, 15–21.

Otrel-Cass, K., Cowie, B., & Khoo, E. (2011). The SCIAnTICT project: Technology-enhanced teaching and learning of primary science. *set: Research Information for Teachers, 3*, 26–31.

Owston, R. (2006). Contextual factors that sustain innovative pedagogical practice using technology: An international study. *Journal of Educational Change, 8*(1), 61–77.

Sahin, S., & Ham, V. (2010). *Outcomes for teachers and students in the ICT PD school clusters programme 2006–2008—A national overview*. Report to the Ministry of Education. Christchurch: Core Education.

Selwyn, N., & Facer, K. (2007). *Beyond the digital divide: Rethinking digital inclusion for the 21st century*. Bristol, UK: Futurelab.

Shaw, R. (2007). Pedagogic learning that grounds e-learning for secondary school science students in New Zealand. *e-Learning, 4*(4), 471–481.

van Zee, E., & Minstrell, J. (1997). Reflective discourse: Developing shared understandings in a physics classroom. *International Journal of Science Education, 19*(2), 209–228.

Wallace, R. M. (2004). A framework for understanding teaching with the Internet. *American Educational Research Journal, 41*(2), 447–488.

Webb, M. E. (2005). Affordances of ICT in science learning: Implications for an integrated pedagogy. *International Journal of Science Education, 27*(6), 705–735.

Wright, N. (2010). *mLearning capability pilot project at Howick College*. Unpublished research report for the Ministry of Education.

Woodgate, S., & Titheridge, D. (2008). BestChoice: Interactive web-based learning. *Chemistry in New Zealand, April*, 63–67.