MINISTRY OF EDUCATION
Te Tāhuhu o te Mātauranga

e-in-science: Future-oriented science learning

Cathy Buntting and Rachel Bolstad

Science in the New Zealand Curriculum

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

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Report prepared for the Ministry of Education

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EXECUTIVE SUMMARY

This report covers the final phase of the e-in-science project funded by the Ministry of Education. It brings together findings from earlier phases (Buntting, 2012; Buntting, Jones, McKinley, & Gan, 2012) and parallel research on school engagement with the science community (Bolstad & Bull, 2012).

The e-in-science project is premised on the following assumptions:

- e-learning encompasses ICT or digital technologies in the 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.

This phase of the project focused on developing a conceptual tool to explore the potential for digital technologies to support future-oriented science education. Two focus groups were convened, comprising experts from the school, tertiary and research and development sector. The conversations were wide ranging and recognised e-learning as only one of many influences that might change future science education thinking and practice. Following are the important themes that arose during discussion.

- School science needs to be 'believable' in order to be relevant and engaging.
- Links with the science community can have a hugely formative impact on students' interest and engagement in science.
- It is difficult to imagine what hasn't yet been experienced.
- Ideas about the future of e-in-science interconnect with other ideas for the future of education and e-learning.
- There is value in thoughtfully playing with digital technologies to discover how they might support science teaching and learning.

In both focus groups, interactions with other professionals with a wide range of different expertise and interests were seen as being key to sparking new thinking. This raises two important questions:

- How can science teachers be supported to share ideas and engage in 'big picture' thinking?
- Is a more formal mechanism needed and what might it look like? Who would be its champions?

In response to these questions, a discussion document was developed with the aim of sparking just these sorts of conversations among teachers of science and other key stakeholders.

Underpinning the work is a theme of profound change—a paradigm shift—in education. Teachers of science (both primary and secondary), their schools, policy developers and the wider community are all called on to think deeply about the kind of science education that is needed to appropriately equip students for living and working in the 21st century.

[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.

INTRODUCTION

This is the final report for a 17-month Ministry of Education project investigating e-learning in science education (e-in-science).[2] In recognition of the increasing access that schools will have to digital technologies, the work aims to enhance understanding about how these technologies might be harnessed to support students' engagement in and understanding of science across their schooling experience. The project has involved three phases.

Phase one (February–May 2012)

The first phase (reported in Buntting, 2012) identified examples of how digital technologies can be used to support students to work like scientists, work with scientists and/or work with each other. However, this type of classroom practice appeared to be happening in small pockets rather than being widespread. An online survey completed by 343 teachers suggested that they were far more likely to use ICT for retrieving and sharing scientific information than for collaborating or creating knowledge, although many indicated they would *like* to use ICT in these ways.

Teachers who were very confident in their ability to implement the various strands within the Science learning area of *The New Zealand Curriculum* were more likely than others to use ICT resources to update their own knowledge, find student activities, have students collect and analyse scientific data, and have students communicate with a scientific expert. This finding suggests that sound curriculum knowledge and strong professional support from teachers may coincide with the innovative use of digital tools to support students' science learning.

Phase two (June–December 2012)

The second phase (reported in Buntting et al., 2012) involved a series of focus groups and case studies in which participants explored how digital technologies might be used to enhance school science. Drawing on this information we developed a series of vignettes, each depicting students' use of digital technologies for different purposes: as an additional information source, for communicating with an audience, to collaborate with peers, to interact with scientists, and to generate their own scientific data.

In analysing these vignettes we found Keats and Schmidt's (2007) 'evolution of education' to be helpful. The framework works like this.

- Education 1.0, like Web 1.0, is largely a one-way process. Students 'get' knowledge from their teachers or other information sources.
- Education 2.0 happens when Web 2.0 technologies are used to enhance traditional approaches to education. New interactive media, such as blogs and social bookmarking, are used, but the process of education itself does not differ significantly from Education 1.0.

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[2] 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. Together the three strands investigated different aspects of contemporary and future science education:

1. curriculum support, particularly in relation to resources supporting teachers' understanding of the curriculum's Nature of Science strand
2. the nature of engagement between schools, teachers and students and the science community of practice
3. the potential for e-learning to enhance and even transform school science.

- Education 3.0, by contrast, is characterised by rich, cross-institutional, cross-cultural educational opportunities whereby the learners play a key role as creators of knowledge artefacts, and the distinctions between artefacts, people and processes become blurred, as do distinctions of space and time.

The vignettes developed in phase two largely represented Education 2.0, suggesting that even good examples of *current* e-in-science practice may be insufficient for generating ideas and understanding about possible *future* practice.

From current practice to a future focus

As part of phase two we considered what 'future-oriented' science education might look like. Future-oriented educational literature argues that the learning needs of contemporary and future students are likely to be different to the needs of students in the past, in part due to the scale of technological, social, environmental and economic changes over the past century. Future-oriented educational research foregrounds, among other things, the need for learners to acquire the skills to access, analyse and evaluate information that is constantly changing, and to use this knowledge in collaboration with others to support personal and workplace decision making.

It is also clear that 'doing science' has changed, and that it continues to change in the 21st century. Today's scientists and others who collaborate in science-related work need more than just knowledge of science:

> People need to be able to connect with the different knowledge/expertise of others. They need to be able to articulate their contribution, and to listen to, seek clarification from, and negotiate with the others in the space. Doing this successfully requires: (i) having knowledge to contribute; (ii) well-developed thinking skills; and (iii) well-developed inter-personal skills. (Gilbert, 2012, p. 7)

Gilbert further argues that

> If we accept that one of science education's roles is to represent scientific work with some accuracy, then we have a problem. At the individual, practical level, there is a problem: many young people won't be making informed choices about whether or not to go on in science, [and] we won't be fostering the qualities needed in today's science professionals …
>
> But there is also another problem … Becoming a 'smart' knowledge and innovation-oriented country does not mean producing more 'knowledgeable' people—more people who have been 'filled up' with existing knowledge. It means having more people with a new and different *orientation* to knowledge, people who know enough to *do things with* knowledge, and who can work *with others* to do things with it. (p. 8)

She concludes:

> If we think it is important to: (i) engage more young people in science; (ii) foster the attributes and dispositions to knowledge our science professionals of the future will need; and (iii) create our future innovators, then doing more of what we do now (even if we were to do it better) is very definitely *not enough*. (p. 9)

During the second phase we looked for research synergies in schools' engagements with the science community, which was the focus of a separate strand of inquiry.[3] Drawing together findings across these projects, the second phase of the e-in-science project developed a visual

[3] See Bolstad & Bull, 2012.

framework for thinking about future-oriented e-in-science. This framework drew on the prior research work to propose that e-in-science might be understood in terms of:

- its potential to support more opportunities for science learning in contexts that are relevant to the community, including the science community
- increased opportunities for learners to be actively involved in shaping the direction of their science learning.

The intention of this framework was to initiate productive conversations about the role of digital technologies in the future of science education, both to develop in all young people a life-long interest in science[4] and to foster the skills necessary for those who want to pursue science-related careers.

Phase three (January–June 2013)

The third phase of the project (presented in this report) focused on developing a conceptual tool for:

- exploring the potential of digital technologies to support future-oriented science learning
- supporting teachers and school leaders to reflect on and enhance their practice.

In the next three sections we outline the methodology for the development of the conceptual tool, discuss key themes that arose from the expert groups' discussions, and finally present the conceptual tool/framework and explain how and why it was developed to promote engagement and discussion about the future of e-in-science.

[4] This is related to notions of scientific literacy, whereby one aspect of responsible citizenship involves being able to contribute effectively to decision making about science-related issues.

METHODOLOGY

In order to develop a conceptual tool that would help teachers and school leaders to explore the potential of digital technologies to support future-oriented science learning, two expert groups were convened for one-day workshops: one in Hamilton and one in Wellington. Prior to the workshops the participants were sent a copy of the draft framework for future-oriented e-in-science along with two other readings.[5]

Composition of the expert groups

The composition of the expert groups reflected our view that valuable discussions occur when people with a variety of expertise and interests come together. The participants were therefore selected to ensure a mixed set of expertise and positionings. Although the groups were small (ten in Hamilton and six in Wellington, plus the two researchers), they included:

- four teachers (two primary, one intermediate, one secondary)
- five education researchers (specialists in education, science education, e-learning)
- three secondary school students, covering a diverse range of in- and out-of-school science experiences
- two first-year university students who had both had extraordinary engagements with the science community during their secondary schooling
- a science PhD student
- a software engineer
- a university-based co-ordinator of science outreach programmes and activities
- a project director and ex-teacher working in an ICT-focused education consultancy, professional learning and research agency.

The mix of expertise meant that the conversations of both groups represented several perspectives:

- learners (the secondary and tertiary students, as well as other participants reflecting on their own school experiences)
- teachers (the teachers themselves, as well as the teacher educators and others who work with teachers)
- educational theory (many of the members of the group raised ideas related to shifts in educational thinking about knowledge, learning, science, science education, and the challenges therein)
- research and development (offering insights into emerging technologies and cultures of innovation).

As is always the case when working with small groups, many others could have been represented at the table who would have brought something of value to the discussion. However, all the participants had a connection with science education, and many had been engaged with school–science links—during their secondary school experiences, as teachers

[5] In preparation for the focus groups, the participants were asked to reflect on the following documents:

1. a portion of the preceding e-in-science report (Buntting et al., 2012), which included six vignettes of e-in-science practice and a framework for future-oriented science education
2. a summary of the community engagement project (Bolstad & Bull, 2012)
3. an article by Jane Gilbert (2012): 'Science 2.0 and school science'.

linking with scientists, as scientists meeting with school students (e.g., the PhD student and the software engineer), and as brokers of school–science partnerships.

The researchers were also able to draw on previous reports completed as part of this project (Bolstad & Bull, 2012; Buntting, 2012; Buntting et al., 2012), which enabled them to access an even wider range of perspectives, including the perspectives of teachers recognised as being innovative in their use of digital technologies and stakeholders in a variety of school–scientist partnerships.

It should be noted, however, that all participants in the focus groups and in the previous studies were successful as students and/or professionals. Although care was taken to explore participants views' of what the experiences of disengaged science students and teachers might be, the perspectives of these students and teachers is likely to be under-represented.

Participants' feedback on the workshops

The purpose of the expert groups was to critique and extend the framework for future-oriented science education developed in the earlier phase of the study, and to explore the potential of digital technologies to support future-oriented science learning. The depth and richness of conversation in both expert groups demonstrated the value in bringing together groups of mixed expertise and interests to address the open-ended challenge of developing a future-oriented view of e-in-science. Conversation was wide ranging, and there was a desire among the participants to consider the potential of digital tools within the context of wider shifts in science education and education as a whole. As one participant said near the end of the day:

> I thought today was going to be more about e-learning, but I'm pleased it wasn't—that we were looking at aspects that are much bigger than that. e-learning should be sitting in the background. Learning in schools is by definition e-learning these days, it has to be. So I've been delighted that we've been talking about big issues—changes shaping where this is going to go.

Participants also gave positive feedback on the opportunity to meet with others to discuss a topic they considered to be both important and engaging: science education and the challenges of making it relevant, engaging and meaningful for contemporary and future students at all levels of the school system. The sense of connection between participants seemed critical for sparking thinking and providing new insights. Many, including all the teachers, expressed an interest in continuing to engage in these types of conversations.

THEMES ARISING FROM THE FOCUS GROUPS

A number of interconnecting themes arose during the focus group discussions. These had strong implications for the way we developed the conceptual tool, which takes the form of a discussion document, including a framework for future-oriented science education (Bolstad & Buntting, 2013).

1. Science needs to be 'believable' in order to be relevant and engaging.

The secondary and tertiary students were strong advocates of a focus on real-world science in school science. They saw this as an important part of making the science they were learning seem 'believable'. For this reason, they favoured science teachers who were able to naturally and authentically intersperse science teaching with stories and examples of 'why it matters'.

They valued it when teachers made connections between different areas of science and were scathing of approaches that lacked relevant contexts or were not meaningful to them.

They reported that at senior secondary school many students, including themselves, take science because it is required for their intended future study. Their motivation for learning science therefore centres around having been told it is important to their future careers. However, they did not always understand *why* the topics specified in the curriculum had to be learnt and understood, or what the deeper purpose was in particular assignments. One said, “You need to know the long-term applications of what you’re learning.”

Science as presented in school was not seen as being a “tool of empowerment” or “a way I can live my life”. In spite of this, the students in the focus groups saw science as being “all around”; that is, science can describe so many of the world’s phenomena. The two tertiary students were also both passionate about seeing greater links between science and the humanities.

These reflections raise questions about the perceived relevance of students’ science learning and the need to link science learning to their everyday experiences and interests—concerns that have been raised in the international literature for decades and that continue to be addressed in New Zealand commentaries on science education (e.g., Education Review Office, 2012a; Gluckman, 2011).

2. Links with the science community can have hugely formative impacts on students’ interest and engagement in science

Many of the participants talked positively about interactions they had experienced when school students interacted with the science community. These included programmes managed by outside agencies, such as the Royal Society’s CREST awards and the University of Otago’s Science Wānanga (see https://sciencewananga.otago.ac.nz/).[6] When reflecting on these types of opportunities, the students valued being able to work on real scientific problems.

They also commented on the shifts in relational power that occurred—that they felt empowered to relate to the scientists as co-workers on a common project. They found this very different to their classroom experiences, where the teacher was seen as the person who held all the relevant knowledge. One of the participants, who is involved in facilitating school–science links, said:

> The students talking about the change in the power structures between students, teachers and scientists … that reliance on the context [in which the learning occurs], that’s something that’s really leapt out at me—that we’re trying to change something about the relationships between teachers and students and what’s actually happening in that room.

More extensive analysis of a range of school links with the science community is provided in the reports by Bolstad and Bull (2012), Buntting (2012) and Buntting et al. (2012). The potential benefits of such interactions—whether digitally mediated or not—are raised here because the expert groups kept returning to this theme when thinking about how to enhance science learning in schools. While some of the challenges associated with setting up and sustaining these links were noted, the discussions tended to focus on creative possibilities for supporting work in this area.

[6] These programmes are experienced by only a very small number of secondary school students when compared to the total cohort, and many are reserved for top-achieving students, with little real investment in lower-ability classes having access to these opportunities.

One suggestion was to use an existing social networking infrastructure (e.g., Facebook) to create a forum where teachers could advertise their needs and interested parties could respond. The thought was that local businesses, such as mechanical or electrical repair businesses, might be willing to engage at this level—and get positive promotion for their business in the process. Another suggestion was for scientists or postgraduate students to make themselves available for conversation online at a particular time (e.g., using Google+ Hangouts). Once again, this would involve using an existing digital technology but for the purposes of science education. These possibilities are explored further in the accompanying discussion document (Bolstad & Buntting, 2013).

3. It is difficult to imagine what hasn't yet been experienced.

Another recurring theme in the focus groups was the difficulty of imagining digital technologies that do not yet exist and that might be commonplace in the near future. It is also difficult to imagine what future schooling might look like, including how curriculum and assessment structures might change. For example, there was extensive conversation on just how much input students and the community might be able to have—and should have—in the design of science education programmes. Conversations of this type have the potential to lead to rich explorations of the purposes of schooling, the place of students and community interests in designing teaching and learning programmes, and how teachers' professional expertise and judgement might be valued and enhanced.

System-wide curriculum and assessment structures *do* already exist. Although they need to be interpreted and implemented at the school and classroom level, which allows for some variation, there is no doubt that they should and do have an impact on classroom practice. *The New Zealand Curriculum* (Ministry of Education, 2007) ("NZC") focuses in its opening sections on inclusive and future-oriented approaches to education. This gives permission to schools to "enter the territory of 21st century educational change" (Lock, 2008, p. 72). However, a report by the Education Review Office (2012b) on 113 primary and secondary schools identifies the *future focus* principle as being the least evident of the eight principles listed in NZC.[7] This principle is about "supporting learners to recognise that they have a stake in the future, and a role and responsibility as citizens to take action to help shape that future" (New Zealand Curriculum Update, 2011).

Community engagement was the fourth most evident principle, suggesting that schools were finding it easier to work towards providing a curriculum that has meaning for students, connects with their wider lives, and engages the support of their families, whānau and communities. However, this principle was still only evident in less than two-thirds of the school curricula that were evaluated.

At the senior secondary level, the National Certificate of Educational Achievement (NCEA) is a flexible, outcomes-based assessment system and science has an extensive range of standards. This allows schools to adopt a future-oriented approach to science education in that they can offer—and assess—programmes that not only engage students but also reflect the multi- and interdisciplinary nature of contemporary science. The variety of standards also allows, in theory, for greater customisation and individual learning programmes and qualifications. However, insufficient targeted professional development and the ongoing pressures from university entrance requirements have in practice constrained what many schools offer their students in terms of science (Buntting et al., 2013). This suggests that even when mechanisms for supporting more future-oriented approaches are in place, the shift is not automatic.

[7] The other principles are: *high expectations*, *Treaty of Waitangi*, *cultural diversity*, *inclusion*, *learning to learn*, *community engagement* and *coherence*.

4. Ideas about the future of e-in-science interconnect with ideas about the future of education and e-learning

There was extensive discussion about the extent to which our focus on the future of *science* education/e-in-science could, or should, be bracketed off from a focus on the future of education or educational technologies generally. For example, while it was assumed that digital technologies would play a key role in education in the future, they were not considered to be the *only* driver of changes in educational thinking and practice. The focus group discussions suggested the need to tease out the relationships between digital technologies, education, *science* education and future-oriented educational thinking.

Thus, participants kept asking, 'What is it about *science* education that will need to change in the future?' Important considerations here were:

- the ways in which contemporary science is changing and the need to reflect contemporary science in science education programmes (see Gilbert, 2012)
- the specific ways in which digital technologies might support the learning of science, as opposed to other subjects
- the areas of science learning that students find difficult
- the specific professional learning needs of science teachers.

Of course there are no easy answers. However, this theme highlights the need to consider the different educational possibilities created by digital technologies, the purposes and structures of future-oriented education, and the needs and opportunities within science education.

5. Digital technologies for a purpose, or a purpose for digital technologies?

Many of the participants in the earlier focus groups believed that digital technologies need to be selected and used for *specific purposes*, not just "because we can". In other words, they wanted to find and use digital technologies that would meet the learning need they had identified—'finding a tool for the purpose'. They were far less interested in finding purposes for the tool (digital technology). This seemed to reflect, in part, the pressures they felt were imposed on them when their schools embraced digital technology policies.

In contrast, both focus groups convened for the third phase of the project made a strong case for playing with digital technologies to see how they might be used to support students' learning. They thought this was how novel insights might originate, as reflected in the following conversation:

> Person 1: If it is about how the learning takes place, that takes us back to the opening assumption—finding a tool for the purpose, not a purpose for the tool.
>
> Person 2: I like that. That's a great statement.
>
> Person 1: I think it's a great statement. Except I think that sometimes it is the tool that prompts you to think about the learning that can take place. If we're just finding a tool for the purpose, then we can get stuck in the particular purpose that we have at the time and we're looking for the tool that does what we're currently wanting. Whereas sometimes we need to look at the tools that are available, and think, What is the potential? Where can this take us?

This difference—between starting with the need to identify an appropriate technology to address a teaching purpose and starting with a technology to identify what needs it might address—represents different, but not mutually exclusive, ways of approaching digital technologies in education. Importantly, in both cases the emphasis is on ensuring that the technology is used *purposefully*, not just for the sake of it.

Discussion

The conversations in the focus groups were deep and wide ranging, drawing on the experiences and wonderings of participants with very different backgrounds and expertise. The themes discussed above highlight possibilities for strengthening science education programmes—science learning that is relevant and engaging and that links with contemporary science practice. They also recognise that new opportunities in science teaching and learning will open up as digital technologies continue to evolve.

Overall, there was a sense that in an era of widening diversity in terms of learning possibilities in science, it will become increasingly impossible to describe an ideal science classroom: a one-size approach will not fit all. The time of providing model classroom examples of best practice has passed, because this risks closing down creativity rather than opening up space for it. Instead, participants favoured opportunities for ongoing professional conversations and reflections. They recognised that effective science teaching takes energy and commitment. Those who are or had been teachers valued opportunities to engage in professional learning, as well as being part of a school culture that supports risk taking.

This was also highlighted by teachers who had participated in the second phase of the research (Buntting et al., 2012). The need for a stable digital infrastructure appeared to be essential to really exploring how digital technologies might transform how learning can occur in a science education programme.

Finally, interactions with others were seen as being the key to sparking new thinking. This raises important questions:

1. How can science teachers be supported to share ideas and engage in big-picture thinking?
2. Is a mechanism needed, and what might it look like? Who would be its champions?

We hope that the conceptual tool, outlined below and detailed in Bolstad and Buntting (2013), will provide some stimulus to begin these sorts of conversations.

DEVELOPING A CONCEPTUAL TOOL

Conceptual frameworks attempt to connect all aspects of a research inquiry in order to succinctly distil and convey key ideas. A draft framework for future-oriented e-in-science was developed at the end of phase two (see Appendix). However, it quickly became apparent in the phase three focus group discussions that this framework would need considerable unpacking by the target audience (i.e., teachers). The conceptual tool we subsequently developed therefore comprises two interconnected parts:

- a visual framework for future-oriented science education (further developed from the phase two draft)
- a discussion document designed to support rich professional conversations among science teachers and other key stakeholders, adding depth to the ideas captured in the visual framework.

A framework for future-oriented science education

The aim in developing the future-oriented framework for science education is for it to act as a thinking tool that teachers can use to reflect on their science programmes and explore ways in which they might shift what they are doing towards more future-oriented practices. Future-oriented science education both engages with contemporary science practice and allows space for students to make choices about the nature of their science learning. This does not negate the key role of the teacher in supporting learning. Rather, it creates opportunities for students to influence what happens in their classrooms in ways that support more empowered and powerful learning.

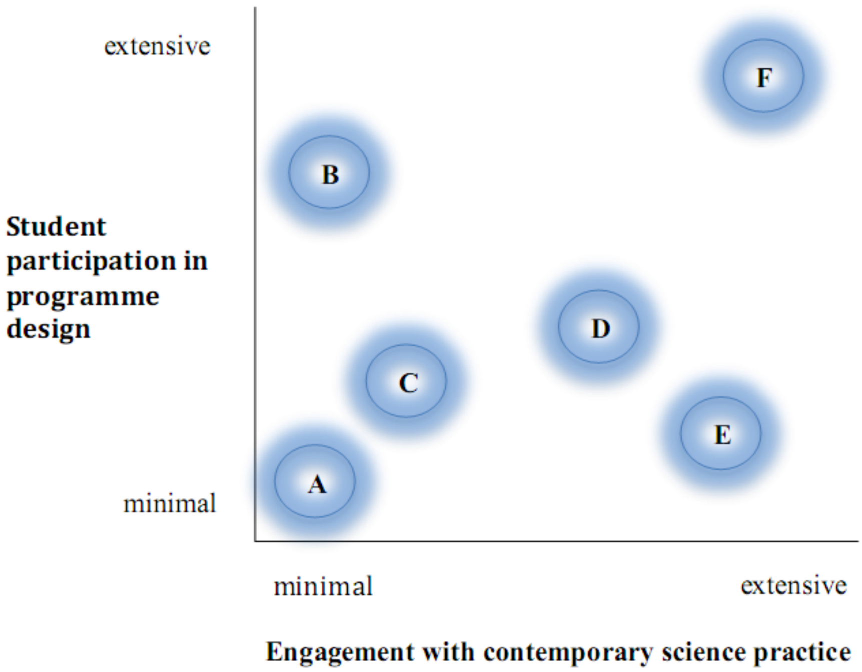
The framework sits within the context of broader discussions about educational change in general and changes in science education in particular. For example, the ways in which digital technologies might change the nature of education are only just beginning to be understood, and these will continue to change as technologies change.

The framework for thinking about future-oriented science education (presented below) is based on the following assumptions.

1. If school science is to be relevant and engaging for students, it will require greater student decision making about their own learning—what is learned, how it is learned and how it is assessed. This does not downplay the important role of the teacher or the curriculum. However, it does recognise the value of taking into account student interests when designing a future-oriented science education programme.
2. If school science is to meet the needs of students in the 'knowledge age', it needs to engage with contemporary scientific practice. This means that students gain, through their science education, insights into science as a complex, multidisciplinary endeavour addressing real-world questions. Offering students opportunities to engage with contemporary scientific practice may require them to interact with the science community, as well as other people who are engaged with, using or generating scientific knowledge.
3. Digital technologies will play a key part in transforming what might be learned, and how learning might occur.

Classroom programmes—whether single activities or whole units of work—can be plotted on the framework to indicate the level of input students have had in terms of the programme design and how the learning opportunities support students to engage with contemporary scientific practice (see Figure 1). In doing so, a range of classroom scenarios can be considered (see Table 1).

Figure 1. A framework for thinking about future-oriented science education



Note: The letters A to F represent different teaching scenarios, which are described in Table 1.

In this way the framework can act as a conceptual tool to help teachers reflect on their current practice and explore the ways in which they can support greater student participation in shaping learning and/or provide stronger connections with contemporary scientific practice. It is important to note that over a term or a year, meaningful school science programmes are likely to include a range of different teaching and learning episodes that will be locatable at different positions within the framework. The important thing is for the teacher to reflect on the learning intentions, and the opportunities that exist to broaden these, and give students richer opportunities for science learning and skill and disposition development.

Table 1. Scenarios related to the framework for thinking about future-oriented science education

	Description	Example	Commentary	Questions for reflection
A	A highly structured lesson with clear learning intentions. The activities and their sequencing are determined by the teacher.	Physics students view a Web-based animation of an electrical circuit, build their own circuit, do manual calculations, and check additional calculations using an app on their mobile device.	The teacher determines the learning intentions and how these might be realised. Valuable learning can occur, although there is little linking to how or why scientists use knowledge about electrical circuits.	Should some lessons/units focus on students' conceptual development without making links to contemporary scientific practice? If so, why? If not, why not?
B	Students pursue a topic of individual interest that is related to the class's broader unit of work. Learning is heavily focused on scientific content and there is little engagement with contemporary scientific practice.	After learning about weather processes on Earth, junior secondary students choose a topic for further research. Many choose a planet and find out about conditions on this planet and any moons that are associated with it, although one student wants to learn more about how the moon influences the Earth's tides. The students use books and the Internet for research. They decide on assessment criteria and choose how they will present their learning to their classmates.	Students choose a topic to study and how to present their findings. However, this scenario may miss opportunities to spiral into further interesting questions for contemporary scientific practice. For example, how do scientists know about the conditions on other planets? What scientific knowledge has been gained from projects like Mars Rover? Is the expense of these projects justified by the scientific value of the knowledge gained?	How can science learning balance opportunities to expose learners to knowledge *to pique their interest*, with opportunities for learners to generate and explore *their own questions* once their interest is piqued? How can other skills and dispositions—research skills, digital literacy, communication skills—be fostered as part of the learning?
C	Students have some input into the direction of their own learning and there is some engagement with contemporary science.	Senior primary students learning about the brain view a 3-D app of the brain, manipulate plastic models, watch as a vet dissects a goat's brain, and negotiate with their teacher about what to include in a movie demonstrating their learning. Because they are interested in scientists' jobs, finding out about someone working with brains becomes an important aspect in their videos.	Students have greater input into the direction of their learning. For example, because the students show an interest in jobs that involve working with brains, they negotiate that researching this be part of the assessment criteria. The teacher uses this interest to develop students' understanding of the nature of science (e.g., that our understanding of the brain is still developing, and that scientific knowledge can change).	Is it necessary for all students in the class to learn the same thing? How might assessment tasks be framed to recognise the different learning of different students?

D	Students have greater input into the direction of their own learning, which includes engagement with contemporary science.	An intermediate teacher wants her students to do some science learning involving two nearby streams, one on farmland and one in an area of native bush. She invites someone from the regional council to talk to her students about water quality and why it is important. She then asks her students what scientific questions they could investigate. She also asks them to clarify why their chosen question is important to investigate. Students carry out their investigations and decide how to present their findings, explaining the significance of the results and suggesting a follow-up question that could be asked.	Students choose what to investigate using samples collected from the two streams or their surrounds. To expand the options available, some samples are sent to a laboratory for testing (e.g., if one group wants to test for Giardia). By choosing how to present their findings, students have input into how they demonstrate their learning.	What science-related contexts lend themselves to different questions that could be investigated? How interested are students in these contexts?
E	Students engage with contemporary science practice.	Year 13 biology students collect data for a rocky shore investigation. They upload their data to the Marine Metre Squared Project (www.mm2.net.nz) upload information. They then choose to map and graph their data for comparison over time, between regions or between species. They investigate how and why information like this is collected and used by scientists.	Students participate in learning that reflects contemporary scientific practice. For example, they analyse large data sets looking for trends. They learn about why many scientific investigations are carried out in this way and begin considering ideas of complexity.	The Marine Metre Squared Project is a 'citizen science project' run by the University of Otago's NZ Marine Studies Centre. What other projects like this exist that students can contribute to? What other ways can students join together, from different classes or schools, to compare scientific data and contribute to scientific knowledge?
F	Students choose a scientific question to investigate. Multiple methods are used during the investigation, which may be carried out in groups.	Digital technologies are used to facilitate interactions between students, support the co-construction of knowledge, and present or share outcomes. Students might consult with someone in the community.	The students choose their own project, although they are not used to doing this and many find it difficult. The teacher offers some possibilities, but encourages the students to choose their own question within broader areas of possibility. The teacher facilitates student access to experts who are able and willing to help with the project.	What knowledge does the teacher need in order to support students' diverse projects? What knowledge do the students need? How can the teacher and students access relevant experts? What aspects of the nature of science can be identified in the students' work?

Here are some questions to guide your professional reflection and discussion.

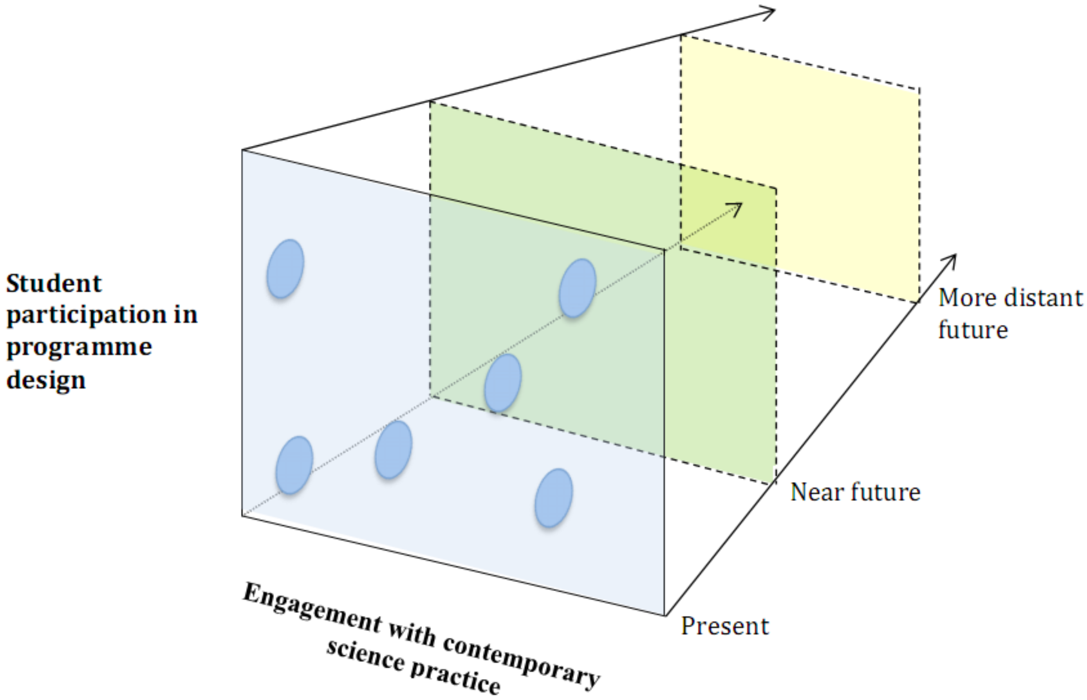
- Are we using the framework to describe current practice or to inspire change in practice? If the latter, why do we think that change is needed?
- Is one position on the framework better than another? Does this vary at different levels of schooling?
- Should teachers aspire to include all positions of the framework at some time during a science programme?
- What school structures are needed in order to enact different positions on the framework?
- Does allowing students to have input into the design of the science education programme detract from the role of the teacher in selecting learning objectives and the best tools and activities to support learning?
- Are students ready, willing and able to have input into programme design? How can expectations for this be established?
- What knowledge do teachers need about the nature of contemporary scientific practice, and how can this be accessed?
- What implications does this framework have for planning?
- What implications does this framework have for designing valid assessment that reflects the learning intentions?

Thinking further into the future

It is interesting to ponder—but difficult to speculate—what trends might emerge over time (see Figure 2) because of the number of variables that have an impact on school change. However, a number of questions seem worth discussing.

1. Will we continue to see 'more of the same', and what will this mean in terms of preparing students for life and careers in the 21st century?
2. Will there be increased opportunities for students to have input into their learning programmes? What teacher change is needed to enable this? What changes in school structures and culture are needed? How might national assessment need to change?
3. How might science continue to change? Can school science keep pace with these changes? What teacher support will be needed?
4. What other changes might occur in school science in the future? Will the traditional subjects be retained? Will there be shifts towards cross-curricular investigations?
5. What should be the focus in primary science? How can primary teachers be better supported to teach science?
6. What digital technologies might be developed in the future, and how might these alter the ways in which science can be taught and learnt?

Figure 2. A framework for future-oriented science education



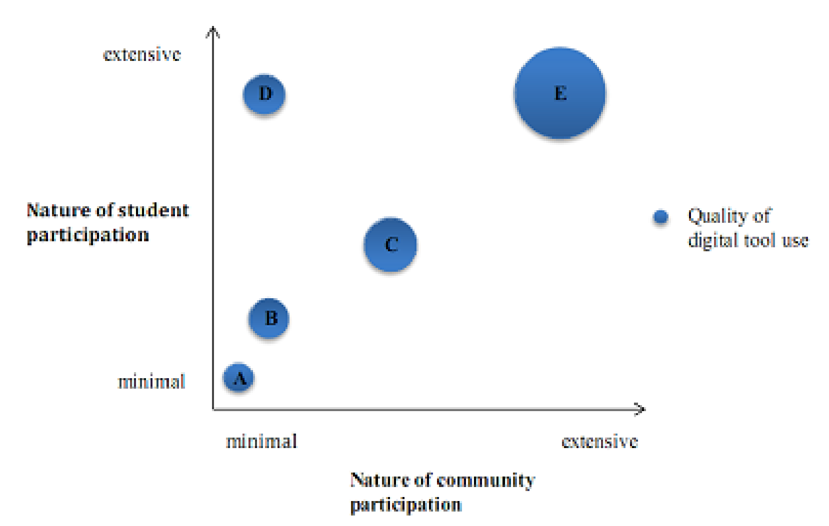
A discussion document to support professional conversations

It was clear from our work in phase three that the framework for future-oriented science education needs to be considered within the context of broader discussions about changes in science education. To do this, we proposed developing a discussion document or resource to stimulate professional conversations among teachers and to promote thinking about future-oriented e-in-science.

The content of this resource (see Bolstad & Buntting, 2013) draws on the exploratory thinking of the expert focus groups as well as ideas explored in the earlier phases of this work. The discussion document currently takes the form of a text-based document, but it is our hope that it will be published in a form that enables teachers to interact with it via a digital medium.

Appendix: Previous framework for future-oriented science education

A framework for future-oriented science education



A – A highly structured lesson with activities and activity sequence determined by the teacher. May involve a range of digital tools. E.g., physics students view an animation of an electrical circuit, build their own circuit, do manual calculations, check calculations using an app on their mobile device.

B – Students have greater input into the direction of their own learning. There is also some community input. E.g., students learning about the brain view a 3-D app, watch as a vet dissects a goat's brain, manipulate plastic models, and negotiate with their teacher about what to include in a movie demonstrating their learning.

C – Students and the community work together to establish the direction of learning. E.g., students communicate with a science community either synchronously (e.g., using video conferencing) or asynchronously (e.g., using blogs), their questions influencing the nature of the discussion.

D – Students determine the direction of learning but do not consult with an external community, e.g., deciding on a topic for a science fair project. Digital tools may or may not be used, e.g., to collect, analyse or report data.

E – A vision for future-oriented learning, where the students and the community together determine what to learn, how to learn it, and how to assess what has been learned. ICT is fundamental to this process for facilitating interaction, constructing knowledge, and communicating, presenting and evaluating outcomes.

Assumptions:

1. Future-oriented science education has **extensive student and community input** so that what is achieved is greater than what could be done in isolation.
2. ICTs are transforming the nature of what can be learned, what needs to be learned, and how learning occurs. This transformation needs to be supported by **ideas and contexts that enable transformative practice in schools.**

Note: This framework was developed during phase two of the project. See Buntting et al., 2012 and Buntting, MacIntyre & Falloon, 2012). It has now been modified for phase three.

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