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Science in the New Zealand Curriculum e-in-science

Report prepared for the Ministry of Education

Cathy Buntting with Bill MacIntyre, Garry Falloon, Graeme Cosslett and Mike Forret

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New Zealand Council for Educational Research
P O Box 3237
Wellington
New Zealand

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Wilf Malcolm Institute of Educational Research (WMIER)
Faculty of Education
University of Waikato
Private bag 3105
Hamilton
New Zealand

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Executive summary

This milestone report explores some innovative possibilities for e-in-science practice to enhance teacher capability and increase student engagement and achievement. In particular, this report gives insights into how e-learning might be harnessed to help create a future-oriented science education programme.

“Innovative” practices are considered to be those that integrate (or could integrate) digital technologies in science education in ways that are not yet commonplace. “Future-oriented education” refers to the type of education that students in the “knowledge age” are going to need. While it is not yet clear exactly what this type of education might look like, it is clear that it will be different from the current system.

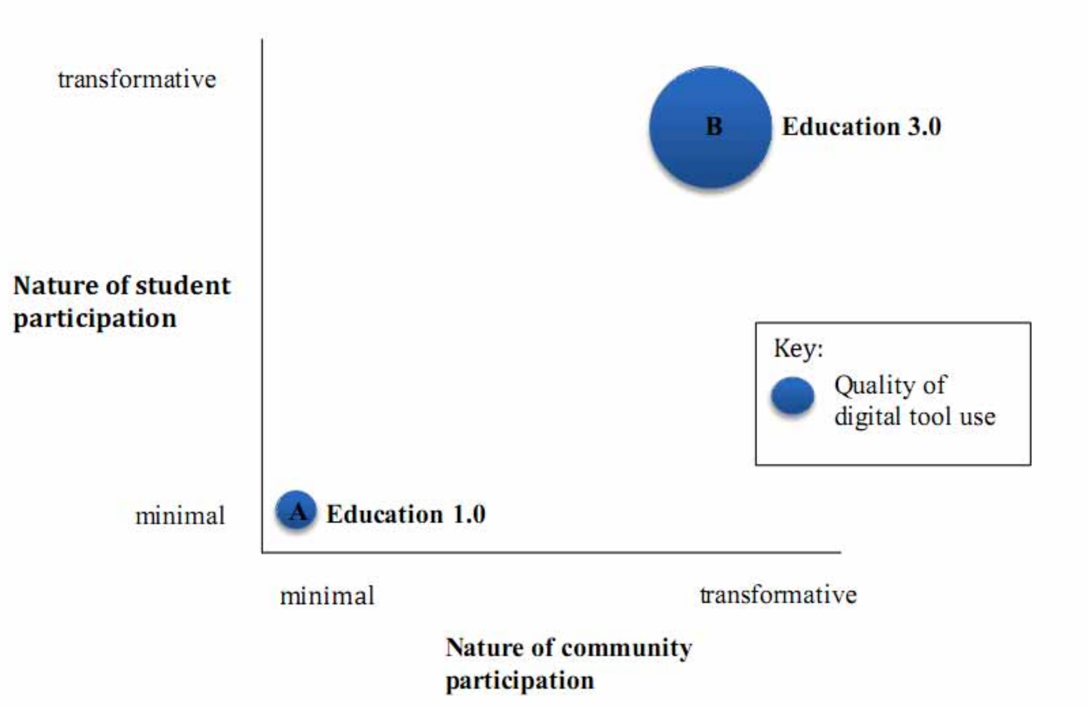
One framework used to differentiate between these kinds of education is the evolution of education from Education 1.0 to Education 2.0 and 3.0 (Keats & Schmidt, 2007). Education 1.0, like Web 1.0, is considered to be largely a one-way process. Students “get” knowledge from their teachers or other information sources. Education 2.0, as defined by Keats and Schmidt, happens when Web 2.0 technologies are used to enhance traditional approaches to education. New interactive media, such as blogs, social bookmarking, etc. are used, but the process of education itself does not differ significantly from Education 1.0. Education 3.0, by contrast, is characterised by rich, cross-institutional, cross-cultural educational opportunities. The learners themselves play a key role as creators of knowledge artefacts, and distinctions between artefacts, people and processes become blurred, as do distinctions of space and time. Across these three “generations”, the teacher’s role changes from one of knowledge source (Education 1.0) to guide and knowledge source (Education 2.0) to orchestrator of collaborative knowledge creation (Education 3.0). The nature of the learner’s participation in the learning also changes from being largely passive to becoming increasingly active: the learner co-creates resources and opportunities and has a strong sense of ownership of his or her own education. In addition, the participation by communities outside the traditional education system increases.

Building from this framework, we offer our own “framework for future-oriented science education” (see Figure 1). In this framework, we present two continua: one reflects the nature of student participation (from minimal to transformative) and the other reflects the nature of community participation (also from minimal to transformative). Both continua stretch from minimal to transformative participation. Minimal participation reflects little or no input by the student/community into the direction of the learning—what is learned, how it is learned and how what is learned will be assessed. Transformative participation, in contrast, represents education where the student or community drives the direction of the learning, including making decisions about content, learning approaches and assessment.

Different teaching and learning scenarios can be placed on this framework, with the bottom left corner of Figure 1 representing Education 1.0 (point A) and the top right representing Education 3.0 (point B). In addition, each scenario can be analysed for the quality of digital use, indicated by the size of the circle (small for minimal, surface use of digital tools; larger for more transformative use).

Using the data from four focus group interviews and two case studies, we developed a series of vignettes demonstrating different uses of digital tools in science and mapped them on the framework. In doing so, we were able to identify which aspects might need to be further developed, or even transformed, if the goal is to create an education experience more like Education 3.0 than Education 1.0 or even 2.0.

Figure 1 **Framework for future-oriented science education**



To help identify how teachers and schools might move further towards Education 3.0, we used Bolstad and Gilbert's (2012) six principles for future-oriented learning and teaching. These six principles are:

1. personalising learning
2. new views of equity, diversity and inclusivity
3. a curriculum that uses knowledge to develop learning capacity
4. rethinking learners' and teachers' roles
5. a culture of continuous learning for teachers and educational leaders
6. new kinds of partnerships and relationships: schools no longer siloed from the community.

Using these principles to interrogate the data from the focus-group interviews and case studies, we note that while some teachers are beginning to explore notions of personalising learning, there is limited evidence of teachers exploring how students or the community, or both, might shape the direction, scope, content and contexts for student learning. There is also little evidence of teachers grappling with the question of how to meet the learning needs of diverse cultural groups, and even less evidence of teachers considering how to harness "diversity" (in terms of people, and knowledge and ideas) as an integral part of learning.

Several of the teachers see a conflict between what they perceive to be more general aims of science education (e.g., passion for science as a way of knowing) and the traditional emphasis on content knowledge. This makes it difficult for them to offer science curricula that use science to develop learning capacity. Clearer direction is needed in curriculum and assessment policy for the desired purposes of science education in the compulsory sector. The recent report *The future of science education in New Zealand* (Royal Society Education Committee, 2012) is likely to be important here.

At least some of the teachers see the need for changes in their roles and a shift towards more student-centred approaches to teaching and learning. For example, blended e-learning and "flipped classroom" strategies are being introduced to help students gain ownership of their learning. However, there is little evidence of teachers moving to develop ways of working with their students to co-generate knowledge.

Innovative teachers are very appreciative of the autonomy and trust that they are accorded in their schools. They also recognise the importance of professional reflection and inquiry. However, while the Ministry of Education has—or is currently funding—a wide range of initiatives, there appears to be a need for more opportunities for "teacher innovators" to collaborate.

Links with the wider community for access to knowledge and expertise is seen as being important and valuable, but difficult to establish and maintain in the current education paradigm. ICTs have potential to help address challenges in communication across space and time, although this is still seen as being problematic for sustainability and scalability. There is strong support from teachers who have been involved in the LENScience senior seminar series for this kind of model to facilitate school access to scientists. Within this scenario, the challenges associated with the points referred to above—personalising learning, changes in teacher and student roles, harnessing diversity—need to be carefully considered.

A profound ideological shift is still needed for teachers and schools to understand and work towards a system that truly offers future-oriented learning and teaching. While digital technologies may be part of this change, they will only enable change in the formal education sector when they are supported by ideas and social contexts that facilitate transformative practice. Other factors are also important. These include: teacher dispositions and skills; school culture and leadership; infrastructure and support; and community involvement. Teachers need to be resilient, motivated and determined. School leaders need to make strategic decisions about resourcing and have a clear vision for the type of education offered by their school. The wider community needs to demand system-wide change, and to participate actively in it.

The significant investment associated with projects such as Ultrafast Broadband in Schools, the School Network Upgrade Project and the Network for Learning is important if New Zealand education is to support 21st-century learning needs. However, if this investment is to be worthwhile, systemic scaffolding is needed for a parallel shift in the thinking of teachers, principals and school communities. We hope that this report helps the Ministry of Education to plan this support.

1. Introduction

This is the third milestone report for a 17-month Ministry of Education project investigating e-learning in science education (e-in-science). The project is one of three strands in a larger programme of work being led by the New Zealand Council for Educational Research, in partnership with the University of Waikato and Learning Media.

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 associated with implementing these possibilities
2. work with students and teachers to explore innovative possibilities for e-in-science practice which will 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 second phase of the project (June–November 2012), detailed in this milestone report, was to investigate creativity and innovation for e-learning in science, both to enhance teacher capability in science and science education, and to increase student engagement and achievement in science. Our approach—which included focus group interviews and case studies—was premised on the following assumptions:

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

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[1] 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.

Our overarching goal was to gain insights into how e-learning might best be used by schools to create future-oriented science education programmes.

2. Harnessing e-learning for future-oriented science education

In considering how e-learning might be harnessed to help create a future-oriented science education programme, we acknowledge two things. First, ICTs and digital technologies have a ubiquitous presence in “developed” society and culture; and secondly, an extensive literature from the 1990s and 2000s discusses the multiple affordances ICTs have to offer education when integrated thoughtfully and purposefully. However, we do not see e-learning as transformative in and of itself. Rather, ICTs are one of several factors contributing to reforms in science education, and education as a whole.

Over the last decade or more, New Zealand’s Ministry of Education has supported ICT development in schools through a range of initiatives. Recently, there has been a focus on infrastructure development through the roll-out of Ultrafast Broadband and the School Network Upgrade Project. Some past and continuing examples include:

- providing enabling tools (e.g., the Laptops for Teachers scheme)
- supporting teacher professional development (e.g., through the ICT-PD clusters and the Virtual Learning and Professional Development initiative)
- supporting innovation (e.g., the digital opportunities programme and e-learning teacher fellowships, although both are now finished)
- providing opportunities for connections between people and ideas (e.g., through the Virtual Learning Network).

The Ministry also funds an extensive array of online curriculum materials (e.g., material delivered via Te Kete Ipurangi (TKI) and digistore), and learning ventures specific to science and environmental education (e.g., LEARNZ). Beyond these initiatives by the

Ministry of Education, the New Zealand Government invests in e-learning in science education via the Ministry of Business, Innovation and Employment, which funds the Science and Biotechnology Learning Hubs. e-Learning in New Zealand's formal education system is also stimulated by conferences such as ULearn and Learning@School, which expose teachers to new ways of integrating ICTs into their classrooms.[2]

Together, these initiatives represent a substantial economic investment in supporting the development of e-learning in the compulsory schooling sector. Consistent with this investment, the *New Zealand Curriculum* (Ministry of Education, 2007) 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
- facilitating shared learning.

New Zealand has many teachers who are working creatively and purposefully to integrate digital technologies into their science education programmes to enhance the learning opportunities available to their students. However, these "innovator" teachers can be difficult to identify. In addition, innovation is not yet a feature of the system, but continues to be limited to individual enthusiasts.

If we are to achieve a 21st-century education system, system-wide innovation is needed. However, supporting the development of this innovation involves many challenges. While digital technologies will play a role in transforming our education system, their use needs to be accompanied by parallel changes in thinking about *learning* and *knowledge*. As Dumont, Istance and Benavides (2010) put it:

> The rapid development and ubiquity of ICT are resetting the boundaries of educational possibilities. Yet, significant investments in digital resources have not revolutionised learning environments; to understand how they might requires attention to the nature of learning.

Twenty-first century (or "knowledge age") learning needs differ from learning needs of the past (Gilbert 2005; Bolstad & Gilbert 2012). For instance, future social and workplace roles will not have the stability and predictability that they once did, and much of the "knowledge" that will be needed has not yet even been created.

This report investigates creativity and innovation for e-learning in science, both to enhance teacher capability in science and science education, and to increase student engagement

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2 For science teachers, Scicon is held biennially with subject-specific conferences held in the intervening years although it is interesting to note that of 125 presentations and workshops at Scicon 2012, only 17 (14%) focused specifically on ICT-based resources and/or pedagogies.

and achievement in science. Together, the data represent four teacher focus groups and two case studies. Our premise in collecting the data was that:

> Research into present-day practice in schools and classrooms on its own cannot provide sufficient knowledge about how to address system-level challenges for innovation and transformation. However, looking at today's innovative teaching and learning practices can provide some insights into future possibilities, when integrated with theoretical arguments about the future of education. (Bolstad & Gilbert, 2012, p. 1)

In other words, through this small research undertaking we were not expecting to see the whole of what future e-learning in science might look like. Rather, we were exploring what it *could* look like, and looking for practices that could foster its development.

Innovation is obviously an important dimension of future-oriented practice. For this report, we adopted the OECD/Eurostat's (2005) definition of innovation as the implementation of production and delivery processes (e.g., science education) or products (e.g., digital technologies adapted for science education) with new or significantly improved characteristics. More broadly, we sought practices that integrate (or could integrate) digital technologies in science education in ways that are not yet commonplace. These innovative practices form an important part of the greater puzzle that the Ministry of Education is piecing together as it develops a vision of what future-oriented education could look like for New Zealand learners. Exploring innovative practices gives insights into what the conditions for innovation might look like for individual teachers—in the science curriculum, and in the education system as a whole.

In analysing the data that we obtained from the focus groups and case studies, we consider two theoretical frameworks. The first draws on work by Keats and Schmidt (2007) outlining three generations of education: Education 1.0, 2.0 and 3.0. Education 1.0, like Web 1.0, is considered to be largely a one-way process. Students "get" knowledge from their teachers or other information sources. Education 2.0, as defined by Keats and Schmidt, happens when Web 2.0 technologies are used to enhance traditional approaches to education. New interactive media, such as blogs, social bookmarking and the like, are used, but the process of education itself does not differ significantly from Education 1.0. Education 3.0, by contrast, is characterised by rich, cross-institutional, cross-cultural educational opportunities. The learners themselves play a key role as creators of knowledge artefacts, and distinctions between artefacts, people and processes become blurred, as do distinctions of space and time. Across these three "generations", the teacher's role changes from one of knowledge source (Education 1.0) to guide and knowledge source (Education 2.0) to orchestrator of collaborative knowledge creation (Education 3.0). The nature of the learner's participation in the learning also changes from being largely passive to becoming increasingly active: the learner co-creates resources and opportunities and has a strong sense of ownership of his or her own education. In addition, the participation by communities outside the traditional education system increases.

In a separate analysis of 21st-century learning, Bolstad and Gilbert (2012) posit six principles that need to be considered for developing a future-oriented education:

1. personalising learning
2. new views of equity, diversity and inclusivity
3. a curriculum that uses knowledge to develop learning capacity
4. rethinking learners' and teachers' roles
5. a culture of continuous learning for teachers and educational leaders
6. new kinds of partnerships and relationships: schools no longer siloed from the community.

While not new in and of themselves, these principles summarise the key issues involved in moving from Education 1.0 or 2.0 to Education 3.0.

Both frameworks—considering student and community participation within an Education 3.0 model, and the six principles for future-oriented learning—were used to guide our analysis of the focus group and case study data. The frameworks helped structure our thinking about how e-learning might be harnessed to support the development of future-oriented science education.

3. Methodology

For the purposes of this study, four focus groups were convened and two case studies constructed. An interpretive approach was used: we sought to understand teachers' multiple social constructions of meaning (Robson, 2002) associated with using digital technologies in science education, paying attention to the "real world" nature of the schools in which the teachers currently work (Patton, 2002).

Focus groups

Four focus groups were held with teachers. The four-fold purpose was to:

1. explore participants' views of the goals of science education and how ICTs might support these goals
2. identify innovative practices
3. identify personal and school characteristics that support innovative use of ICTs in teaching
4. consider the implications for supporting more widespread uptake of ICTs to transform science education in meaningful ways.

Three focus groups involved secondary school teachers and took place in Auckland, Hamilton and Wellington. One focus group involved primary and intermediate school teachers and took place in Hamilton. Rural and urban schools were represented at these focus groups, as were schools across the decile range. The participants were identified through a variety of means:

- their responses to the survey administered during the first phase of the project (see Hipkins & Hodgen, 2012)
- having been awarded a national teaching award or an e-fellowship
- recommendations by school advisors
- recommendations by those who had already been invited to a focus group
- through the research team's professional networks.

In total they included:

- four primary/intermediate teachers, all with science education as an area of special interest
- 10 secondary science teachers
- four secondary teachers who teach subjects other than science
- one secondary school's IT manager (who had originally taught science).

Each participant had been recognised by someone else as being innovative within the e-learning space. For instance, those who were invited to participate in a focus group because of their survey responses had been classified in the survey report as being "e-learning innovators".[3] Those who were recommended by school advisors or through our professional networks were known for their interest in using ICTs extensively and creatively in their classes.

Many participants held formal roles within their schools as lead teacher of ICT or the equivalent. This suggests that they not only are recognised within their school for their thinking about ICTs in teaching and learning, but also that they are more likely to be cognisant of the multiple factors senior leaders juggle when making strategic decisions about the school's direction and purpose.

Participants were contacted before the discussion with a proposed agenda, which included:

- examples of how they use (or would like to use) an ICT in a classroom programme—what was done (or could be done), the purpose for using the ICT, and what new aspects of learning were enabled by the ICT
- purpose(s) of science education, and how these might be supported by ICT initiatives
- how ICT initiatives might change how we think about science, science education, teacher roles, assessment and so forth.
- personal characteristics that tend to drive innovative use of ICT in classrooms
- school characteristics that tend to support innovative use of ICTs in classrooms
- possible ways to support teachers to use ICTs more innovatively.

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[3] Participants in this group had all used ICT, at least weekly, to do a combination of the activities listed in the survey, such as finding resources, demonstrating concepts, updating their own science knowledge, supporting students to collaborate with each other or someone beyond the school, having students collect and/or analyse scientific data, and/or having students publish on the Internet.

Each focus group took about three hours and discussion was highly animated throughout.

Case study 1

The first case study represents a large-scale e-learning programme targeting Scholarship biology students: the Senior Biology Seminar Series (SBSS) offered by LENScience from 2009 through 2011. It was chosen because of its national reach, its dependence on digital technologies for delivery, and the insights it offers in terms of how e-learning can support both the professional learning of science teachers, *and* the engagement and achievement of science students. Some of the science field trips offered by LEARNZ might have been similarly worthy of investigation.

While SBSS was not offered in 2012 because of a lack of funding, we were able to retrospectively interview some key people. These included: Jacquie Bay, director of LENScience and co-ordinator of SBSS when it had been running; three experts involved in setting up the required infrastructure and technical support; a Hamilton teacher; and three teachers from the greater Wellington region who met for a two-hour focus-group discussion. The four teachers were all recommended by LENScience because of how they had fully embraced participating in the programme with their students.

Jacquie Bay and three others representing the technological infrastructure behind SBSS were asked to comment on:

- their beliefs about the purpose(s) of science education
- the role of e-tools in supporting connections between schools and science communities—and why such connections are important
- the scope of the seminar series
- the advantages and disadvantages of using an online format
- sustainability and scalability issues.

Teacher participants were contacted before the discussion with the following agenda:

- reasons for enrolling in the seminar series
- impacts of the seminar series on their understanding and capability in science
- impacts of the seminar series on their views of science education, its purposes and how it might be enhanced
- impacts of the seminar series on students' engagement and achievement in science
- advantages and disadvantages of the online delivery
- possibilities for using a similar type of programme with more junior students
- how online services might be used to professionally support science teachers to enhance science understandings and pedagogy.

Case study 2

The second case study took place in a high-decile primary school. It investigated a one-off professional development programme to support the integration of digital technologies in primary science education, with a focus on the Nature of Science. It involved the following:

1. A pre-study interview with two Year 5–6 teachers and the deputy principal (who is responsible for curriculum leadership) to investigate their understandings about science, science education, ICT tools and e-learning in science.
2. A half-day professional development (PD) workshop facilitated by the researcher, with three senior syndicate teachers, the deputy principal and an external observer (a practicing primary school teacher involved in another science professional learning and development (PLD) project). The PD was based on the collaborative "unit" planned by the deputy principal and the senior syndicate team on "working as scientists" using the "Landforms and erosion" context. During the session, the participants were introduced to the ProscopeHR[4] (the researcher had arranged for the school to borrow five for the duration of the inquiry), stream trays[5] and dripping tubes (also on loan). Their use was modelled, so teachers could identify where and when the equipment could be used in their classroom programmes. The second part of the PD focused on two aspects associated with the Nature of Science[6] and relevant to the planned programme of work which introduced "working as a scientist"—constructing ideas and critiquing ideas (Hipkins, 2011). The participants explored activities through which students could develop their understandings of these two aspects.
3. Classroom observations by the researcher and the external observer were carried out in two of the teachers' classrooms over a 6-week period. Notes of the teacher actions, students' responses and the context were recorded during each observation. Static and video images were recorded alongside informal discussions with the students. Copies of student written work (on paper and published on classroom blogs) were captured. After 6 weeks, random groups of students in each class were formally questioned about the ICT embedded in the science inquiry and their views about science.
4. The two teachers were interviewed at the end of the term, and this was recorded. The external observer was also interviewed in order to capture another perspective about the PD programme and the "Landforms and erosion" unit.

The two case studies are described in more detail in Appendices 1 and 2. Here we draw on material from the focus groups and case studies to construct a series of vignettes designed to illustrate the kinds of e-learning opportunities that are currently available to students.

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4 A digital hand held microscope with connections to a laptop via USB.

5 Hard plastic trays measuring 1.5m (length), 30cm (width) and 10cm (depth).

6 It is important to understand that scientists ask questions, find evidence and explore simple models to develop their understanding of our world—Investigating in Science (Level 3).

4. How digital technologies are being integrated into school science—some examples

The following vignettes have been constructed from teacher reports of how they are using e-learning in their science programmes. Together, they represent different forms of current e-in-science practice. The teachers involved were working within traditional school structures.[7] The vignettes presented here "ground" further discussion about how digital tools could be used to transform science education.

Vignette 1

Year 5 students at a small country school are learning about the brain. Their teacher, Jess,[8] has a model of the brain borrowed from her doctor. She also has a 3-D interactive animation that they play with on her iPad, and she has arranged for a local vet to bring in some birds' brains and a goat's head, which the vet dissects: "And because I had two classes there, I just plugged my iPad into the data projector and then I just filmed it as she was doing it, and it was projected up onto the screen so they all could see."

At the end of the unit the students work in small groups to make a movie demonstrating what they have learned. The assessment criteria are negotiated and clarified. There is a high level of engagement, and Jess is impressed with the level of learning: "I could see they'd

7 These include: traditional timetabling structures; large classes of students grouped by age rather than ability or interest; assessment-driven curricula; and school, student and community expectations regarding what happens in schools.

8 Pseudonyms have been used for all teachers.

done some research and they'd really learnt." It was also very positive seeing students "excited about a different way of presenting information".

For Jess, a significant advantage of allowing her students to use her iPad included the ease of use: "It's portable, it's all in one place, they can do it so much quicker. They don't have to have a huge amount of technical knowledge to be able to use it." Access to the iPad was also an incentive for the students to complete their research and storyboarding. In addition, the movies could be shared with peers for feedback, and completed movies were published on the Internet and displayed to a broader audience, including whānau. It also spawned significant collaborative creative activity and movie-making during lunch times.

Jess is the teacher in charge of science and has a passion for both science and ICT. She values professional freedom and loves that she is "in a school where they've pretty much given me free reign to do what I like". She had access to, and taken up, multiple PD opportunities. She finds her students' interest and enthusiasm for science infectious, and believes that this enthusiasm—her students' and her own—helps foster innovation: "It's exciting and they love it, and because they get excited about it, you just want to do it. [...] The more you do it, the more you enjoy it, and the more you want to do. As you get into it, you find more things."

She finds the Nature of Science strand liberating in the sense that it allows her to focus on topics that she might not otherwise have found easy to fit into any of the four "content" strands: "I really like looking at the Nature of Science, and what scientists do. Communicating in science, and getting kids involved. I find that's where I put a lot of my focus."

Vignette 2

Sheryl's Year 6 students experience a curriculum that integrates literacy with science. She is passionate about both, and sees integration as a strategy that allows her to emphasise literacy while still keeping a focus on science: "I have been able to keep my science passion alive through my literacy programmes."

The conceptual focus for the term is "change", and the students' learning culminates in a book of experiments exploring chemical and physical change. First, students examine science texts and note that templates are used in the design of each page within a book: "Once the reader figures out how to work the first page, when they turn the next page, it's actually templated. You don't have to re-navigate every page. You don't have to figure out what the function is of every text on every page."

Students also try the experiments presented in the different science books, focusing on what they are learning about change. They then are tasked with designing a class science book of experiments related to change. They co-construct a page template, which includes different genres (e.g., persuasive writing to "sell" the experiment, a stylised diagram, an explanation of the science, etc.).

The work is completed on computers. The templates are easy to manipulate. Changes can be made quickly, and the work can be projected for whole-class viewing and discussion: "I'd flick through them as a class, and they would see what other people were doing, what they were up to, how they were solving problems.

"Yes, it's something that could be done without computers. But the computers make many of the more mundane tasks associated with editing far less tedious, and student engagement remains high throughout the project. There are also opportunities for learning about the authenticity and validity of content on the Internet."

Sheryl has since moved to a smaller school with far less access to ICT. She is finding it challenging having to "strip away" her programmes to recreate something of similar rigour and educational value. She reflected: "I don't think I realised how important it [ICT] was to me until I didn't have it. It was just part of the culture of what was important at that school, and so it seemed normal."

Vignette 3

A Year 5–6 composite class is exploring "Landforms and erosion". The 2011–2012 rock slip in the nearby Manawatu Gorge is used as a relevant real-life context to engage their interest. Using VoiceThread, the students record their initial response to various images of the Manawatu Gorge slip using the framework: "I see, I think, I wonder".[9] The recordings are posted on the class blog to share with the wider school and whānau community. On a class trip to the Manawatu River, they video-record their initial observations of the eroding cliffs. During class time, they video-record their experiments with stream trays[10] and dripping tubes, and use the Proscopes[11] that the school has borrowed to capture long-term dripping of liquids (water and vinegar) onto rocks and look closely at and photograph "crystals" forming on the rock. They share their thinking and wondering via Google Docs and give one another feedback. A video clip from YouTube (the formation of different types of rocks) is used to help guide the students in classifying rocks that they had collected on the field trip.

Yasmine, the teacher, is a competent ICT user who participated in a professional development programme supporting the use of ICTs in science.[12] She enjoyed using the digital tools, including the Proscope: "I was just as excited as the students when we were

[9] Ritchhart, R., Church, M., & Morrison, K. (2011). *Making thinking visible*. San Francisco, CA: Jossey-Bass.

[10] Hard plastic trays for modelling erosion.

[11] Digital hand-held microscopes with USB connections.

[12] See Appendix 2 for the full case study.

using the ICT tools". Importantly, her willingness to "play" and take risks was emulated by her students. Although there was a lack of purposeful observation during the 6-week inquiry, and many opportunities for further observation were missed, student engagement remained high throughout. It seems that encouraging the students to explore with the digital tools in semi-structured activities helped foster in the students the dispositions and competencies to use appropriate digital tools to develop their investigation skills as well as their science understanding.

Yasmine had initially been unsure about the differences between science and science education, and how ICTs might be embedded in science inquiry. However, by the end of the unit she felt empowered as a primary school teacher teaching science. Having access to adequate PD as well as collegial support—for help with both the digital tools and the science concepts—was key to her thinking differently about teaching science.

Vignette 4

Year 13 students in Jack's physics class are grappling with electrical concepts and the associated equations. In class, they measure the AC voltage across some devices using an oscilloscope. An animation is running on Jack's laptop for them to interact with. Students also do some manual calculations, checking each one using an app on their smartphones that allows them to build a (virtual) circuit and check the measurements against their calculations. There's very little time for considering some concluding questions, so they use ClickerSchool's virtual clicker to make responses that Jack can then use for formative assessment purposes. They take photographs of the notes Jack has generated on the board during the lesson as they head out the door for their next class.

For Jack, the integration of the digital tools with other teaching and learning activities needs to be seamless. In this case, he chose the tools because he believes they help accelerate student learning of the concepts: "In 55 minutes they took an idea that perhaps in the past would have taken 2–3 hours." Much of the content is also portable, in the sense that students can continue to process their understanding of the ideas by accessing the digital tools out of class time.

Jack definitely does not believe in technology being able to replace teachers, but he does see it as enhancing what is possible within a classroom: "I think you still need structured teaching, but it doesn't have to be me chalking and talking." He enjoys playing with ICT, and each year sets himself an ICT goal—in 2012 it was incorporating apps in his teaching.

Vignette 5

Year 13 biology students aiming for Scholarship participate weekly in the Senior Biology Seminar Series offered by LENScience.[13] Other students also come along, some because they want to improve their Level 3 achievement from Merit to Excellence, others because they are interested in the topics, or simply because they like the atmosphere. Occasionally other teachers come along, too.

Every third week they watch a live broadcast by a scientist.[14] At the same time they participate in the online wiki connected with the broadcast. They can use this to ask the scientist a question, or clarify what the scientist is talking about with other students logged in from across the country. Tim, the biology teacher, turns these sessions into "events". There is food, and live interaction via the wiki between the students and their counterparts across the country, as well as with the scientists.

The following week the students meet to explore the topic further. Tim encourages them to ask their own questions, and supports collaborative discussion in response to these questions. The students also continue to contribute to the wiki. Those who missed out on the live discussion are able to access and watch a recorded version. This enables them to participate in the follow-up conversations, both with Tim and their peers from the same school, and with other students from around New Zealand via the wiki.

After three years of participating in the programme, Tim was very disappointed that it did not run in 2012. He reflected: "I think it's a very vital part of biology. One, it's current and important information. Two, it's relevant particularly to what they're doing. Three, it's actually set up by, for and with teachers. Finally, it's got a sense of community with Scholarship biology kids throughout the country."

Commonalities

Within these vignettes there is a focus on using digital tools as an additional information source (e.g., apps of brain structure, electrical circuits), a tool for communicating with an audience (e.g., making a movie / book, using the virtual clicker), or a medium supporting collaborative interactions with peers (e.g., VoiceThread, Google Docs, wikis) or interactions with scientists (e.g., the online chat available during the Senior Biology Seminar Series). Only in Vignette 4 is a digital tool (a Proscope) used by students to generate their own data.

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13 For a detailed description of the Senior Biology Seminar Series, see Appendix 1.

14 Each "topic" has a three week cycle: in week 1, students discuss the topic for the live broadcast, referring to a comprehensive discussion guide provided by LENScience; in week 2 they participate in the live broadcast; in week 3 they consider follow-up questions. An online wiki is accessible throughout the year.

Additional vignettes, provided in the previous report (Buntting, 2012), offer further examples of ways in which digital tools might be used in science education, including:

1. using digital technologies to broaden students' scientific inquiry (e.g., a Year 5/6 class using digital equipment such as digital microscopes and an infrared night vision camera, borrowed from a CRI, in an ecological investigation)
2. using digital data to enhance student engagement and support authentic learning (e.g., a Year 7/8 class using a mobile sensor unit to run sporting events, and Year 10 students using data from their own glider flights to carry out a range of vector calculations)
3. using digital technologies to connect with scientists (e.g., a Year 13 class accessing a distant CRI for a series of seminars and virtual lab visits)
4. using digital technologies to support peer collaboration (e.g., Year 5/6 students using wikis, Year 9 and 10 students using Moodle, and tertiary students using Google Wave).[15]

Within New Zealand, two Government-funded digitally-rich resources that also need to be mentioned within the e-in-science space are LEARNZ and the Science and Biotechnology Learning Hubs. LEARNZ offers 15 virtual field trips per year, predominantly in science, and has 4,800 registered teachers in 1,837 schools (Pete Sommerville, personal communication, 16 October 2012). The Science and Biotechnology Learning Hubs showcase a wide range of contemporary New Zealand research projects as well as associated teaching activities. Over 2,400 teachers are currently registered users of the Biotechnology Learning Hub (BLH), which recorded 23,153 unique visitors to the site in October 2012. The Science Learning Hub has over 3,500 registered users of the Science Learning Hub, with 132,439 unique visitors recorded in October 2012 (Di Hartwell, personal communication, 9 November 2012).

[15] Google Wave is no longer available, although alternatives such as Shareflow exist.

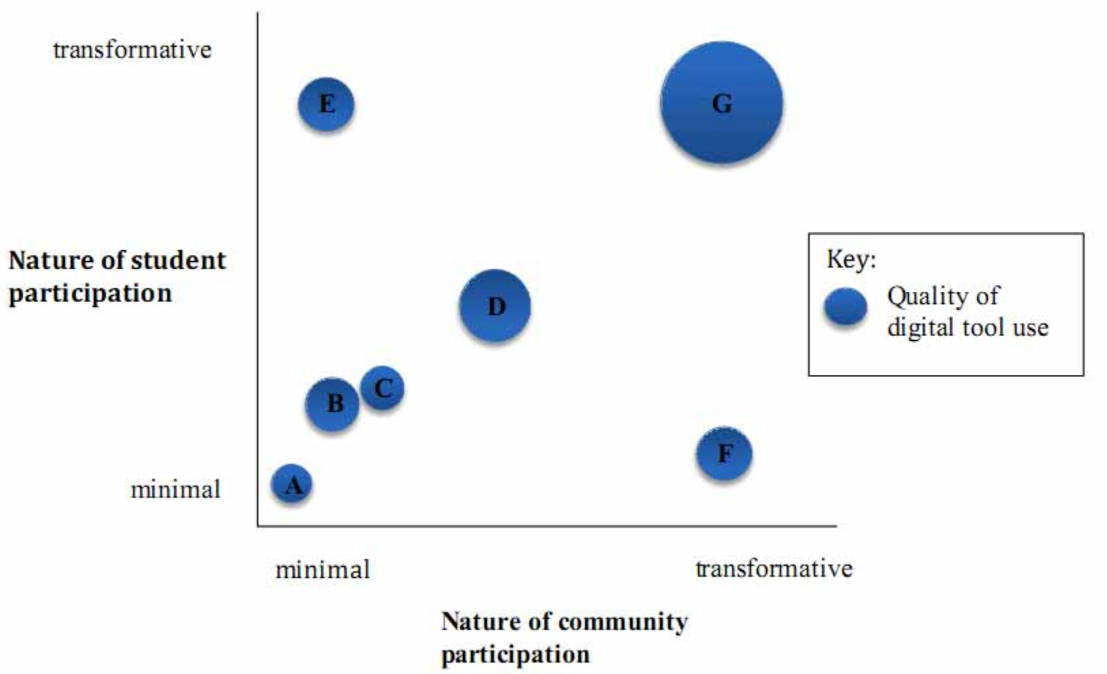
5. A framework for future-oriented science education

Participation by individual learners and the community is important when visioning future-oriented education scenarios. Therefore, we posit that mapping some of these vignettes against two continua—one relating to the nature of student participation in the learning process, and the other relating to the nature of community participation—offers insights into how different scenarios might be extended to become more transformative.

These continua are presented in Figure 2 as a framework for future-oriented science education. Both continua stretch from minimal participation to transformative participation. Minimal participation entails relatively passive participation by the student in the learning of a curriculum prescribed by the teacher with little input from the wider community. At the transformative level, for students, there is active engagement in the co-construction of knowledge in an area of personal interest and choice. In other words, there is high student input regarding what will be learned and how it will be learned. Similarly, a transformative view of community participation involves high community input into what will be learned, and how.

To take into account the extent to which digital tools are used to enable or support learning, or both, we represent each learning scenario with a circle, the size of which provides an indication of the quality of digital tool use. Thus, a small circle represents minimal use, or scenarios where the digital tools that are used do not enhance learning in any way, but merely increase efficiency. A typical example is the display of teaching notes via PowerPoint rather than an overhead projector. A larger circle, in contrast, represents a scenario where digital tools form an integral and meaningful part of the learning process.

Figure 2 **Framework for future-oriented science education**



Looking at the framework, then, point A represents a classroom scenario within an Education 1.0 context. The lesson is highly structured and follows a formal sequence determined by the teacher. Although there are a variety of specific learning activities, all students tend to engage in each activity at the same time and there is little scope for students to influence the activities or their order. The students might be engaged and compliance might be high, but there is also very structured teacher control. There may be varying amounts of digital tool use.

For example, point A might be represented by Vignette 2, where computers were used by the students to create a book of experiments about chemical or physical change. In this scenario, the computers dramatically increase the efficiency of the task, but they do not change the learning that might have been possible if computers had not been available. The task is also very prescribed, even though the students have input into the template design and which experiment they choose to include in their page of the book. However, students' learning was meaningful and powerful, and other primary school teachers present at the focus group where this learning sequence was described were very keen to try something similar with their students.

A larger dot might be used at point A to represent Vignette 4. Compared with Vignette 2, a greater range of digital tools has been introduced—for Vignette 4, an animation on a laptop computer, an app for building electrical circuits on students own mobile devices, and the use of a virtual clicker—but there is still high teacher control and direction, with predetermined learning outcomes and a well-defined sequence of learning activities. While digital tool use is relatively high, student participation is similar to that in the classroom scenario described for point A.

Point B represents a learning environment such as that depicted in Vignette 1, where students use a variety of digital and non-digital resources to find out more about the brain and those who research brain activity. Students then negotiate the assessment criteria with the teacher and present their learning in the form of a movie. Through this negotiation, students are able to assert a little more control over the direction of their learning. There is also some community participation, with the community (a veterinarian) acting as a knowledge resource.

Point C represents a learning environment where there is also some reliance on digital tools for supporting student learning, but the students have greater control over the direction and focus for their learning in each activity. This scenario is perhaps best depicted by Vignette 3, where students use a variety of digital and non-digital resources to support their learning about "Landforms and erosion". Learning is more self-directed than at point A on the framework in the sense that the "I see, I think, I wonder" strategy (Ritchhart et al., 2011) gives the students greater freedom to determine and pursue their own questions of interest. Community involvement through the teachers' connection with the professional development opportunity (see Appendix 2) also had an impact on the nature and direction of students' learning. This input is reflected in the placing of point C further to the right of the figure when compared with point B.

Point D is where we believe the LENScience senior biology seminar series (Vignette 5) might be represented. Digital tools are used to support the live broadcast as well as synchronous and asynchronous communication between students, their peers at other schools, and the scientists. Background information and possible questions for discussion are provided by LENScience to the teachers to help scaffold student learning before and after the live broadcast. However, Tim (the teacher in Vignette 5) is less reliant on these guides—particularly after participating in the series for the 3 years that it ran—and hands control for the discussion and learning over to the students, encouraging them to collaborate together to consider their own and others' questions. This, particularly at Scholarship level, seems to be extremely appropriate and desirable.[16]

Point E represents a scenario where the student is highly involved in determining the direction of the learning, but there is little community involvement. An example might be the research undertaken for a science fair project, where the student is highly self-directed, but seeks minimal input from external expertise. Digital tool use may be low or high (e.g., to collect or analyse scientific data, or both).

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[16] Another scenario at point D might be a class engaging in a LEARNZ field trip, depending on how the rest of the teaching and learning programme is formatted to sit around the field trip.

A description for point F seems somewhat contrived since it is difficult to conceive of a scenario where there is high community engagement but little student participation. Perhaps this is because there is not currently a precedent for communities taking ownership of formal learning opportunities.

Point G is of particular interest. While point A, in the bottom left corner of the framework, represents Education 1.0, point G, in the top right hand corner, represents Education 3.0. Here, there is a strong emphasis on the co-creation of knowledge in an area valued by the learning community—a community connected by a common interest and connected by digital media across age, culture, background and distance. Clearly, point G is difficult to fully imagine at this stage. Perhaps the impact projects at Albany Senior High School—while problematic to establish and implement (Hipkins, 2011)—go some way towards providing an example of point G.

The power of this framework, however, lies not so much in its clarification of what point G might actually look like,[17] but in its ability to direct a teacher wanting to move to a different point. For example, a teacher who is using a lot of digital tools in a very structured manner (akin to point A on the framework) might consider how to empower students to have greater ownership over the direction of their learning, and how to foster genuine community participation in the learning. These steps would be the beginning of the journey to what NZCER describes as "future-oriented education" (Bolstad & Gilbert, 2012).

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[17] Indeed, as soon as a "vision" is produced of what "best practice" might look like for point G, this vision is in danger of becoming prescribed and "less than' what was originally intended.

6. Principles for future-oriented science education

In considering how future-oriented education (including science education) might be supported, Bolstad and Gilbert (2012) identify six emerging principles:

1. personalising learning
2. new views of equity, diversity and inclusivity
3. a curriculum that uses knowledge to develop learning capacity
4. rethinking learners' and teachers' roles
5. a culture of continuous learning for teachers and educational leaders
6. new kinds of partnerships and relationships between schools and the wider community.

The majority of these principles relate to how the teacher thinks about the purposes of education, and how these purposes might be realised. In the sections below, each principle is explored in the context of the data we obtained from the focus groups and case studies.

Principle 1: Personalising learning

Personalising learning focuses on tailoring the education system to suit the learner, rather than expecting the learner to fit into the system. It is perhaps more helpfully referred to as "customising learning"—deploying the resources for learning (teachers, time, spaces, technology) more flexibly to suit learners' needs. Key features might include:

- Students working at their own pace. Although this is not necessarily done individually but could be done collaboratively.
- Digital technologies enable students to access relevant learning experiences when they are ready to do so.
- Students take responsibility for their own progress.
- The teacher monitors students' progress and intervenes in a formative manner at critical points, possibly by brokering connections with relevant outside experts.

In Vignette 3, Yasmine's class rotate around "science stations". There they use equipment (including digital equipment such as the Proscopes) to observe and investigate what interests them regarding rocks, landforms and erosion patterns. This means that different groups likely focus on different aspects, depending on their skills and interests. While the observations were not "purposeful" in a traditional sense (i.e., the students did not have a predetermined, structured focus for their activities), the opportunity to pursue personal interests and "wonderings" is perhaps indicative of a personalised (or customised) approach—and is likely an important contributor to students' engagement in science as an area of endeavour.

Similarly, in Vignette 4, physics students were able to engage with multimodal representations of electrical circuits and to do so—within the single period—at a personalised pace. In particular, mapping the results from their calculations against the answers provided in the app that they had downloaded on their mobile devices meant that they weren't reliant on the teacher providing the correct answers before they could "move on". Circulating among the students, and also considering students' responses sent via a virtual clicker, enabled Jack to monitor the students' progress and intervene at appropriate points.

Several of the focus group teachers saw moves towards BYOD (bring your own devices) as opening up opportunities for greater customisation of learning pathways. Others were exploring the use of Moodle to offer multiple learning pathways to students. Isaac reflected on this becoming more possible with changes in technology:

> Sometimes something happens which enables you to make a jump in terms of your own teaching strategy. For example, Moodle … When we went to Moodle 2, all of a sudden, for me, it becomes personalised learning. You can do conditional pathways.

Within the current schooling system, it is difficult to envisage deeper levels of customisation, where students or the community, or both, might shape the direction, scope, content, and contexts for learning (Bolstad, n.d.). Hipkins and Spiller (2012) also note that, in instances of innovative curriculum design which they identified at the senior secondary sector:

> [T]eachers worked hard to make space for students to learn about themselves and their own potential—to bring something of who they were and what they were interested in learning, and to build from this positive, more personalised foundation. (p. 38)

Alongside this is a need, in science education, for students and teachers to be thinking about *what* science learning is important, and why.

Principle 2: New views of equity, diversity and inclusivity

Developing new views of equity, diversity and inclusivity involves recognising the need for learners, family/whānau and communities to work together to co-shape education to address their needs, strengths, interests and aspirations. This represents a complex challenge to current thinking in education. There was little evidence in the conversations with teachers that they were beginning to grapple with this alternative paradigm, where learning programmes are genuinely designed for and with specific students, rather than the programmes being designed within a "one-size-fits-all" model.

Many of the teachers recognised changes in the ways they were interacting with students, and spaces for new conversations. For example, Glenis encourages her Year 13 biology students to submit a "mini essay" once a week. The whole process is managed digitally by email. There are improvements in the students' essay writing, and Glenis values the enhanced relationships she has with some of her students, particularly the quieter ones: "I see a different side to a lot of students. Some girls I've got to know quite differently." A few focus-group participants were also exploring ICT-based pedagogies involving greater customisation of learning pathways.

Clearly, however, system-wide change is likely to be needed before teachers are able to fully engage with what alternative views of education might actually look like—and how they might be enacted. For example, new views of equity, diversity and inclusivity will involve moving beyond fitting learning support to meet students' different needs, interests, prior knowledge, planned futures and so forth, and towards thinking about how to harness "diversity" (for people, and for knowledge/ideas) as an integral part of learning. It also involves preparing young people not just to know about difference and diversity at an intellectual level, but to actually experience the complex interactions of diverse ideas and people as they are intertwined in real-world problems (Bolstad, n.d.). Within science education, it likely means exposing students to authentic, multifaceted issues of relevance to them and their communities, and helping them to consider and evaluate multiple possible responses. While the New Zealand Curriculum (Ministry of Education, 2007) signals opportunities to do this, current NCEA assessment tasks do not go far enough in valuing the multiple skills students would need to bring to such a task.

Principle 3: A curriculum that uses knowledge to develop learning capacity

From this point of view, science content knowledge is seen not as an end in itself, but as a context within which students' learning capacity is developed. Developing learning capacity is therefore another facet of the paradigm shift that is needed to move modern education towards a future-oriented model. This model equips students for life in the "knowledge age", where learning ability is far more important than knowledge *per se*. The Industrial Age model—where curriculum development involved determining which knowledge students would need, and organising this knowledge into logical sequences that could be taught step-by-step—is no longer appropriate. Rather, education for the knowledge age must prioritise developing learners' dispositions, capacities and competencies to deal with new situations and environments, including those with high degrees of complexity, fluidity and uncertainty. This does not mean that knowledge no longer matters. Rather, a more complex view of knowledge is adopted, where knowledge is not "stuff" but something that "does stuff" (Gilbert, 2005).

The strength of Vignette 2 is not in its use of digital technologies, but in the way literacy skills are developed in a science context. In particular, science knowledge is developed—in this case, understanding about chemical and physical change—so that the Year 6 students can use this as the context for de-constructing and then re-constructing non-fiction text. In other words, the learning objectives are focused not so much on the understanding of science concepts, but the students' ability to transfer this knowledge into a "template" that they had co-constructed and that had meaning and purpose. Access to a data projector and digital templates, images, editing tools and the like made managing the learning with a whole class far more efficient. It also meant that student engagement and the momentum that developed through the learning experiences could be maintained, rather than these being eroded by the tedium of modifying or recreating handwritten pages that are difficult to display to the whole class for discussion and collaborative knowledge building. Clearly, this example is still situated within a fairly traditional type of problem—how to read and interpret non-fiction texts—but the *science* knowledge offers an engaging and authentic context in which students undertake this learning.

In Vignette 3, Year 5–6 students use Google Docs to share their questions and observations, and collaboratively build an understanding of landforms and erosion. One student commented that this helped: "speed up information gathering and sharing instead of waiting to share what you have". Again, the ICT appears to have supported the learning by increasing the efficiency with which the students could interact and learn with one another.

In a similar vein, several secondary school teachers reported using forums within Moodle to facilitate learning discussions among students. In some cases, these were related directly to content-rich NCEA-type questions. In other cases a socio-scientific issue was used. For example, Chris talked about his Level 2 biology students debating the pros and cons of IVF on Moodle. This latter use hints at what might be possible when the focus of science education shifts from access to a fixed stock of knowledge to "equipping people to enter and navigate the constantly shifting networks and flows of knowledge that are a feature of 21st century life" (Bolstad & Gilbert, 2012, p. 32). Such a focus will also need to include greater connection with views and expertise from outside the class and school, and ICT has significant potential to help mediate this (see principle 6, below). Although Chris's class had not invited external input in their Moodle discussion, he was keen to explore this possibility.

Of course, any shifts towards curricula where knowledge is used more overtly to build learning capacity need to be reinforced at the system level.[18] While the New Zealand Curriculum (Ministry of Education, 2007) acknowledges the importance of 21st-century views of knowledge and learning (e.g., in its vision, values and principles), there is still a strong focus on the development of specific content knowledge and skills (outlined in each of the learning areas). At the senior secondary level, NCEA assessments in science, by and large, also continue to rank content knowledge highly. Schools, teachers and students are under significant pressure to "conform" to these priorities in order to "do well" under the current assessment regime. Despite this pressure, some secondary teachers are able to envisage ways to develop future-oriented learning within and around existing assessment approaches (Bolstad, 2010; Hipkins & Spiller, 2012).

In our study, Isaac appeared conflicted by the apparent contradictory demands for content knowledge and scientific literacy in the senior chemistry curriculum. Although he focused on conceptual understanding at Years 12 and 13, his overall purpose for science education is: "Ideally, for students to learn to observe, to question, to make meaning for themselves based on scientific information." The conflict between conceptual outcomes and more general learning objectives was not limited to secondary school teachers. For example, Sheryl, a deputy principal at a small primary school, reported that science is important because "it breeds curiosity, and it breeds inquiry, and good talk and language and problem solving and risk taking". At the same time, however, Sheryl also talked about "preparing our kids for high school and for content-based learning". Similarly, Grace, a specialist science teacher at a middle school, reported: "Science has got so many skills attached to it. I also think the content knowledge is probably important, going to high school." These teachers obviously care about their students' learning, and find it a challenge juggling content knowledge with other, broader, aims for science education.

Others saw the Nature of Science strand within the science curriculum as offering greater freedom to explore a broader science curriculum. For example, Sam described how he develops his units at both junior and senior secondary level around a core Nature of Science focus: "What I'm trying to do is get them to work more like scientists do. I want them to be carrying out the process of science. I want them to be excited about science,

[18] This includes the school system and nationally through, for example, assessment policies and practices.

and learning more about what science is and how it relates to their everyday lives." Similarly, Jess, who featured in Vignette 1, couldn't really relate the form and function of the brain to any of the content strands, but she was able to do it with a Nature of Science focus—"looking at what scientists do and their learning of the brain—how it works".

Schools, in prioritising a "learning to learn" focus, have curriculum and assessment challenges. A possible further challenge is the need to re-evaluate existing school structures, including how schools tend to divide up their timetables, learning areas, teaching staff and even student year levels. Primary schools likely have more flexibility in this regard than secondary schools, although schools such as Albany Senior High School and Wellington High School's "tukutahi" groups offer alternative models for consideration. The ideal, according to future-oriented teaching and learning literature, is that "21st century" schools are knowledge producing, not knowledge consuming entities (see Bereiter, 2002; Bigum, 2003).

Principle 4: Rethinking learners' and teachers' roles

As argued by Bolstad and Gilbert (2012), if we believe that the main role of future-oriented education is not to transmit knowledge, but cultivate students' abilities to engage with and generate knowledge, then teachers' roles need to be reconsidered. Similarly, if the role of the learner is not to absorb and store up knowledge for future use, then the learner's roles and responsibilities also need to be reconsidered.

Within the focus groups, Sam was cognisant of digital technologies being used to either reinforce traditional views of teachers and learners, or to transform these: "From my experience, the technologies are not actually shaping the way that they [teachers] are thinking, so it becomes more student-centred rather than teacher-directed. That's when the technology would really come into its own." Others similarly expressed an awareness of student-centred approaches and how these might be facilitated by digital tools. For example, Jen, a director of e-learning, was able to articulate the following:

> e-Learning is a whole new environment. The whole pedagogy of teaching needs to move away from what has been the traditional industrial model of teaching, to the student at the centre. Because now the student is able to have far more up-to-date information. That is itself should provide some changes in what we do.

How this belief was translated into her classroom practice, however, was difficult to unpack.

Several teachers were exploring "flipped classroom" pedagogies where the "content" is provided online for students to access before the lesson so that the lesson itself can focus on discussion and interaction (as opposed to "teaching"). In other words, instead of students being given problems to consider for homework, they do homework on the day before (i.e., access the relevant content knowledge before the lesson) and spend the lesson discussing problems. While still potentially strongly directed by the teacher, there is opportunity within this scenario for far greater student ownership and involvement in setting the direction of the discussion—if the teacher enables this to happen.

Among the focus-group participants, there were also indications of students helping co-construct assessment criteria, and flexibility in the ways in which "learning" could be presented. Several examples were shared of students who appeared more engaged in their science learning because their skills in IT were being valued. For example, Richard spoke about a video-based assessment: "One of the students created a wonderful video because he was a media studies student. He commented that he really appreciated that, because he could bring in his other skills." Diverse assessment opportunities were considered to be important, though. For example, Jess reported that when her Year 5 students made a video to demonstrate their learning about the brain, some students became so distracted by the technical possibilities that they lost sight of the assessment criteria that they had negotiated as a class.

Julie described a shift in her practice so that her junior secondary students had far greater control in choosing the questions they would investigate for their science-fair projects. She talked about running the science lab and computer lab at the same time, and reported that:

> Some of the research that's being done, by quite limited pupils, is quite amazing. They have an idea, and because they don't think the same way as we do, rather than me directing them to a traditional project, they're going off in some quite interesting directions, and they're actually researching stuff that's actually beyond my knowledge. They're coming out with quite in-depth studies, and linking the whole thing together. I think we have to accept now that we've got to go in a student-directed direction.

In each example, there are glimpses of teachers seeking student "voice" and input into their classroom learning. It is far more challenging, however, to move beyond notions of "student-centred" pedagogies to thinking about how teachers and learners might work together in a "knowledge-building" learning environment. Within this context, roles and relationships are structured in ways that draw on the strengths and knowledge of each in order to support co-learning. For example, while teachers often reported learning IT skills from students, a future-oriented interaction would involve the students and the teachers working together to maximise opportunities for co-learning in other areas as well.[19] In this environment, where the Internet is used for production of information in addition to retrieval, an effective teacher is a facilitator of knowledge acquisition and manager of the visible interactions among members of the learning community (Haythornthwaite & Andrews, 2011). This is likely to be an unsettling and challenging role for teachers,

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19 For further commentary on this issue, see research on the early years of the Tech Angels initiative at Wellington Girls' High School (Bolstad & Gilbert, 2006).

particularly where they are uncertain about what knowledge will be needed—and need to be developed—to pursue the task that has been agreed to.

Principle 5: A culture of continuous learning for teachers and educational leaders

Change can be difficult to articulate and implement. The transformation to a more future-oriented, participatory learning framework will not be easy for many teachers and educational leaders—in part because most have been socialised into educational ideas and practices common within 20th-century education systems.

The majority of teachers who participated in our study specifically reported that they appreciated support from their schools to participate in professional development opportunities. This included permission and encouragement from their senior leadership team, in addition to financial support. As Jess said, "I've been really supported with all the extra science PD that I've had … which always has a compound effect—you do better, and you do more." For many, school financial support was a significant barrier, as was time away from class. Participation in the focus groups—themselves an opportunity for professional reflection and learning—was greatly facilitated by the teacher-release funding available. The costs associated with attending teacher conferences such as Scicon were also discussed.

Many participants had experienced meaningful professional learning embedded within their school culture. For example, Glenis reported: "We have a very intense professional development programme. […] We work on our appraisal system like that. We choose to explore a particular area. For instance, for a whole year I explored Moodle."

Glenis worked on this project with a small group of other teachers, surveyed students, had teachers observe her teaching, and shared her learning with other staff. She concluded: "Those sorts of things grow within a school." As further demonstration of her own commitment to her ongoing learning, she reflected on how she had enrolled in an online course before using Moodle with her students—just so she could experience it as a student first.

In his school, Neil has set up and is leading a professional learning group about future pedagogies, looking at how ICT is going to change classroom practice. He also has visited several New Zealand and Australian schools to observe how they are using digital technologies in their programmes. Several other participants had similarly been awarded prestigious awards or fellowships that had allowed them to explore their professional interests (often in ICT) in greater depth.

It is important that the professional development is appropriate for teachers' current stage and interests. For example, Sam talked about the need for exemplars that are "not something so futuristic it scared the living daylights out of them … it's more about the guidance and the appropriate challenge that you set for the staff."

One aspect that some teachers considered to be particularly intimidating in the context of professional learning related to ICT use in their teaching was the over-emphasis on how technology literate students are. This appeared to have two foundations: first, it made them feel less than competent, and that the students were "way ahead"; secondly, they quickly discovered that the students needed a lot more "education" about digital literacy than they had expected. As Glenis reported:

> I do find it surprising that, at my age, I am teaching a lot of students how to do this—the [digital skills] they need for what I'm doing. While it may not be first nature for me to do all this, and I'm learning as I go, a lot of our students don't know how to do it.

The theme of teachers needing to see themselves as learners was raised in each of the four focus groups. It also seems noteworthy that many of the participants had entered teaching after a first career doing something else. Perhaps these participants have an intrinsic belief in on-going (lifelong) learning. Many also enjoyed "playing" with ICTs—which ties in with Wagner's (2012) view of innovation requiring play, passion and purpose.

Many teachers considered that learning about and playing with ICTs was intensely time consuming. For the most part, this was offset by the benefits that resulted for their own learning, and the ways in which they were able to incorporate ICTs in their teaching and learning programmes. However, any resources to help circumvent the time-consuming process of searching for relevant tools were appreciated (e.g., lists of appropriate apps for different science concepts).

There was significant frustration expressed about the perceived futility of attempts to encourage resource sharing between schools, and sometimes even within departments. For example, Isaac commented: "This is a communication world. Everybody is wired to everybody else, and yet we have no mechanism for sharing all those resources currently." As an individual, he has collated chemistry animations and other digital resources numbering in the thousands. He has also participated in several initiatives to encourage teacher sharing, but considers that they have either not met their potential, or they have petered out over time.

At the primary level, there was support for access to examples of quality science teaching, with the possibility of online delivery. For example, Sheryl suggested publishing movie clips of teachers teaching their class and reflecting on their decisions:

> That would be a wonderful addition to the likes of the Science Learning Hub, to have some clips on there of teachers in action and a follow up interview. That would give everybody the opportunity to tap into that.

While face-to-face professional development was considered by Alan (at the same primary teacher focus group) to be even more beneficial, he acknowledged the enormous costs associated with this.

For many teachers, it was also important to be in a school culture where they were allowed to take risks. Jess, for example, said, "I've been fortunate enough to be in a school where they've pretty much given me free rein to do what I like."

Others talked about asking for forgiveness, rather than for permission. There was also an understanding that senior leaders were not always able to be abreast of the latest changes, but that the teachers really valued the trust that was given to them. For example, Sam reported: "My principal said to me, 'I have no idea what you're talking about, but it sounds like a great idea. Go for it.'"

The majority of the participating teachers were also highly reflective about how and why they were using digital tools, and there seemed to be a strongly held view that a deep understanding of teaching and learning in science—pedagogical content knowledge—was important to effectively and purposefully integrate digital tools into teaching and learning programmes.[20] This allowed them to "find the tool that fits the purpose" rather than "finding a purpose for the tool". As Richard, an IT manager, put it:

> The problem with IT is it is presented as a solution to the problem. Now find me the problem. Whereas we need to come from, 'This is what I can do. Where's the solution that will fit it?'

Similarly, Sam lamented:

> That is where technology falls down. Too often, it's 'Let's take the gee whiz gizmo aspect' which is passing and fleeting … You have to go to what is the fundamental purpose of what you are trying to achieve, and how is this best supported by ICT?

Isaac is a big supporter of using animations to support chemistry learning because "that's the one thing I could not do in any other way". He elaborated:

> To me, that's the acid test. Could I do this in any other way? No, I can't. Lots of other things I look at and say, I can do that with other means that are at least as good as with technology. And that, I think, is what we don't ask ourselves often enough: Is this enhancing learning?

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[20] The survey carried out for the first phase of this project (Hipkins & Hodgen, 2012, see also Buntting, 2012) showed that teachers who are most confident in their ability to implement the various strands within the science learning area of the New Zealand Curriculum (Ministry of Education, 2007) are more likely than their counterparts 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. In addition, sound curriculum knowledge and strong professional support are likely to precede innovative ICT use.

It is therefore not surprising that there was strong support for the professional development of teachers' pedagogical content knowledge, particularly newly registered teachers.

There was also strong support for actively identifying and supporting innovators, particularly in terms of intellectual support. For example, both Sam and Isaac thought it was important that innovators are encouraged to evaluate what they are doing in ways that are valid and meaningful—but that they are not always equipped to do this, nor do they have the time.

In thinking about support for teachers, aspects such as sustainability and scalability are not easy to address. Clearly, the needs are likely to be different at primary and secondary level. There is also the broad range of needs across a typical staff or department grouping. In addition, the needs of teachers—and the school system as a whole—are likely to change across time. For example, a "cycle of need" was identified by Cowie, Jones and Harlow (2011) in their evaluation of the Laptops for Teachers Scheme: professional development leads to changes in classroom practice, which in turn leads to changed infrastructure needs; when these were met, additional professional development results in more changes to classroom practice and new infrastructural needs. Developments in e-learning therefore involve professional development of individual teachers,[21] ongoing access to digital tools and an appropriate technological infrastructure, and a school culture where learning, teaching and curriculum can be discussed and re-thought.

Principle 6: New kinds of partnerships and relationships between schools and the wider community

The future-oriented literature drawn on by Bolstad and Gilbert (2012) suggests that schools, as they are currently set up, simply do not have the resources to provide "in house" all of the very different kinds of expertise needed to develop 21st-century learning experiences in which students contribute to the development of new knowledge. Future-oriented teachers require strong pedagogical knowledge, but they also need to be able to collaborate with other people who can provide specific kinds of expertise, knowledge, or access to learning opportunities in community contexts.

Among the focus-group participants, several efforts had been made to engage with scientific expertise beyond the school. For example, Jess had invited a local vet to come in to dissect a goat's brain, and Chris had liaised with a university science lecturer who had encouraged some of her postgraduate students to comment on school students' science fair proposals that they had published on blogs. Several of the teachers had participated with their

[21] These might include online forums, where innovators can meet, exchange ideas, *and* be challenged about the *educational* implication of these ideas.

classes, or had students participate, in formalised school-scientist programmes such as some of those described by Bolstad and Bull (2012).

For many, there were concerns about the sustainability and scalability of school–scientist partnerships even when ICT was used to facilitate communication. For example, Isaac responded to Chris's example about the science fair blogs with some cynicism: "If everyone did that, it's not sustainable … If you look around, it's the same very small group of people involved all the time. And they can't spread themselves out any more." In line with this, Teresa had found it very difficult to get university scientists to contribute to her students' e-portfolios. Angela had tried over 2 years to establish a video-conference programme between her classes and scientists, but had found this enormously difficult: "It's the facilitation, finding the people who are relevant, at the right time that it fits into what you're teaching, when the class can go … Getting all that to happen at once was impossible." Angela also raised questions about how sustainable such interactions might be for when students pursued different learning interests: "Because you have small groups focusing on different content areas, you can't really take the whole class on one particular field trip [or video conference interaction]."

The four teachers who participated in the LENScience Senior Biology Seminar Series (see Appendix 1) were all extremely supportive of the programme and how it broadened the scope of their students' learning and thinking. Importantly, Jacquie Bay and her team identified appropriate contributors, managed many of the logistics, and facilitated the communication between the scientists and students. This facilitation was seen to be key. In particular there was acknowledgement of the LENScience team's ability to skilfully navigate between the worlds of science and science education. Angela identified this as: "That key component, of having somebody who can bridge the gap, who can make sure that what's provided really meets the needs in the classroom".

It was also important that the facilitator had access to such a wide variety of scientists. Tim wanted students: "To get access to top quality NZ scientists. And interesting scientists. And women scientists. And Māori and Pacific Island scientists."

In addition, the facilitator pre-screened the content and presenter for the likely value and interest. For example, Glenis told the following story:

> There was one about algae in Antarctica, and I wasn't sure. I just couldn't see it working. But wow! She was the most beautiful, exciting woman who had accidentally discovered … done ground-breaking research, and look, all of about 23 or 24. Because of that model—that 23, 24 year old who was down diving in Antarctica, collecting seaweed from all these remote places and finding their relationships through phylogenetic trees. And then some famous scientist picked it up, and the next minute she was plucked into the world arena. My kids realised, then, that seven years later it could have been them. It was so powerful!

> And it blew me away, because it was real science that she was doing, and suddenly it just didn't add up to what the geologists had said. And the idea that there's still so much more work to do. That they [my students] can be part of that. I think for those girls that night, that's what they got out of it the most.

As well as helping some students imagine themselves in science, the interaction of the students with the programme as a whole was considered to be very validating for them. This encouraged them in their learning:

> Not only were they part of a wider learning community, but they felt important as learners, and as part of the science community. Because the people presenting were presenting to them, and interacting with them. It made the students feel important. (Angela)

> My students were able to take risks, especially with the feedback from the scientists being so positive. (Lana)

> They were asking questions. They had an effect on it. (Tim)

There was also important learning that had nothing to do with the specific content:

> It shows NZ has cutting-edge science, and top quality scientists. (Tim)

> It shows scientists as men and women; Māori, Pākehā, Pasifika, Asian. (Tim)

> It raised the profile of biology within the school. (Tim, Lana)

> Students saw that their counterparts in other parts of the country had different ethnic mixes. (Glenis)

> Students saw they were asking the same sorts of questions as their counterparts around the country. (Tim)

Angela described one instance where the scientist was an ex-student of hers, and how this had a dramatic impact on her current students' views of themselves as being able to pursue a career in science.

All four teachers saw potential for the model to work in other science subject areas, and also with students of different ages. Two had participated in similar programmes run by LENScience for more junior students (e.g., the diabetes unit), and found the input via the live broadcast to be very worthwhile.

In addition to the seminar series supporting their students' learning, the teachers found it was "great PD" for themselves. After participating for successive years they were able to themselves start seeing how rapidly science can change, sometimes year-to-year.

What the examples above show is a growing awareness of the value of community input in contemporary science education, and the access and logistical challenges that teachers face. In a world of increasing connectivity, digital tools seem to offer a means of addressing these challenges, at least in part. The value of a facilitator with specialised expertise should not, however, be overlooked. In the case of the senior biology seminar series, for example, the LENScience team accessed the science expertise, helped facilitate the communication, and managed many of the logistics. As argued by Bolstad and Gilbert (2012):

> If this work [connecting schools and the community] is to be scaled up, it needs more systemic support—in contexts where it is seen as being part of the platform on which a 21st century education system is possible. This support will need to provide opportunities for the partners to work in the spaces between their different areas of expertise, to talk and listen to each other—across professional and/or cultural boundaries.

7. Summary

The analysis above draws together findings from the focus groups and case studies in order to offer insights into how digital tools might help support a shift towards future-oriented science education. The findings highlight the importance of critical reflection regarding which digital tools are used, when and for what purpose. They also emphasise dispositions related to passion, purpose and play (Wagner, 2012) for teachers working in this space.

By grounding the findings in the Education 1.0, 2.0 and 3.0 framework, we were able to identify learner and community participation as key components of future-oriented education. Mapping existing and future scenarios against our framework of future-oriented science education we demonstrated how particular scenarios might need to shift to reflect characteristics of Education 3.0. Building from this, we used NZCER's six principles for supporting future-oriented education to examine the current education landscape, as understood from the focus groups and case studies, in order to consider challenges and opportunities.

We noted that:

- While some teachers were beginning to explore notions of personalising learning, there was limited evidence of how students, or the community, or both, might shape the direction, scope, content and contexts for learning.
- There was little evidence of teachers grappling with how to meet the learning needs of diverse cultural groups, let alone how to harness "diversity" (for people, and for knowledge/ideas) as an integral part of learning.
- Several teachers experienced a conflict between what they perceived to be more general aims of science education—passion for science as a way of knowing, or notions of scientific literacy, or both—and a heavy emphasis on content knowledge. This potentially acts as a barrier in their endeavours to move towards offering science curricula where science knowledge is used to develop learning capacity, as opposed to being an end in itself. Clearer direction is needed from curriculum and assessment policy for the desired purposes of science education within the

compulsory sector. The recent report *The future of science education in New Zealand* (Royal Society Education Committee, 2012) is likely to be important here.

- Many teachers were cognisant of changes in their roles as teachers and a shift towards more student-centred approaches to teaching and learning. For example, blended e-learning and "flipped classroom" strategies were being introduced to help facilitate student ownership of their learning. However, there was little evidence of how teachers might move further towards an environment where they work with their students to co-generate knowledge.
- Innovative teachers were very appreciative of the autonomy and trust that they were accorded within their school context. They also recognised the importance of professional reflection and inquiry. Identifying strategies through which "teacher innovators" could collaborate together appeared to be more difficult, although a range of initiatives have been or are currently funded by the Ministry of Education.
- Links with the wider community for access to knowledge and expertise were seen as being important and valuable, but difficult to establish and maintain. ICTs have potential to help address challenges in communication across space and time, although this is still seen as being problematic in terms of sustainability and scalability. There was strong support from teachers who had been involved in the LENScience Senior Biology Seminar Series for this kind of model to facilitate school access to scientists. Within this scenario, the challenges associated with many of the points referred to above—personalising learning, changes in teacher and student roles, harnessing diversity—would need to be carefully considered.

8. Key enablers for a future-oriented education

Our purpose in preparing this report was to offer insights into how e-learning/digital technologies might be harnessed to help support a shift towards future-oriented science education. This involved seeking "glimpses" of what future-oriented science education might look like, and identifying some key enablers for future-oriented education practices. In the section above we identified learner and community participation as key indicators of progress from Education 1.0 to Education 2.0 and 3.0. We also considered what NZCER's six principles for supporting future-oriented learning and teaching might look like in science education.

As outlined above, new technologies will only help enable transformation in the formal education sector when they are supported by a parallel shift in educational ideas and infrastructure. In particular, changes are needed in:

1. teacher dispositions and skills
2. school culture and leadership
3. infrastructure support
4. community involvement.

Many of the participants involved in this study demonstrated intrinsic motivation, and a valuing of difference and unconventionality—key qualities identified by Wagner (2012) as necessary for innovation. Most were driven by the desire to empower their students through improving the learning experiences:

> If you're an innovative teacher, you do it for the kids. (Teresa)
>
> [Innovative teachers] are driven by getting good student outcomes. They seem to realise what the end game is before they get too high tech. They're very reflective. (Neville)

As indicated above,[22] the participants valued opportunities for thoughtful risk taking, space to pursue interests, opportunities to collaborate and opportunities to create. Each of these is also a condition identified by Wagner (2012) for supporting innovation. School leadership could help foster these opportunities without necessarily being directly involved, but it was also clear that, eventually, strategic decisions would need to be made by senior leaders. These related in particular to decisions about resourcing—purchasing of hardware and software. For example, Sam reported:

> [Innovation] comes from the bottom up. Initially the school infrastructure was shocking … I could easily have given up. But now the Board and senior management team have seen [what's possible] and are starting to give us the resources. Then you start to make some progress and evaluate, is it making a difference?

Resilience, motivation and determination were identified by the participants as being important attributes of teachers in this kind of scenario. There was also acknowledgement that this could be very lonely:

> Realising how hard it is for an individual. There's power in somebody saying to you, 'What do you want? How can we do it?' That's what's going to lead change in terms of risks, the way we support each other.

Several participants reflected on how they used their own resources, particularly iPads, in their classrooms. Sheryl even described teachers as "walking charity shops" because of the way that they used their own resources. However, once they had made a case for the benefits, schools tended to "get on board", often through parent-run fundraising activities.

Other participants were in schools where there was significant leadership in e-learning:

> Our school has been using ICT for years. It was because we had a visionary who had the power to actually implement it and put the budget in place. And she took the school with it. It wasn't driven from the ground up. There were people doing isolated bits in ICT, but in terms of a comprehensive programme across the school it was driven from the leadership. (Isaac)

Even in this environment, however, it was important for teachers to think critically and reflectively about how and why they were using ICT:

> We had a laptop roll out. There was immense pressure to justify the cost. And the science department sat down and said, 'What do we want to use these for? Not to justify them, but how can they help our teaching? (Isaac)

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22 See Principle 5: A culture of continuous learning.

A developing culture of e-in-science is therefore shaped by the interplay between teacher professional development and support, school technological infrastructure, and school organisation and leadership. This was also highlighted by the national evaluation of New Zealand's laptops for teachers (TELA) scheme carried out by the University of Waikato leadership (e.g., Cowie, Jones, & Harlow, 2011), and 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 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 needs were met, additional professional development resulted in more changes to classroom practice and new infrastructural needs. In line with this, Frank et al. (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 that:

> 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)

It would seem that, if there is to be system-wide change towards more future-oriented learning and teaching regarding the nature of learner and community participation, then school leadership will be critical in driving this shift.

The wider community also has an important role to play—both in asking for change, and participating in it. They need to ask for change because, as Bolstad and Gilbert (2012) argue:

> If we are serious about building an education system that is capable of preparing young people for the 'knowledge societies' of the future, we need to reconfigure [education systems] in new, more learning-centred ways. However, it will only be possible to do this when there is wider public awareness of the growing gap between the kind of learning our young people are getting, and the kind of learning they need. There will also need to be wider public support for teachers and school leaders as they attempt what is effectively a paradigm shift in practice. (p. 14)

Young people need to participate in change. Schools, as they are currently set up, simply do not have the resources to provide all the very different kinds of expertise needed to develop 21st-century learning experiences in which students contribute to the development of new knowledge (see principle 6, above).

The depth of this shift in community expectation and participation in education should not be overestimated. Parents and whānau want their children to be "successful", with the predominant measure of "success" being the current assessment practices. Even small deviations from this, such as those pioneered by Paul Lowe in his "Problit" programme with gifted and talented Year 10 students, can meet with parent—and student—resistance. Lowe, Taylor and Buntting (2011), in a report on this project, comment that:

> [S]everal parents expressed concern that the key competencies emphasised by Problit, whilst inherently valuable, were not directly related to achieving well in traditional forms of assessment such as NCEA, recognised as the official gateway to future opportunities ...
>
> Parental expectations can therefore form a significant barrier to substantive teacher change. Whilst some felt that their concerns were alleviated during the course, it is not clear whether this would have held weight had their sons or daughters been participating in 'high stakes' school assessment activities like NCEA.
>
> Students, too, may struggle with the shift in emphasis and the self-directed approach to learning. (p. 29)

Underpinning this report is a theme of profound change—a paradigm shift—in education. The significant investment associated with projects such as Ultrafast Broadband in Schools, the School Network Upgrade Project, and the Network for Learning is an important step if New Zealand education is to keep pace with the 21st-century needs of its students. However, 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.

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Appendix A: LENScience Senior Biology Seminar Series

Cathy Buntting

Background

The Liggins Education Network for Science (LENScience) is based within the Liggins Institute, a research unit within the University of Auckland. It was established in 2006 by Professor Sir Peter Gluckman to provide schools with access to scientific research communities and to support the development of the scientific and health literacy required for the economic and social well-being of 21st-century societies. Science communication with the wider public is also a key goal. Currently, LENScience receives funding from public good teaching and research grants (about 70 percent), government contracts (about 22 percent) and philanthropy (about 8 percent).[23]

LENScience offers a range of educational programmes to schools. These include:

1. face-to-face learning experiences, including learning experiences outside the classroom (LEOTC) run out of the special-purpose science classroom hosted within the Institute[24] and in-school professional development opportunities for teachers
2. the Māori and Pasifika Initiative, which includes the face-to-face LEOTC programme, research-based extension programmes for gifted and talented students, a school to university summer-school transition programme, and an undergraduate programme
3. LENScience Community, which connects into the school community as a broker for wider public connections
4. LENScience Connect, which uses Web 2.0 tools and broadcasts via satellite television to communicate with and link to schools across the country.

LENScience has also hosted several Science and Technology Teacher Fellows, an initiative funded by the Ministry of Business, Innovation and Enterprise and administered through the Royal Society of New Zealand.

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23 http://www.lenscience.auckland.ac.nz/uoa/home/about/about-lenscience/funding-and-support

24 See Bolstad & Bull (2012) for a case study of this programme.

Overview: The Senior Biology Seminar Series

The Senior Biology Seminar Series (SBSS) is the largest of the programmes within LENScience Connect both for the numbers of teachers and students involved, and the duration of the programme. It was selected as the context for a case study showcasing e-learning in science because it represents a large-scale model of the science community partnering with schools in a format that relies on digital technology. It also has potential to offer insights into both how e-learning can support the professional learning of science teachers, and how e-learning can enhance the engagement and achievement of science students.

Schools from across the country are able to register at no cost for the programme, which targets students aiming for Scholarship biology. Level 3 biology students wanting to improve their achievement from Merit to Excellence are also often encouraged by their teachers to attend. The programme runs in a 3-week cycle. In the first week, teachers discuss the topic with their students. A comprehensive information pack is provided, specifically produced for the programme. The pack includes background information, scientific data, and questions. In the second week there is a live broadcast that can be accessed via the Internet or satellite TV.[25] There is also a live chat option available via a wiki, which is monitored by postgraduate students so that they, or the presenting scientist/s, or both, can respond to questions from the remote audience. In week 3, student learning is facilitated by their teacher, who has access to more advanced questions about the seminar. They can also continue to interact with one another via the wiki.

The SBSS was first trialled in 2008 with schools from Kaitaia, Auckland, Tauranga and Gisborne. In 2009 it was extended to eight 3-week modules run over a period of 7 months, and opened to a greater number of schools. By 2011, 150 schools had participated, 71 with high Māori and/or Pacific populations, and 85 not in Auckland.

Topics that have been explored include:

- Gene expression:
  - Feast or famine: Understanding gene expression
  - Insights into blindness: Whānau–science partnerships for discovery
  - Using animal models to understand aging
  - Huntington's disease: Understanding a gene mutation

- Gene expression and biotechnology:
  - Breast cancer and biotechnology
  - Aneuploidy and related biotechnologies

- Evolution

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25 Provision of the satellite time has been generously funded and managed by Kordia.

    - Ancient secrets in seaweed (climate change and evolution)
    - Rethinking Polynesian origins: Human settlement of the Pacific

- Human evolution
    - Walking upright: The cost of human evolution
    - The evolving brain: Social interaction and complexity

- Organisms and the environment
    - How do plants grow? (Mechanisms underlying auxin action)
    - Food for a hungry world: Optimising plant growth
    - Animal navigation: Magnetic sense
    - Circadian rhythms: Keeping time
    - Harnessing Biodiversity

All were closely linked to Level 3 biology achievement standards.

Perspectives from the programme designers

The Director of LENScience and co-ordinator of SBSS, Jacquie Bay and three others representing the technological infrastructure behind SBSS were asked to comment on:

- their beliefs about the purpose(s) of science education
- the role of e-tools in supporting connections between schools and science communities—and why such connections are important
- the scope of the seminar series
- the advantages and disadvantages of using an online format
- sustainability and scalability issues.

Not surprisingly, key people involved in setting up the programme—either in terms of content or providing technical infrastructure and support—were all convinced of the value of using digital tools to facilitate connections between schools and the science community. From Jacquie's perspective as the Director of LENScience, the face-to-face programmes would always be limited, owing to the number of teachers and students who could be involved. However, using Web 2.0 technologies enabled the "reach" to be extended, geographically and in terms of student numbers.

The development of a learning community was seen by LENScience to be essential in this, although it does also offer one-off e-learning opportunities at lower school levels. However, the SBSS was designed to maximise opportunities for in-school and between-school connections via a wiki. Live chat was also possible during the seminar—students watching the seminar from a remote location could also have an impact by asking questions through the wiki. It also enabled them to interact with their peers. This interaction proved to be so powerful that students attending the live seminar in person also asked for access to the live chat via laptop computers—an unanticipated outcome.

Several aspects were considered to be important:

- an effective working relationship between the SBSS facilitators, scientists, and schools
- careful selection of the topics and presenters, including consideration of curriculum needs and student interests
- facilitation of the seminar by an experienced teacher who is able to "translate" where necessary between the scientist and students, and vice versa
- providing supporting resources to teachers
- having technical support available on-site for schools not able to connect during the live seminar
- offering the live seminar via both high-speed Internet and satellite television
- support from partnering organisations such as REANNZ and Kordia
- regular communication with schools
- timetabling the seminar for out-of-school hours to avoid timetabling issues with schools
- a strong Nature of Science thread running through the series demonstrating science as evidence-based and dynamic
- being attached to a physical "centre"
- strong links with a science community so that the facilitators are, in effect, immersed in the science—"You need to know it deeply enough to be able to make it simple"
- collecting and monitoring participant feedback
- personnel who no longer consider themselves to be classroom teachers, but agents of change—empowering classroom teachers to extend their own and their students' learning
- long-term, consistent, committed funding.

Scientists who participated in the programme were reported as saying that their involvement was "immensely rewarding", and that the programme offered them "a platform to share their work". As a result, there has been tremendous buy-in within the Liggins Institute and with partner organisations. There was also recognition of the challenges science teachers face in obtaining and translating up-to-date information; and the challenges scientists face not knowing about the school curriculum or teacher needs.

Funding

The SBSS was not able to be offered in 2012 because of lack of funding.

The 2008 trial was supported by service in-kind from Kordia, The University of Auckland's ITS Division and VoltTV Productions, and by a grant from The University of Auckland's Schools Partnership Office.

Funding for LENScience Connect, including the SBSS, from 2009–2011 was enabled through

- in-kind contributions from The University of Auckland's ITS Division and Kordia
- a science communication grant from The National Research Centre for Growth and Development (NRCGD)
- in-kind contributions from Massey University's Allan Wilson Centre for Molecular Biology and Evolution, Lincoln University's Bio-Protection Research Centre and The University of Auckland's Centre for Brain Research
- a REANNZ KAREN Capability Fund Grant (2009).

Within the Liggins Institute, LENScience is considered to be a research group with research responsibilities and outputs. This can be challenging given the nature of much of the funding, and particularly lack of funding "tagged" for research. The challenge is compounded in that research is only possible after the resources have been developed and implemented, and so the first period in any venture is spent setting it up rather than producing research outputs.

Participants' perspectives

Four teachers were interviewed regarding their experiences with the SBSS. Each of these four teachers was nominated by LENScience because of their commitment to the programme and perceptions about how their students had embraced being part of the e-learning network. Three of the teachers participated in a focus group interview in Wellington, and the fourth was based in Hamilton.

The teachers were contacted prior to the discussion with the following agenda:

- reasons for enrolling in the seminar series
- impacts of the seminar series on their understanding and capability in science
- impacts of the seminar series on their views of science education, its purposes, and how it might be enhanced
- impacts of the seminar series on students' engagement and achievement in science
- advantages / disadvantages of the online delivery
- possibilities for using a similar type of programme with more junior students
- how online services might be used to professionally support science teachers to enhance science understandings and pedagogy.

Not surprisingly, the teachers were all very supportive of the programme, and disappointed that it had not been offered in 2012. Angela[26] went as far as saying: “It’s the best example of ICT in science education that I’ve seen.”

Generally all of the teachers used the programme in the way that it was intended, with student groups meeting weekly for discussion. The scenario depicted in Vignette 5 earlier in this report was typical.

Vignette 5

Year 13 biology students aiming for Scholarship participate weekly in the Senior Biology Seminar Series offered by LENScience. Other students also come along, some because they want to improve their Level 3 achievement from Merit to Excellence, others because they are interested in the topics, or simply because they like the atmosphere. Occasionally other teachers come along, too.

Every third week they watch a live broadcast by a scientist. At the same time they participate in the online wiki connected with the broadcast. They can use this to ask the scientist a question, or clarify what the scientist is talking about with other students logged in from across the country. Tim, the biology teacher, turns these sessions into “events”. There is food, and live interaction via the wiki between the students and their counterparts across the country, as well as with the scientists.

The following week the students meet to explore the topic further. Tim encourages them to ask their own questions, and supports collaborative discussion in response to these questions. The students also continue to contribute to the wiki. Those who missed out on the live discussion are able to access and watch a recorded version. This enables them to participate in the follow-up conversations, both with Tim and their peers from the same school, and with other students from around New Zealand via the wiki.

The perceived value of the programme was closely linked to the “resourcing need” that it fulfilled at Scholarship level:

> I was taking on Scholarship biology and other than a couple of past Scholarship exam papers, there wasn’t anything else out there that I could put my hands on and know that I was meeting those students’ needs. I felt quite inadequate in that sense. Especially in biology, because it is changing so quickly, you need to be on top of the most recent research. But I felt I had a complete programme in place through using it [SBSS].
>
> It made me, first, able to run a Scholarship programme and, second, feel like I was doing a really good job. (Angela)

[26] Pseudonyms have been used.

Having said this, the teachers were also very supportive of the introduction of similar initiatives for more junior students, and talked about how they had modified some of the content for use with more junior classes. In particular, there was recognition of a need for greater resourcing in relation to the Nature of Science strand in the New Zealand Curriculum (Ministry of Education, 2007).

The advantages of the SBSS, from their perspective, included:

- The "live" component:

> I really recommend, if it is possible, for it to be live. Although the running wiki could interfere in some ways with learning, they got to see what other kids around the country were doing. (Tim)

> It's great you can watch it later, but if it was just 'you can watch anytime', I imagine quite a few of my girls would have not got around to it. (Angela)

- The calibre of the presenters:

> To get that access to top quality NZ scientists. And interesting scientists. And women scientists. And Māori and Pasifika. (Tim)

- The ability of LENScience facilitators to translate between the scientists and schools:

> That key component, of having somebody who can bridge the gap, who can make sure that what's provided really meets the needs in the classroom (Angela)

- The validation the students received as a result of their participation:

> Not only were they part of a wider learning community, but they felt important as learners, and as part of the science community. Because the people presenting were presenting to them, and interacting with them. It made the students feel important. (Angela)

> My students were able to take risks, especially with the feedback from the scientists being so positive. (Lana)

- Presentation of current, cutting-edge science:

> Once it's in a book, it's dead information. We're teaching artefacts of stuff we once thought was important. What's happening now is changing at such a rate that they need to be part of it. (Tim)

- Opportunities for students to interact with their peers around the country, and the validation that this enabled:

> Students enjoyed seeing that other students had similar questions. (Angela)

You're not just the one or two biology geeks at your school. You are part of a whole community of scholars. (Tim)

- Portability:

It's able to be downloaded, stored, distributed on CDs, DVDs, loaded onto your intranet, your YouTube. So it can travel really easily. (Tim)

- It was designed by science teachers and was relevant to school needs:

It is related to the exact content and exam structure that we as science teachers need. So often people come up with brilliant ideas and resources, which are nothing at all to do with us. (Tim)

- Opportunities for the teachers to learn:

It was great PD for me. (Angela)

- Insights into science careers:

Seeing people who were working in science in such a wide range of fields was opening up ideas for them. (Lana)

The idea that there's still so much more work to do. That they [my students] can be part of that. (Glenis)

- The technical support that was available:

I felt like they really were there, and they wanted to make it work for you. The technical support was beyond anything else I've experienced. (Angela)

Insights into e-in-science

This case study offers a range of insights into how digital tools might be harnessed to facilitate the development of learning communities supporting future-oriented science education. In particular, it offers an example of an education programme that:

- has potential to support both teacher and student learning
- relies on and is developed in conjunction with community participation
- has potential to support peer collaboration and knowledge co-construction
- has potential to explore complex, open-ended, cross-disciplinary problems.

These are explored in greater detail in the full report.

Appendix B: E-in-Science professional development and implementation at a primary school

Bill MacIntyre

Background

The primary school (School JC, a pseudonym) is a decile 10 that carries out its teaching and learning of the New Zealand Curriculum (Ministry of Education, 2007) through their Connected Curriculum. Each Connected Curriculum unit has a major learning area focus with minor learning areas connections. Students at the school engage with the Connected Curriculum at different times during the day and during different days of the week.[27] The school's deputy principal is responsible for curriculum leadership across the learning areas and works with the different syndicates to plan Connected Curriculum units. The school's Connected Curriculum uses an inquiry learning cycle that is based on Tuning In, Finding Out, Sorting Out, Knowledge Synthesis and Taking Action. Each classroom had 6–8 laptops with wireless connections to the school's server. The laptops are 2–3 years old with a school server capable of handling several classrooms at one time. Each classroom has a "blog" on School JC's website.

School JC's involvement in the project was precipitated by the Education Review Office's (2012) science and the desire to focus on one of its suggestions—teaching science using a Nature of Science (NoS) approach. The senior syndicate had delivered a "science focus" Connected Curriculum in Term 1 2012 and with the support and leadership of the deputy principal planned a second "science focus" Connected Curriculum in Term 3 that would focus on a NoS idea—working together like scientists, asking questions and finding evidence and exploring simple models to develop their understanding of landforms (Planet Earth and Beyond). The 2011–2012 rock slip in the Manawatu Gorge was being used as a focus in their science inquiry. The school approached the science inquiry using the "I see, I think, I wonder" framework (Ritchhart et al., 2011).

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[27] Individual teachers in the syndicate decide when Connected Curriculum is delivered in their classrooms.

There are three classes in the senior syndicate (Year 5–6). Two classes with their teachers (Teacher E and Teacher Y) participated in the study. Table 1 provides a comparison between the two teachers.

Table 1 **Attributes and competencies of Teacher E and Teacher Y**

Teacher E (Enid)[28]	Teacher Y (Yasmine)
• Initial teacher education overseas	• Initial teacher education in Aotearoa New Zealand
• Two years' teaching at School JC	• Seven years' teaching at School JC
• Two years' teaching in senior syndicate	• One year's teaching in senior syndicate
• Co-leader in Ministry of Education ICT cluster project in Manawatu for 1 year	• Competent with ICT
• Highly competent with ICT	• Classroom teaching and learning environment is "organic" (as described by the principal)
• Classroom teaching and learning environment is structured	• A risk taker and willing to venture into unknown
• At first uneasy with researcher in the classroom owing to Teacher E having no prior contact	• At ease with researcher in the classroom from beginning because of prior contact
• Researcher was on the "sidelines" during observations	• Willingly engaged the researcher with the teaching and learning during observations

Methodology

The researcher provided a half-day of professional development (PD) two weeks before the unit began. The PD was based on the collaborative "unit" planned by the deputy principal and the senior syndicate team around Planet Earth and Beyond—"Landforms and erosion". It was held at School JC with the three senior syndicate teachers, the deputy principal and an observer (Observer K)—a practising primary teacher involved in another science PLD project. A pre-study interview with the two teachers and deputy principal captured some of their initial understandings on science, science education, ICT tools and e-learning in science.

The researcher and Observer K carried out classroom observations of Teachers E and Y and their students during the 6-week period. Notes of the teacher actions, students' responses and the context were recorded during each observation. Static and video images were recorded alongside "informal talks" with the students. Student written work on paper and that placed on classroom blogs were captured. At the end of the 6 weeks, random groups of students in each class were "formally" questioned about the ICT embedded in the

28 Pseudonyms have been used.

science inquiry and their views about science. At the end of the term, separate interviews with Teacher E and Teacher Y were recorded. Observer K was also interviewed and recorded, capturing another perspective of the e-in-science project at School JC.

Professional development

The half-day involved an introduction to and ICT tool and science equipment. The ICT tool is the ProscopeHR,[29] as the school would have use of five for the duration of the inquiry. Stream trays[30] and dripping tubes were also on loan. Modelling activities were demonstrated using both so that the teachers could identify where and when the equipment could be used in their "unit plan". The other part of the PD focused on the Nature of Science included in the unit plan. It was identified as a "deep understanding" for the inquiry:

> It is important to understand that scientists ask questions, find evidence and explore simple models to develop their understanding of our world.

To assist with this focus, the two roles of "working as a scientist" were introduced to the syndicate team—constructing ideas and critiquing ideas (Hipkins, 2011). The teachers and deputy principal identified an opportunity to use the roles in developing an understanding about science as students work collaboratively like scientists in developing their understanding about landforms.

Findings

Uses of ICTs in the science inquiry

The table below identifies the ICT tools embedded in the science inquiry by teachers E and Y. It also provides the context in which they were used. They may not be all the ICT tools that the teachers have used but these tools are the ones observed "in action" in the classroom.

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[29] A digital hand held microscope with connections to the laptop via USB.

[30] These are hard plastic trays measuring 1.5m (length), 30cm (width) and 10cm (depth)

Table 2 **Use of ICT tools**

ICT tool	Teacher E (TE)	Teacher Y (TY)
Classroom blog	This class updates it frequently, done by students every week, for communication to parents and wider community about their learning, repository of what was done.	Used to communicate to parents and wider community about their learning, repository of what was done, not changes as frequently as TE's blog.
VoiceThread (very familiar with this tool)	Introduction to inquiry, used an image of a landform, had students working in groups of three to record • what they "see" • what they "think" • what they "wonder" on their classroom blog for parents and rest of community	Introduction to inquiry, used an image of a landform, had students working in groups of three to record • what they "see" • what they "think" • what they "wonder" on their classroom blog for parents and rest of community
Digital camera (experts (?) – familiar with static images and video)	Used through the science inquiry, in collaborative groups, to: • video their initial observations of Manawatu River and eroding cliffs [class trip] • take static and video images [with voice] of stream trays investigations	Used through the science inquiry, in collaborative groups, to: • video their initial observations of Manawatu River and eroding cliffs [class trip] • take static and video images [with voice] of stream trays investigations • take static images of rocks / river bed stones etc while undertaking classroom work
GoogleDocs (very little experience) - in conjunction with data projector use	• collaborative groups providing simultaneous critiques of other groups' "thinking" and "wonderings" at their laptops [working as scientist] • collaborative groups providing "further information" from their web searches simultaneously during class time • whole class use of GoogleDocs to critique	• collaborative groups providing simultaneous critiques of other groups' "thinking" and "wonderings" at their laptops [working as scientist], • whole class use of GoogleDocs to critique information

ICT tool	Teacher E (TE)	Teacher Y (TY)
Web 2.0 Search Engines (very familiar)	• search for information • critiquing other groups information by seeking 3 different sources [extensive use and familiarity]	[minimal use within the inquiry]
ProscopeHR (new tool)	collaborative groups • capture process of erosion (video) using the stream trays • uses "time-lapsed" video to capture long term dripping of liquids)water and vinegar) on rocks	collaborative groups • capture process of erosion (video) using the stream trays • uses "time-lapsed" video to capture long term dripping of liquids)water and vinegar) on rocks • uses close-up function to view the "crystals" forming on one rock • uses close-up static images to look closely at and capture the micro particles of the different types of rocks • uses close-up functions to look at and identify the micro things in soil
YouTube	• integrated YouTube video to reinforce the need to verify and critique other information when searching	• integrated YouTube video to reinforce multiple literacies in videos and provide a structured pathway (using graphic organisers) to identifying the different types of rocks of rocks they collected or brought in to school

Student voices using the ICT tools

Students in both classes were very positive about the use of ICT in the science inquiry to help them learn:

> "With them (camera, VT and Proscope) you can look back and not have to do it again." (TE/P)

> "Speed up information gathering and sharing (using GoogleDocs) instead of waiting to share what you have." (TE/H)
>
> "Using Google Docs to see what … others are thinking."
>
> "Look at the particles very closely. (ProscopeHR)" (TY/J)
>
> "More information, faster, easier to use." (TY/M)
>
> "Using different types of tools helped me." (TE/P)
>
> "The YouTube was good because we saw scientists who knew about the different rocks." (TY/C)

The use of Google Docs as a technological pedagogical content knowledge tool did appear to support engagement in the learning. It also assisted with developing the scientists' role of constructing questions and critiquing them. The explicit use of this tool with the classroom data projector helped focus students on the unit's big ideas while collaboratively sharing knowledge. Students in both classes remarked that sharing was faster with Google Docs and that "we do not get bored like we do when we share on the mat" (TY/M). This use of Google Docs, with simultaneous writing, is an innovative use of ICT to enhance engagement with the construction of collaborative knowledge from different groups.

The function or quality of the ICT equipment (not focussing well, where to position the ProscopeHR, difficult to change the lens on the ProscopeHR, identify which mode [static images, video or time-lapsed video] on the ProscopeHR to use) was mentioned more amongst the students in Teacher E's class. Those in Teacher Y's class focused on the slow computers (time to load the ProscopeHR software). This slight difference was observed in how the collaborative groups worked as scientists with the ICT equipment. Towards the end of the science inquiry, the groups in Teacher Y's class collaborated well within their group and between groups, sharing their awe, wonder and knowledge about rocks as well as managing their time spent using the ICT tools. This was not the case in Teacher E's class. Students were still "hogging the equipment" (TE/P) at the end of the science inquiry and the exchange between groups was not observed as in the other class.

The differences could be attributed to the difference between the two teachers' teaching pedagogy, flexibility, science and science education understanding, and personalities. As Teacher Y stated "I was just as excited as the students when we were using the ICT tools." "I would tutu with the equipment before we would use it in class and that is how I learned how to use them." That teacher's disposition was evident among the students, as it was okay to tutu when first learning how to use them. Teacher Y noted that structuring the activities, as a series of rotations for each group (mentioned to Teacher Y by Observer K), assisted with giving the students more time working with the equipment and engaging with the awe of looking closely and working collaboratively as scientists during the inquiries. This observer believes that the length of time spent as a collaborative group working on successive activities with the ProscopeHR enhanced the skill use of all the students in the group. The students could articulate the purpose of using one functional mode over another.

Effective use of ICT tools in science knowledge construction will depend on teachers' ability to rethink the role of their existing pedagogy content knowledge.

Student engagement and achievement

> "The use of ICT tools sustained student engagement with the big ideas and the constructing and critiquing roles of working as a scientist." (YE)

> "Engagement—absolutely." (TY)

> "Syd was motivated and maintained an interest for the entire 6 weeks because he was able to demonstrate his science understanding without an emphasis on the writing, something that he has struggle with in other Connected Curriculum inquiries." (TY)

> "When students come into the classroom and the first thing they want to do is get out the computers and start looking at things with the ICT tools or at the images, that is a good sign that the ICT has maintained their interest in the science inquiry." (TE)

Student achievement and understanding of the purpose for using the ProscopeHR in the science inquiry is demonstrated in the following statements:

> "To see things up close, better than a magnifier cos it goes closer in, the rocks have different formations and so being able to zoom in shows the differences better." (TY/H)

> "If you know more about the rocks then you can think more about the landforms and what they are made of." (TY/A)

> "We can take pictures every now and then, instead of watching it for a long time like scientist use to do." (TE/ S)

Although on-task behaviour of 40–50 minutes was common when students were working with ICT equipment and/or stream trays while investigating their "wonderings", there was a lack of *purposeful observations* by students during the 6-week inquiry.

Encouraging the students to explore more with the use of ICT tools in semi-structured and unstructured activities will promote engagement and develop dispositions and competencies to use appropriate ICT tools for developing their science understanding alongside the scientific skills of investigating.

Professional development, sustainability and scalability

As primary science teachers, Teacher E and Y acknowledged the benefits of having an opportunity to link landform and erosion activities with the stream tray, dripping tubes, ProscopeHR and other ICT tools. Developing their understanding of the two roles (constructor and critiquer) during the PD assisted with identifying in their plan, where they could provide opportunities to develop student understanding of those two when *collaborating as a scientist*. Teacher E, as an ICT cluster co-leader, stated that embedding ICT tools in the science inquiry had not changed the thinking about e-learning in science, but it was the PD that clarified the thinking about science and science education: "I now know the difference." Teacher Y openly admitted that the other two teachers were much better at science, there was a lack of understanding of how ICT could be embedded in science inquiry, and there was confusion about the difference between science and science education. However: "Yes, absolutely my thinking about the use of ICT tools in science has changed." (TY)

Professional development for e-learning in science in primary schools must include:

(a) Opportunities to develop a working knowledge of the ICT tools (e.g., ProscopeHR), associated content knowledge and skills, technological pedagogical content knowledge and teacher dispositions "to change without fear" (TY). Teachers wanting to embed e-in-science will need to be "ready" to accept professional development in the ICT area as well as rethinking their understanding about science and science understanding for future focus education.

(b) A lead ICT teacher. At this school it was fortunate to have a highly literate ICT person as one of the participating teachers. Changes occurred in the teachers and students because of Teacher E. Teacher Y reflected that: "Teacher E was willing to share the expertise with me and others at morning tea, lunchtime and after school and not keep the knowledge from others." Future-oriented primary schools will require an ICT lead teacher who has a willing disposition and the pedagogy to impart the ICT knowledge to other staff (and students) in order to develop a learning capacity in the science curriculum.

(c) A school-wide programme of ICT development across the levels. The school as an ICT progression matrix from Year 1 to 6 and teachers at senior levels know exactly what ICT knowledge and skills the students bring with them to the classroom. The range of ICT knowledge and skills was narrower than expected in both classrooms. Every student was able to show the observer how to use VoiceThread (new ICT tool for the observer).

(d) A lead teacher in science. Teachers E and Y acknowledge their "deputy principal's expertise and passion in science" and it lead to a science inquiry that was flexible enough for both teachers. The school principal supported a second science inquiry, the PD and the school's involvement in the case study. It does appear that in this primary school there is a culture of leadership and a school infrastructure that supports staff development in their teaching and learning. An encouraging leadership will support teachers who want to rethink their role as a teacher in a future focus school.

(e) Quality ICT tools and science equipment. “If there is to be a scalability aspect, then the Ministry must provide quality equipment for every school regardless of the decile if they want elearning in science to be embedded in the primary school classroom.” (TY) Both teachers noted that one can think differently about their science education if the location of the equipment is in proximity and available for unplanned use as well as having ICT tools that work as they should in the classroom. Future-oriented primary schools will require accessible equipment in their schools if personalised learning in science is to be encouraged during school time. Partnerships with the community could assist with the availability of equipment during school as well as away from the school environment.

With an emphasis on having teachers and student think differently about science education, science education PD for teachers should focus on how to teach students to “observe” carefully and the role observations plays in science. Although the school used the framework “I see, I think, I wonder” (Ritchhart et al., 2011), there were many missed opportunities where the students did not observe carefully and hence very little thinking and wonderings were investigated or developed. “The absence of purposeful observations appears to be common in many primary school students” (Observer K).

If a future-oriented primary school wants to adopt a learner-centred, active engagement approach in primary science than future professional development in science must develop teachers’ understanding of the importance of “observing” in the Nature of Science and science knowledge creation.

Barriers to embedding e-learning in science in primary schools

> “Teachers who do not want to change their teaching pedagogy.” (TY)

> “Schools who lack an ICT leader or one to share and support the other teachers in the school.” (TE)

Teachers’ dispositions

> “It was unbelievably exhausting making sure ICT was used for a purpose in the inquiry and as well as ensuring that I was teaching the students about *working as scientist* throughout.” (TE)

> “Physically it cannot be sustained by primary school teachers when there are other learning areas to teach in the Connected Curriculum inquiries.” (TY)

Teachers E and Y have noted that the e-in-science project was physically unsustainable as well as covering the other curriculum learning areas term after term.

To build a sustainable curriculum for teachers and learners alike, primary schools must use "knowledge to develop learning capacity" and that requires some rethinking about the learners' and teachers' roles in the school curriculum.