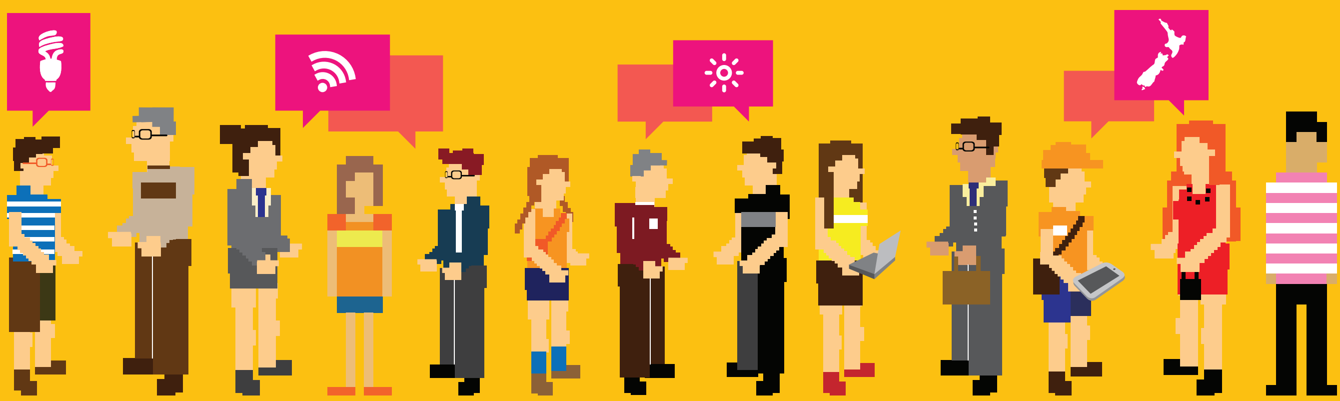
Digital technologies and future-oriented science education



A DISCUSSION DOCUMENT FOR SCHOOLS

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About this document

This document was developed to support teachers and others to engage with findings from the e-in-science research project, carried out by the University of Waikato and the New Zealand Council for Educational Research under contract to the Ministry of Education.

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Quick guide to the four sections

Getting oriented	• What is this document and who is it for? • Interacting with this document
The big picture: Challenges for 21st century science education	• How do we think about school science learning? • Traditional school science, or science learning for the knowledge society? • What is different about science in the 21st century? • Is science education engaging for all learners? • Learning with the science community and wider community? • What makes science learning future-oriented?
e-in-science: Digital technologies and future-oriented science education	• How can we use digital technologies to support science learning? • A purpose for the tool, or a tool for the purpose? • Four ways digital technologies could radically transform science education
Where to from here?	• What can we do within our current curriculum? • What makes a future-oriented science teacher? • What can school leaders do? • What are the implications for school structures and the wider system? • A final word from the authors • Suggestions for further reading

What is this document and who is it for?

This document aims to stimulate discussion about digital technologies and the future of science learning.

What are digital technologies?

Digital technologies refer to any computer-based device or application—sometimes called digital tools, ICTs, mobile technologies or personalised learning devices—as well as the networked/Internet systems that link and connect them.

Some key ideas:

1. Science education needs to be relevant and engaging for learners, whatever their age. It also needs to reflect the complexity of contemporary science.
2. Digital technology has the capacity to transform what is possible in science education. However, accessing and using these technologies is only one part of a complex system of factors that influences what happens in schools.
3. The future is unwritten. We cannot know for certain how digital technologies might change science learning, or what directions those changes ought to take. However, we think there is an opportunity for teachers, school leaders, the science community, resource developers, technology developers, policy makers, researchers and others to engage with some of the ideas that emerged in this research on e-in-science, and use these to begin shaping more future-oriented science education for young New Zealanders.

Who is this discussion document for?

- Teachers and school leaders
- Scientists, science communicators and others in the science community
- Resource developers
- Researchers
- Policy makers
- Futurists
- Anyone interested in the future of science education

I find myself wondering if it's useful learning for them. Does it help them in their lives out of school? How can I connect it with their interests?

The IT landscape is shifting so incredibly fast, and what we're trying to do in schools in ICT is changing fast. It's a good time to re-focus.

Interacting with this document

This document reflects the ideas and experiences of a large number of people who helped us to think about the present and future of "e-in-science". They include primary and secondary school teachers, secondary and tertiary students, teacher educators and education researchers, science communicators, working scientists and software engineers. Their questions and wonderings are included as prompts to help stimulate your own thinking and conversations.

> My job as a primary school teacher is to give them rich experiences of science.

> I want students to be excited about science, and to learn more about what science is and how it relates to their everyday life.

> Science needs to be believable. My teacher tells stories about why what we're learning matters.

We have also drawn on an extensive body of science education research and theory. This recognises that we cannot think about using digital technologies in future-oriented science in a vacuum. Rather, there are broader changes—in education more generally, and in the practices of contemporary science—that also need to be considered. We have tried to avoid cluttering the text with too many footnotes and references but, where possible, we have suggested sources if you wish to read more about these ideas.

> By the time students get to NCEA there's a lot of content that they need to know—the language and symbols of science. It's huge. But I don't want them to stop questioning, to stop being curious.

Because we will all engage differently with the ideas in this document, it is deliberately nonlinear—although you can read it from beginning to end, you could also dip in and out of sections according to your interests. We have tried to use visual organisers and images as much as possible, and to openly represent the different voices of the people who worked together to make this work possible (in the speech bubbles throughout the document, for example). Through these design choices, we hope to share some of the richness of the conversations that took place during this research, and invite you to add your own thoughts and experiences into the mix.

Teachers' feedback on the discussion document

I like that it is a discussion-orientated document rather than a 'how-to guide'. How-to guides expire far too quickly! This document provokes discussion that will hopefully support and challenge schools no matter what stage of the e-learning journey they are at. (Primary teacher)

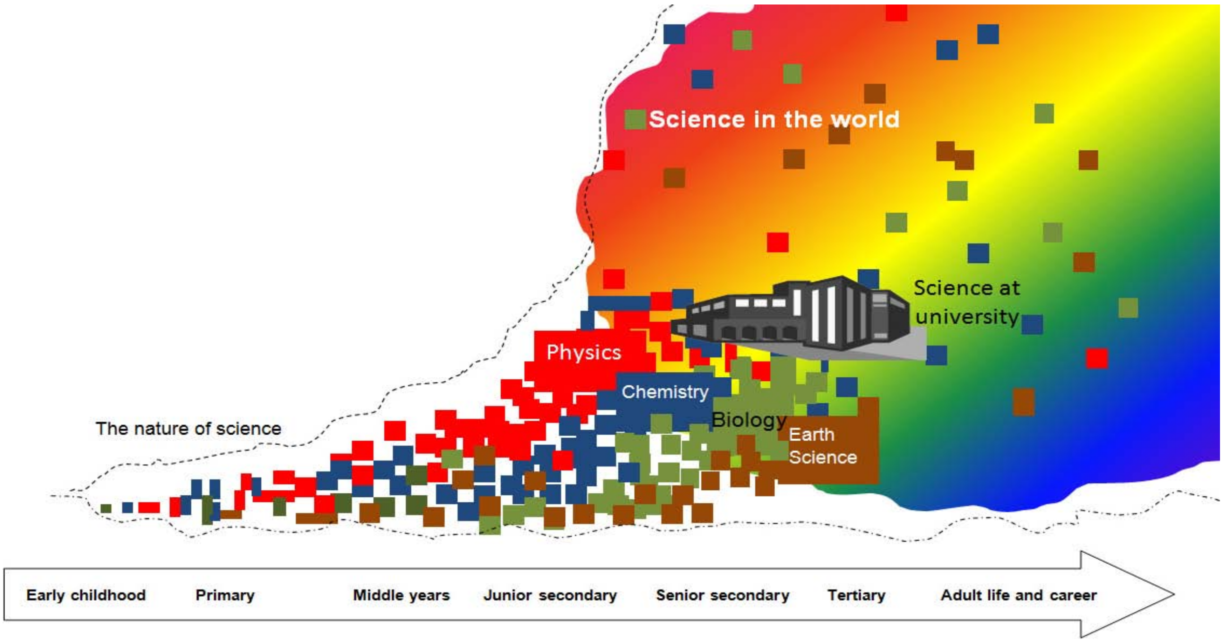
I think the speech bubbles are a great way for providing perspectives and if I was facilitating a staff conversation I would use blank ones to encourage staff to add their own ideas… I am particularly fond of the 'how could it start' bits as they make it seem like I have the potential to act on some of the things discussed in the document… I really like the idea that the document could be added to over time with examples, successes and resources. (Intermediate teacher)

How do we think about school science learning?

People have many different ideas about how school science learning *is*, and how it *ought to be* into the future. Sometimes these ideas seem compatible, and other times they seem to point in different directions.

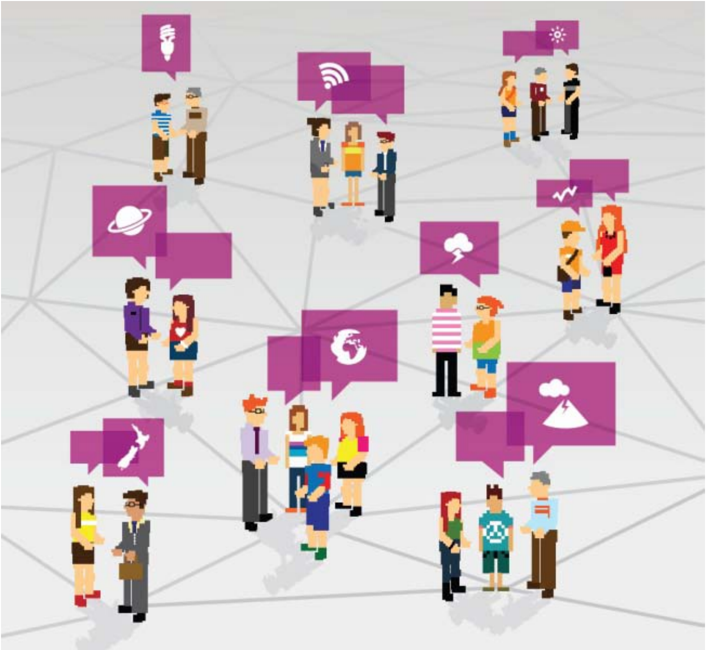
The visual metaphors we have developed below reflect a few of the big ideas that came up during our research conversations, as well as in the science education literature. They are designed to help us think about *how we think about* school science learning, because—as some of our research participants explicitly pointed out—how we think about science learning has a big impact on how we plan for, and *do*, science education.

Building up science knowledge to prepare for the future



The first image represents school science education as a collection of "bits of knowledge" that learners accumulate over the years of schooling. These bits of knowledge are roughly organised around some of the big science disciplines that are familiar in our school curriculum. As students build up bits of knowledge, they get closer to being able to engage with science in the world beyond school—particularly if they are on a pathway to further education and careers connected with science. The dotted lines in the image also show the intention for students to learn *about* science (the nature of science) while they are learning *in* science.

Networks and relationships to support real-world science learning



The second image conveys the idea of learners connecting with science knowledge through networks and relationships with the science community, their teachers and the wider community. They learn in and about science through exploring questions of relevance to themselves, their community and the world. As they engage with different aspects of science in the world, the knowledge they develop may integrate across multiple disciplines. Different learners might engage with different parts of science in different orders, depending on their interests, how they are connecting with the science community and which new questions and pathways open up in their learning as a result.

Your metaphor(s) for school science learning?

This space deliberately left blank

As you can see, we have left the last space blank. We invite you to consider what visual metaphors or imagery might capture the ways that *you* think about learning science at school now and into the future. You may find it useful to collaborate with others to develop an image. Would your image integrate ideas from each of the two previous images? Would you represent school science learning in a completely different way?

Questions:

- Do any of these visual metaphors help you to think about the future of science education?
- What do you think is missing in these images? What would you change?

Traditional school science, or science learning for the knowledge society?

> Students need to know so much stuff. And it builds from year to year. So in junior secondary you cover what they need for senior secondary.

School science has traditionally focused on teaching a pre-determined canon of science concepts. The belief was that this knowledge was important for students to understand and engage with science, whether as responsible, knowledgeable citizens or by pursuing a science-related career. Knowledge development was understood to build incrementally from year to year. However, in a world where the content, volume and accessibility of knowledge, including science knowledge, increase vastly on a daily basis, an educational emphasis on acquiring existing science knowledge no longer seems sufficient. Rather, there is growing recognition of the need for students to develop skills such as adaptability, complex communication/social skills; nonroutine problem-solving skills; self-management/self-development; and systems thinking.

> Ideally, I want my students to observe, to question, to make meaning for themselves based on scientific information. And to discover that science is important in many of the issues that the world is facing.

Of course, expert knowledge is still needed. But it will not, on its own, be enough. In order to contribute effectively and meaningfully, people will need to be able to articulate their contribution, and listen to, seek clarification from and negotiate with others. To do this, they need to have knowledge to contribute, and they need to be able to make connections within and between conversations. This means being able to think and communicate clearly.

Change and uncertainty are likely to be key features of our collective futures. “Wicked problems”, such as climate change, waste disposal, persistent poverty, biodiversity loss, educational underachievement, will not be able to be addressed using more conventional problem-solving strategies. They are highly complex, multidisciplinary, uncertain and value-laden. But many involve science-related components, and will require problem solvers with science expertise to be involved in finding ways in which societies might work together to address them.

Questions:

- What kinds of learning do young people need in order to engage with science in the future?
- Which aspects of current education practice are suited to students’ future needs, and which aspects need to be re-thought?
- How might the strengths and interests of diverse learners be accommodated?

What's different about science in the 21st century?

Hasn't science *always* been dynamic and changing? Is it really that different now, and does this matter for school science education?

There are many interesting books and articles you could read to explore these questions. Jane Gilbert's 2012 article "Science 2.0 and school science" was written specifically for teachers and is a good entry into some of this literature.[1]

The diagram to the right adapts and reproduces a small section of the article to show, in a simplified form, some of the ways that theorists believe science practice has changed over the last century or so.

Gilbert argues provocatively that:

> The influence of this kind of post-academic science—what it is, how it is done, and importantly, the skills and knowledge it takes to be successful in it—is not yet evident in school science… (p. 6)

> If we think it is important to: (i) engage more young people in science; (ii) foster the attributes and dispositions to knowledge our science professional 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)

18th and 19th century

Scientific work usually done by individuals working on their own, pursuing their own research interests

20th century

Academic (university-based) science	Industrial science
Scientists working alone or in small teams, largely following their research interests	Scientists working in large teams in commercially-driven projects

21st century

"Post-academic" or "post-normal" or "networked" science

Scientific work takes place in large teams, which may be networked across several institutions and countries. Projects are often large in scale, multidisciplinary and multimethod. They commonly deal with highly complex systems with many interconnecting effects. Some projects involve ethical issues, some will be of interest to local communities, some will be subject to business and political influence. While scientists are expected to be able to communicate their findings to nonspecialist audiences, they increasingly need to do more than just "explain" or "make accessible" their work to those without expertise in the area—they need to be able to negotiate and work with other experts, from different areas of science, from outside science and from the interested public.

[1] Jane Gilbert's (2012) analysis of contemporary science and what this might mean for school science was published in *New Zealand Science Teacher, 131*, 5–9. www.nzcer.org.nz/system/files/science-2-0-and-school-science.pdf

Is science education engaging for all learners?

These excerpts from New Zealand and international research on young people's engagement with science and science education provide food for thought.

It is widely accepted that all students should leave school with a basic understanding of the ideas and procedures of science. Yet in developed countries across the world, there are signs of decline in young people taking up studies in science and other signs of lack of interest in science. Students are widely reported as finding their school science not relevant or interesting to them. This is certainly their perception of it, whatever the reality. They appear to be lacking awareness of links between their science activities and the world around them. They 'don't see the point' of studying things that appear to them as a series of disconnected facts to be learned…[2]

Research suggests that students who remain interested in science and pursue science pathways later in life have often developed science interests, and can imagine themselves in particular kinds of careers, prior to the age of 14.[3]

Educational theorists point towards the changing nature of youth identity in 'late-modern' society. They argue that young people in the 21st century are increasingly driven by an intrinsic search for personal meaning, while at the same time are expected to make appropriate choices and actively participate in constructing their own lives and careers. There is a growing mismatch between these aspects of today's youth identity, and traditional systems and structures of schooling. In the past, society has tended to value attributes such as obedience, conscientiousness, and humility, while in late-modern society youth are more likely to be motivated by an appeal to the contribution of the individual, and to value such things as care for the environment, democracy, care for others, creativity, and self-realisation. Research suggest that some young people may not associate school science with the kinds of activities which offer the potential for self-realisation or other values they believe will give meaning to their lives.[4]

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[2] See Harlen, W. et al. (2010). *Principles and big ideas of science education* (p. 1). www.ase.org.uk/documents/principles-and-big-ideas-of-science-education

[3] See Hipkins, R., & Bolstad, R. (2008). *Seeing yourself in science. The importance of the middle school years.* Wellington: The Royal Society of New Zealand. http://www.nzcer.org.nz/research/publications/seeingyourself-science

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

Learning with the science community and wider community?

Could future science education involve closer engagements between schools and science communities, and even the wider community? One argument for closer engagements is that schools on their own simply *can't* provide all the learning experiences and resources students need in order to truly engage with 21st century science. Supported by their schools, they also need access to the expertise, knowledge, resources and support of the science community and wider community.

Questions:

- Schools already engage with the science community in various ways, with many positive effects. But what sorts of engagements should schools aim for, and why?
- How can we develop or expand partnerships and relationships between schools and the science community to support future-oriented science learning?
- What knowledge, expertise and resources in the *wider* community could schools access to support science learning?

Research suggests that access to the science community may be an issue for some schools. It is possible for these engagements to be an occasional add-on to "business as usual" school science teaching and learning. Is there a need for more coherent strategies to ensure all learners benefit from involvement with the science community and wider community? What shape might future-oriented school engagements with the science community take? These and other questions were addressed in the science-community engagement research, which also included case studies from around New Zealand (see below).

Where can you read more about these ideas?

Four summary documents highlight key ideas from the science-community engagement research:

1. A rationale for future-oriented engagements
2. Schools' guide to getting connected
3. Key elements for partnership
4. Strengthening engagements across the system

All four summaries are online at http://scienceonline.tki.org.nz/New-resources-to-support-science-education

What if…?

One group of teachers, students and others interested in the future of e-in-science imagined what it might look like if students' science learning involved high levels of active student involvement, participation and engagement with the community.

Society has made it so that schools are responsible for teaching our children…but it shouldn't just be the responsibility of the school. It should be the responsibility of the community…

That's the whole idea—we need to deepen science learning so that it is not just about doing an assignment that finishes at the end of the year, it's an assignment that leads on to a bigger picture. Things that affect not just your town, but your country, not just your country, but the world… It starts small but it has to branch out. The way you do that is by networking, trying to show schools that we are not singular, we're all together and it should be the goal of education to create a better future for *all* of our children.

For a number of us, some of our most valuable experiences of education have been outside the classroom; for example, doing independent or collaborative research…or working with people in the science and wider community. The indirect effect of this seems to be to create good scientists, so how can we transplant those principles and values into the normal education system…?

You said this makes 'good scientists'. What do you mean?

A good scientist is someone who can not only do good research and advance science, but can also communicate that, and have a synergetic relationship with the community. Someone who can share their research with the people it might affect, but is also influenced by the community, so there is a feedback loop…

So if school science learning was more like this, what would it look like? In broad terms, for students it should be problem solving, it should be broad inquiry. Rather than teachers saying 'today the focus is going to be on'…maybe it's a matter of starting with a brainstorm with the community—'What are the problems that we face?' and have a free-for-all brainstorm. And then the teacher might say 'Right, you have until next Tuesday to choose something from this and do a group project.' What this does is give it relevance and so there is this invested value people have in their work, it's not just purely for getting a mark… In real life, science is about solving problems, it's not about ticking a box—'ticking boxes' should be about registering progress towards solving problems, I don't think it should be the end goal.

WHAT DO <u>YOU</u> THINK ABOUT THESE IDEAS?

What if…?

Another group of teachers, students and others interested in the future of e-in-science wondered whether it is possible for students and the community to work together to determine what to learn, how to learn it, even how to assess what is learned.

Is that ever going to happen?… The curriculum, NCEA, is always going to determine what needs to be learned…it has to be within the framework of the curriculum. I don't mean to be a wet blanket, I'm just saying that schools cannot be like that unless some other things change dramatically. So within what we *can* do, what can we do?

I'd like to pick up that point 'unless the other structures change dramatically'—if we are going to say that our students are going to have different needs, then some of those structures *will* need to change.

Then we need to look at the assumption that community involvement is best—for a community to decide what is to be learned, does that elevate the community beyond their expertise?

Are we talking about the *science community* or the general community?

Part of the reason for having a national curriculum is that there is a level of comparability of what is learned across the country. If we move away from that idea, then what is to stop it becoming completely relativist?

I don't see it that way—that it will *all* become relative, or even that community involvement will happen 100 percent of the time, but that some of the agency of student learning is recognised as an important part of the skills they will need for the future.

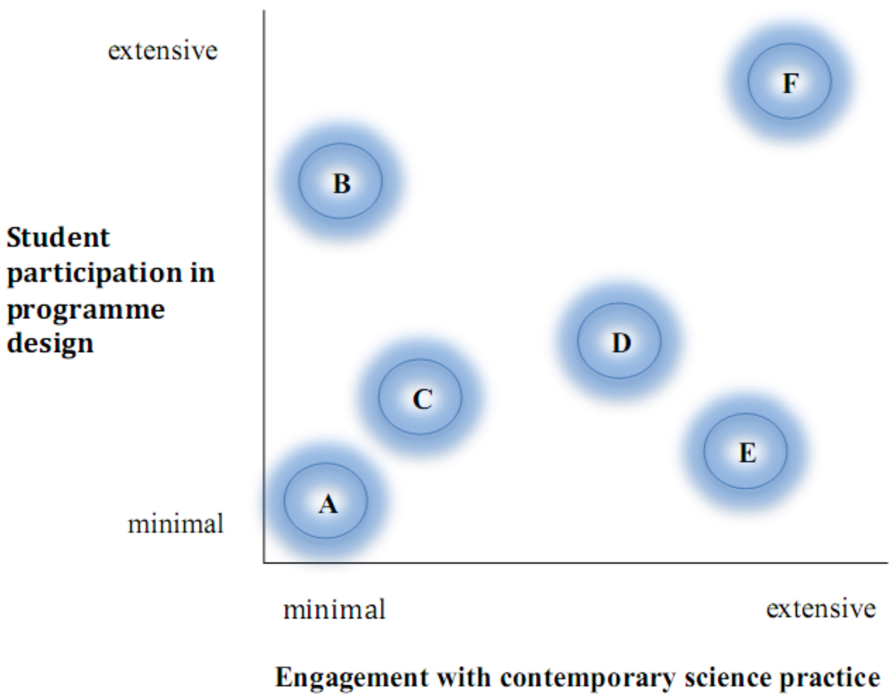
Some things, like curriculum and assessment, are just not up for grabs. But what *is* up for grabs is how the learning takes place.

WHAT DO <u>YOU</u> THINK ABOUT THESE IDEAS?

What makes science learning future-oriented?

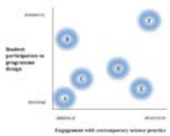
The framework below represents **one way** of thinking about future-oriented science education. It prioritises a couple of key ideas, as indicated by the following assumptions:

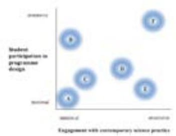
1. School science that is relevant and engaging should enable students to be actively involved in making decisions about learning. This does not downplay the important role of the teacher or the curriculum. However, it recognises the value of designing science learning experiences that connect with, and spark off from, students' knowledge, experiences and interests.
2. School science that meets the needs of students in the "knowledge age" needs to engage with contemporary scientific practice, enabling students to gain insights into science as a complex, multidisciplinary endeavour addressing real-world questions.



Classroom programmes—whether single activities or whole units of work—can be plotted on the framework depending on the level of input students have had in terms of the programme design and the ways in which the students engage during their learning with contemporary science practice. In doing this, a range of classroom scenarios can be considered (see table below).

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 science 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 science practice.	After learning about weather processes on earth, junior secondary students choose a topic for further research. Many choose planets 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 science 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 regarding 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 (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 science 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 teachers and students access relevant experts? What aspects of the nature of science can be identified in the students’ work?

Questions:

- 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?
- Does allowing students to have input into the design of the science education programme take away from the role of the teacher in selecting learning objectives and the best tools and activities to support learning?
- Do students *want* to have input into programme design? How can expectations around this be established?
- What knowledge do teachers need about the nature of contemporary science 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?
- What school structures are needed in order to enact different positions of the framework?

How can we use digital technologies to support science learning?

Schools invest significant amounts in digital infrastructure and an increasing number are encouraging or even requiring students to have their own digital devices in the classroom.

This reflects a widespread view that digital technologies can support learning. Indeed, there are many ways in which *science* learning can be enhanced. For example:

- 3-D animations and simulations can help make abstract concepts more visible.
- Apps can allow the easy manipulation of variables and formulae.
- Digital probes and motion sensors can collect accurate data systematically.
- Virtual labs or field trips give more ready access to laboratory or industry processes.
- Virtual networking enables students to connect and collaborate with each other and others, including scientists.
- Up-to-date scientific understanding can be accessed and shared.
- Data can be accessed or published online, collated, interrogated and interpreted.

If you take things like group work, people have always been able to write or develop something on paper. The thing is they can do it easier now because they don't have to be together. You haven't changed the fundamental purpose of what you're doing. You've just maybe made it easier.

Schools are becoming more and more irrelevant to students. Their lives are spent online. They walk out of school, they turn onto Facebook, they are constantly communicating with friends. They come into school and they sit in rows and they turn off electronic devices. So the relevance of school is decreasing. What you do in school is what happens in school. The real life is out there. We need to turn that around.

Animations are a huge breakthrough. They are perfect for chemistry. They're the one thing I could not do in any other way. In physics we use motion sensors.

Questions:

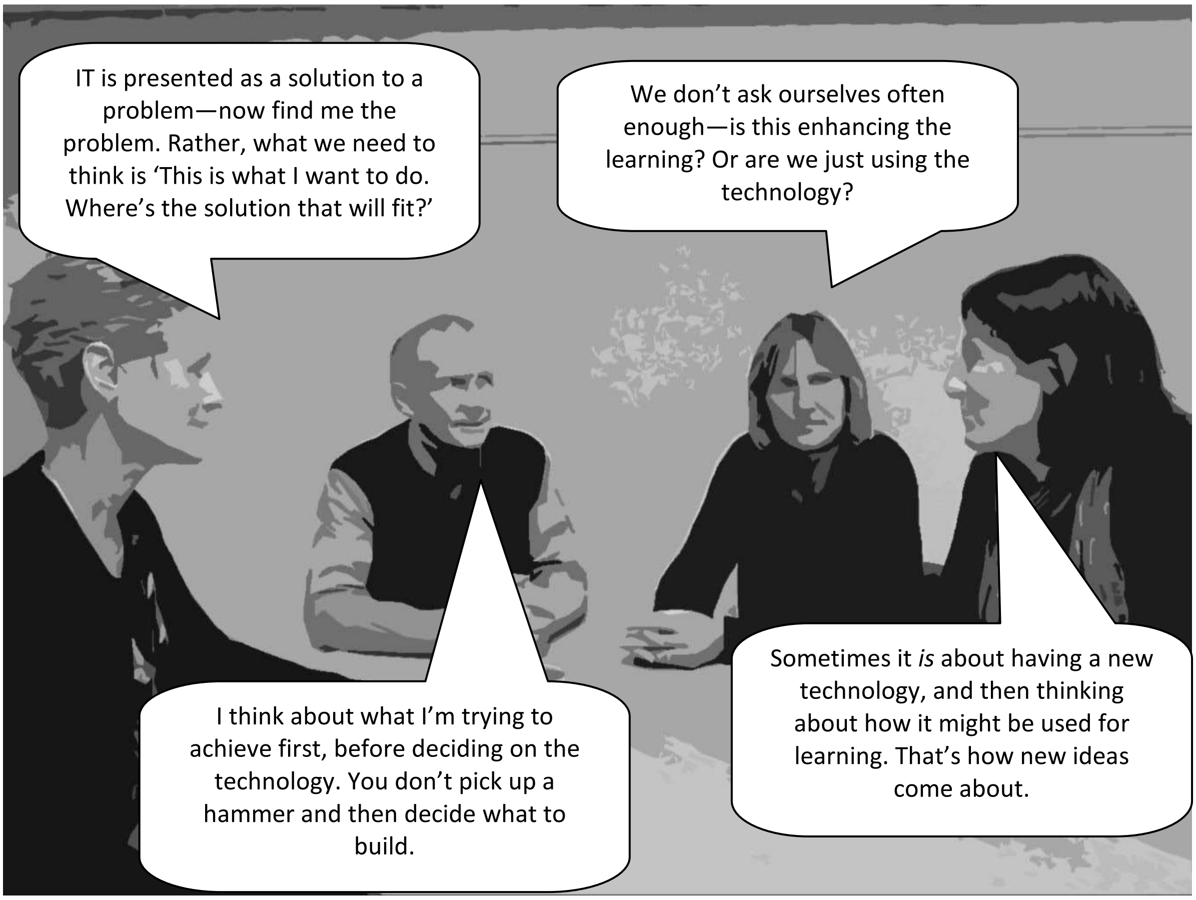
- Have we fully realised the potential of digital technology to support future-oriented science learning?
- What could help us think our way forward?

There has to be a strong connection between the classroom use and the outside use. They won't use the app unless they use it at school. Unless it's embedded in the classroom programme and it's of value to the learning, then it's useless outside the classroom.

All learning depends on whether the kid wants to learn or not—whether they are interested, inspired and so on. And one of the functions of IT is that it can provide that for some kids. And the right sort of IT will help a lot of kids. But there are a lot of other ways that you have to inspire kids, and that's not going to stop just because of IT.

ICT + kids + Ultrafast Broadband does not automatically equal student learning.

Finding tools for a purpose, or a purpose for the tools?



WHAT DO <u>YOU</u> THINK ABOUT THESE IDEAS?

Four ways digital technologies could radically transform school science learning

It can be difficult to imagine how future science teaching, learning, curriculum and assessment might differ from what we are used to seeing in schools today.

When our expert groups of teachers, scientists and software engineers got together, some thought about things that could be done "tomorrow" (with the right resources and enough time to plan and play), while others let their imaginations drift towards possibilities that might be very difficult to do right now, but could perhaps be possible in the near future.

The discussions raised four big ideas that have the potential to radically transform school science learning. Rather than focusing on *specific* digital tools or technologies or *specific* aspects of science that learners might engage with, this section metaphorically "flies kites" about ways that ubiquitous digital technologies might deeply change some of our approaches to school learning.

There are many other possibilities for the future and we do not claim to have identified all, nor even the most likely, possibilities—these are just four ideas to begin with. Our four ideas focus on:

1. Ubiquitous access to resources
2. Ubiquitous connections into the local and global community
3. An "open" curriculum
4. Leapfrogging learners into complex knowledge

Idea 1: Ubiquitous access to resources

Imagine

…a school where ubiquitous Internet connectivity and Internet-enabled devices provide access to an almost limitless range of digital resources. These might include:

- digital content and tools specifically designed for science learning, or any other digital content from the vast pool of human knowledge currently accessible through the Internet
- tools for doing things that were almost impossible to do in the past, like working with enormous datasets, or generating visualisations to represent things that could previously only be described, imagined or simplified into static two-dimensional representations
- tools for creating, sharing, building, adapting, remixing, repurposing and transforming knowledge
- tools for communicating with anyone else connected to the Internet (see "Ubiquitous connections", discussed next)
- tools that enable information to flow from the physical world to the digital world and vice versa
- tools that haven't yet been developed—who knows what these could enable people to do.

The hype

Theoretically in this scenario, learning would only be limited by time, and learners' and teachers' ability to imagine how to use the available resources productively to support learning. Learning opportunities could be personalised to the needs, interests and progress of individual learners, or groups of learners working together on a science learning project or activity.

This **doesn't** mean that it should be left to learners to sift through and decide how to make use of all these resources. It **does** mean that learning how to find and productively engage with these resources would need to be part of what students learn *as they learn science*.

Teachers would need to be empowered technology users who can help learners identify what they need, how to use the resources available to them and what to do when they aren't sure what to do next.

The reality

Simply having the *potential* to access limitless resources to support learning isn't sufficient. Aside from current challenges including reliable access to high-speed Internet and the affordability of digital devices, there are many reasons why the sheer abundance of useful science knowledge and tools amassed on the Internet won't, on their own, transform school science learning. For one thing, there is already so much out

there it is “too big to know”.[5] Learners and teachers need purposeful *reasons* to find and use these tools and resources, and they need to know *how* to find them and use them when they might need them. School science learning is also framed by curriculum and assessment decisions that often emphasise learners acquiring predetermined areas of science content knowledge. Digital resources can certainly help learners to access and understand this knowledge, but these resources can *also* provide a powerful means for learners—with support—to engage in more open-ended inquiry approaches, identifying and pursuing science questions for research and development, connecting with others, testing ideas and exploring and creating new knowledge.

How could this start?

Teachers, learners and researchers collaborating to explore new possibilities and share their learning

Science teachers and learners need opportunities to try new ideas and explore the possibilities enabled through ICT—particularly as the technologies and resources available will continue to change over time! The two small New Zealand studies described below illustrate this point.

Augmenting primary teaching and learning science through ICT

Researchers worked with two primary science teachers and their Years 7 and 8 students over 2 years to explore how teachers used digital tools—including interactive whiteboards, the Internet and digital cameras—to support student interest, motivation, expression of science ideas and understanding. Teachers used visual resources like videos to prepare for science activities (YouTube clips) or reflect on learning (student-generated video clips). Videos that provided time lapse were also used to follow up on practical science investigations. Students also used videos to document and record practical work. Digital photos were used to record activities but also to provide visual evidence for concepts that were new to learn and helped to bridge ideas with new vocabulary. The research underscored the importance of “sandpit time” for learners and teachers. Teachers needed this time to familiarise themselves with the technology and consider where and when it was used to support the teaching and learning of scientific ideas. Students needed sandpit time and reflection opportunities to become familiar with and capable of using digital tools independently and appropriately. Actively reflecting on ICT use also helped the students to articulate their learning.

To learn more about this research, see:
www.tlri.org.nz/sites/default/files/projects/9271_otrel-cass-summaryreport.pdf

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[5] See David Weinberger’s 2007 book *Too Big to Know: Rethinking knowledge now that the facts aren’t the facts, experts are everywhere, and the smartest person in the room is the room*. New York: Basic Books.

Networked inquiry learning in secondary science classrooms

This research project aimed to understand and explore the ways electronically networked (e-networked) tools could support authentic science inquiry in junior secondary classrooms. Teachers in this study considered the use of e-networked tools to be advantageous in supporting all aspects of the science inquiry process including posing questions, initiating investigations, collecting and analysing data and reflecting on and communicating findings. They made use of different tools at various points of the inquiry cycle in support of different goals.

Examples of e-networked tools that provided opportunities for students to access, investigate, share, co-construct and communicate science ideas were:

- online information searches using search engines, Webquests, YouTube videos and mobile devices—to access ideas and resources, students also created YouTube videos and websites to communicate ideas
- online post-it notes such as the Wallwisher—for students to share ideas and questions
- Moodle forums—to facilitate class discussions and understanding of a topic
- Skype and email—for students to ask questions and discuss developing science ideas with scientists
- online presentation tools such as Google PowerPoint, Prezi and Glogster—to co-construct and communicate inquiry findings.

The research concluded that e-networked tools can support students to exercise agency, access and share their own and others' input and access a wide range of sources of information and resources for meaning making. By progressively opening up the inquiry cycle, teachers enabled students to exercise greater agency. The researchers suggested that school management can support teachers and students in e-networked inquiry practices by investing in robust networking platforms, adopting policies that encourage productive e-networked inquiry tool use and establishing flexible curriculum and assessment structures.

To learn more about this research, see: http://www.tlri.org.nz/tlri-research/research-progress/school-sector/networked-inquiry-learning-secondary-science

Knowing what's out there

The number of online resources grows every day. The science community is sharing new knowledge. Educational technologists are promoting their tools and resources. Teachers are sharing their lesson ideas, links and resources, enthusiasm, questions and wonderings. Some universities are putting their whole course offering online. Even students are contributing to the wealth of knowledge on the Web. If it feels impossible to keep up with all of this—that's because it is! It can be useful to seek inspiration from sites that aggregate resources and ideas for e-in-science teaching. For example:

www.vln.school.nz/scienceonline.tki.org.nz www.sciencelearn.org.nz
digitaltechnologies.net.nz www.coursera.org www.khanacademy.org
ed.ted.com/lessons ocw.mit.edu/courses/materials-science-and-engineering/index.htm
www.sciencedaily.com

Idea 2: Ubiquitous connections into the local and global community

Imagine

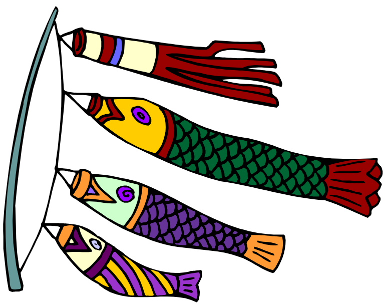
…a school where students and teachers can connect with almost anyone else, locally and globally, through online chats, video- and audio-conferencing, etc. Learners could interact with knowledgeable experts, and share their learning work with interested others.

The hype

Theoretically, learners would not only have their teachers—they would have access to a wide range of people with different knowledge, expertise and experiences who might be able and willing to participate and contribute to students' learning—as well as seeing the benefits they gain from their involvement with these young people. Whether these people were local or international, adults or children, scientists, businesspeople, civic leaders or members of the community, ICT could alleviate issues of distance and cost that might otherwise prohibit the involvement of so many other people in students' learning. Instead, the involvement of many people would become *the norm*.

The reality

As with "ubiquitous resources", we know that simply having the capability to connect with a variety of people beyond the school walls does not mean it will happen. The ability and interest to connect depends heavily on the presence of *relationships* that bind people together for purposeful reasons. Teachers and learners need to know who they could connect to—and why. Conversely, those people need the time, interest and capability to usefully connect with students and teachers to support learning. Schools are already connecting with the science community in various ways that support learning, and research on current engagement initiatives suggests there is scope for strengthening and enabling more of these kinds of connections, and working on coherent strategies to enable these connections to support future-oriented science learning.[6] Technologies can radically reduce the difficulty of sustaining communications and connections, but *on their own* they are unlikely to enable schools and the wider community to develop and sustain the kinds of relationships that enable learners to tap into the human resources of the local and global community. This underscores the importance of another variable: *time*. Learners, teachers and those with whom they might connect need time—and commitment—to make and to sustain these learning relationships.



[6] http://scienceonline.tki.org.nz/New-resources-to-support-science-education

How could this start?

Our expert groups brainstormed a few ideas using existing technologies that could be a small step towards more ubiquitous connections between schools, the science community and the wider community.

The Hangout

In this idea, schools could easily connect to Hangouts (Google Hangouts are online video- and voice-enabled chat features) with people in the science community, or even people at other schools. These forms of low-cost multimedia communication can create a mindshift in how we think about connecting with others through time and space. For example, unlike picking up a phone or sending a message every time communication is needed, office workers today might keep a window open all day to continuously collaborate with colleagues in remote locations (as is common for employees at Google, for example), meaning they are as accessible as if they were sitting next to each other. What if this sense of ubiquitous connection was transferred and normalised in schools? Could those who already provide science outreach support to schools supplement or replace some of their physical visits to schools with scheduled times they would be available online? Could learners, teachers and people in the wider community get used to the idea of being able to connect and communicate with a variety of people in a more free-flowing, as-needed basis?

The science community engagement social network

In this idea, teachers in regional clusters would set up an open group on an existing widely-used social network (e.g., Facebook) where they, their students or anyone else could post questions or requests for advice, ideas or resources from the science community or wider community.

> On the group would be the schools, any institutions that have educational outreach officers and any other organisations or institutions that want to be…people who are willing and inclined and able to contribute to schools—from the big players to the local mechanic. There would be guidelines about how to use the page… For example, I as a teacher might go on there and say 'Hi I'm going to teach a lesson on mechanics, it would be great if an electrician or someone who knows about xx could come in and help or give me some ideas.' You would also post acknowledgements to the people and group that have assisted your school…

The rationale for creating networks on existing social media platforms, whatever those might be, is that:

> …we're not creating 'another thing' for teachers to log into, we're making better use of something that is already there, and we don't need to ask anyone to build it for us, like we would if we were creating a whole new digital network. It would take a little effort to set up but hopefully would then be self-perpetuating.

Idea 3: An "open" curriculum

Imagine…

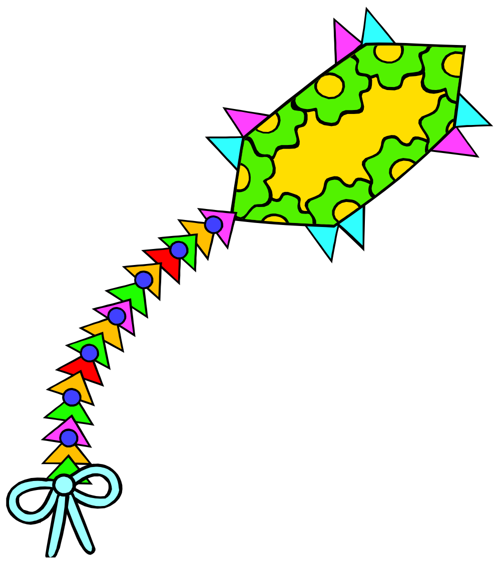
…a curriculum that constantly evolves through the input of many different people: teachers, subject experts, learners and people with the expertise, time and interest to contribute their knowledge and support to help learners engage with the changing dynamics of science in the world.

The hype

Words like "open source" and "open content" are increasingly applied in a range of contexts, from software development, to education, to the design of government services. Although there are different ideas about what these words mean, they connote ideas about transparency, and the freedom and ability for many people to contribute to, share, re-use and re-invent creative works or information which is accessible in the public domain.[7] One familiar example is Wikipedia—a free online encyclopaedia that anyone can edit. Not only can users view the products of many contributors' work, they can also see who made revisions, when these were made and any disputes over content—and they can contribute themselves. What if these same ideas of openness were applied to the design of curriculum for school learners?

The reality

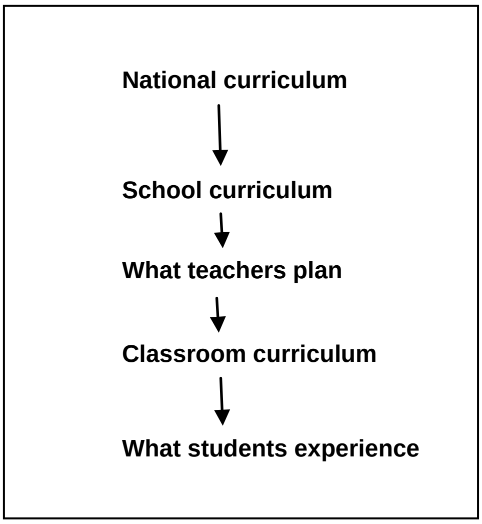
The idea of an open curriculum may seem radical but, in a sense, the curriculum is *already* quite "open". When people say "curriculum" they often mean the national curriculum (e.g., *The New Zealand Curriculum*). However, learners don't learn directly from this document; it must be interpreted by educators and translated into experiences that support learning for students.[8] In this process there are already many decisions and variables that shape what any learner will experience as the "curriculum".



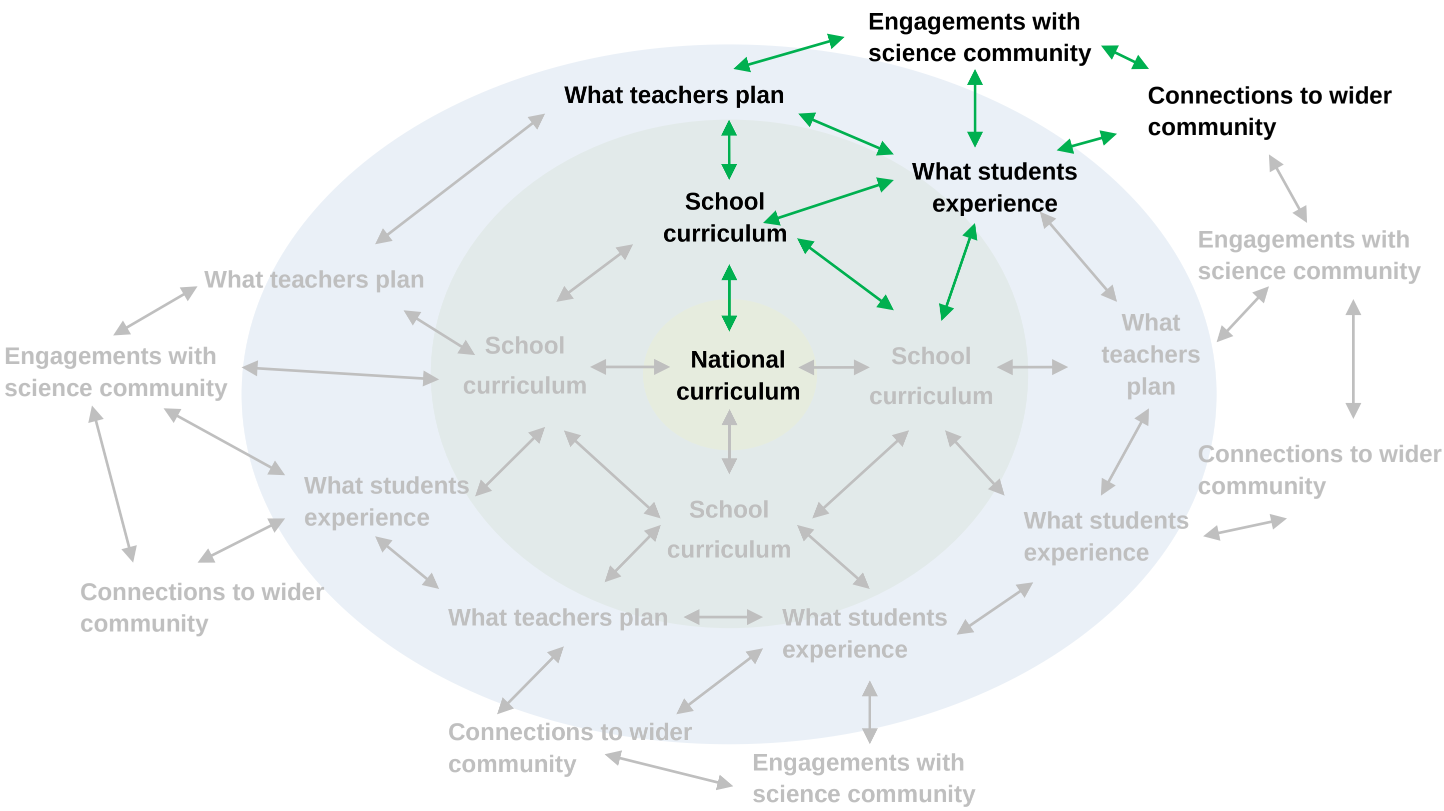
[7] Here is one interesting perspective on the meaning of "open" http://googleblog.blogspot.co.nz/2009/12/meaning-of-open.html

[8] See Bolstad, R. (2006). Who should decide the curriculum? *set: Research Information for Teachers*, *1*, 33–34. www.nzcer.org.nz/nzcerpress/set/articles/who-should-decide-curriculum

Over the past few decades we have become used to the idea of a curriculum not as a prescription of content, but a *framework* which sets out in broad terms the goals for learning, with significant flexibility for schools and teachers to adapt and tailor teaching and learning to meet the needs of their learners and communities. We could think about this as a process of "designing down"—beginning with the framework of the curriculum, many different users (teachers) use the curriculum and other supporting resources, and make decisions that result in teaching and learning experiences for students (shown to the right).



What if the insights and experiences of all these different users could also feed back into the ongoing evolution of the school curriculum *as a shared knowledge commons*? Could the input of teachers, learners, the science community and the wider community also help "design upwards", or even develop curriculum laterally through sharing of knowledge across and between schools, teachers, learners and communities? The diagram below represents this idea with a network of feedback loops and interconnections between the users' experiences and connections and the curriculum.



It is worth noting that *The New Zealand Curriculum* that we have today *is already* the result of many people's inputs and feedback. Many contributors helped to shape different parts of the curriculum, and a draft version was circulated in schools for feedback and consultation in the year prior to the release of the finished document. The idea of a digitally "open" curriculum simply invites us to think about what it could mean to take this iterative and consultative process a little further, make feedback loops a little more visible and perhaps make "curriculum content" a little more modifiable.

How could this start?

Beta-launching?

One expert group pointed to the recent development of an online guide for teaching computer science to secondary students which was beta released in 2012—meaning that it was available for learners and teachers to use even though it was not yet fully complete. The guide is a bit like an online textbook and, like many curriculum documents and supporting resources, its development has involved bringing together groups of teachers for consultation and feedback. Online users can clearly see that there are still chapters and sections yet to be completed. They can also fill in an online feedback form for the developers that might contribute to a better revised version. However, at present users can not directly add to or change the resource, nor is user feedback visible to all other users. Might this change in the future? Could a curriculum or resource in the future include modifiable elements? Could teachers and learners get used to interacting electronically with experts in different fields of knowledge? Could the products of their interactions be easily visible, electronically, to other interested users, and add back into the knowledge commons used by other learners and teachers?

See: http://www.cosc.canterbury.ac.nz/csfieldguide/student/index.html

A "blue-skies research" networks for schools?

Our expert group favoured the idea of supporting learners to undertake what they were calling "blue-skies research" or "research and development" activities. They felt this could support learners to develop the dispositions, as well as the skills, knowledge and capabilities that might empower them to investigate questions that their teachers or even other scientists may not yet have answers to. These could include questions of personal interest or relevance for the student, his or her community or any people or groups with whom learners might form a productive learning relationship. Could networks (both digital and nondigital) support and encourage learners to explore their own questions, or share questions with one another and a wider network, as a routine aspect of school science education?

Idea 4: Leapfrogging learners into complex knowledge, and complex ways of *working with knowledge*

Imagine…

What if school science learning crossed disciplinary boundaries as easily and often as science projects and practice in the world outside school?

Throughout this research, people pointed out that the way school curriculum knowledge is divided and "packaged" into disciplines and sub-disciplines tends to underplay the way that different kinds of knowledge intersect and interact in real-world science situations. What if learners could be easily bridged directly into working with knowledge that crosses disciplinary boundaries, while *also* developing deep disciplinary knowledge?

For example, digital technologies have fundamentally reshaped many aspects of our daily lives and routines. They are a core part of knowledge work across all disciplines and professions today. But what about the people who work with and develop these technologies—computer scientists, software engineers and others? How do they think and work? How do—and will—these ways of thinking and working impact the way *science* operates in the world? If disciplines like computer science and software engineering are not strongly present in schools, students—and teachers—may be unaware of what they are all about, and may miss out on opportunities to find their way into these fields, or they may miss chances to see how these fields are influencing, impacting and interconnecting with contemporary science practice. If there was more crossover between these and other disciplines—including humanities, social science, the arts—might our learners be in a better position to engage with cutting-edge science research and development?

The hype

Digital technologies *already* enable us to do many different things that we couldn't otherwise easily do. We know they have changed many of our routine activities and behaviours, and some people would go further in saying that they also change some of the ways in which we *think*. There is plenty of hyperbole about young people and technology (vis-à-vis the "digital generation"). However, behind the hype there are some important questions to consider. Might today's learners be capable of thinking in different ways *because of*, or *in conjunction with*, their experiences of ubiquitous digital technologies? Might we be missing opportunities to take advantage of these new capabilities? Could we use these capabilities, and digital technologies, to "leapfrog" learners into knowledge and practices that might have previously been thought too complex or inaccessible?

The reality

Of the four ideas presented in this section, this one is perhaps the most "out there". It suggests we might need to radically rethink some of our assumptions, not only of *how* learners might gain science knowledge, but also what *kinds* of knowledge they ought to be engaging with. It opens the door to thinking creatively about how science learning might, as a routine matter of course, intersect with a variety of other areas of knowledge specialisation, not just for learners at postgraduate level, but for younger and older school learners as well. This in turn raises questions of who else (science) teachers might need to collaborate with in order to support these cross-disciplinary knowledge opportunities.

How could this start?

Unplugged education

An enjoyable twist in our thinking occurred when one of our expert participants sent us an article called "Unplugged education" (see reference below), which described teaching approaches that aimed to leapfrog learners directly into disciplinary knowledge and practice (such as statistics, music and computer science) by deliberately bypassing some of the hurdles created by having to first learn certain "fundamentals", such as notation or vocabulary, that are typically taught *before* learners can engage with the more complex dimensions of the discipline. The computer science (CS) example was particularly interesting. As the authors point out:

> While programming is a fundamental skill for CS, learning a language for giving instructions to a computer is not the main point of the discipline, and it typically takes a year or more for students to become confident programmers. Thus students spend a lot of time at the machine learning to give it instructions, before they find out much about what sort of instructions they might want to give it!...
>
> The CS Unplugged project…grew as a reaction to this problem—not only was there a barrier in the form of having to learn to program (or in fact, having access to a computer), but the way computers were being used for routine tasks such as word processing actually deterred students from exploring CS as a subject… To cut through this, CS Unplugged does away with the computer altogether, and gives the students games, puzzles and magic tricks that engage them in real CS problem solving. (Bell et al., 2012, pp. 1–2)

Continues on the next page…

Unplugged education continued…

These activities:

> provide students with such experiences in many areas of CS including error correction, compression, encryption, graph theory, sorting and searching algorithms, human-computer interaction and artificial intelligence. The point of the exercises is not to teach solutions to these problems, but to enable students to experience finding solutions themselves. Many end up discovering algorithms that are known in CS, but more importantly, **they are exercising the kind of thinking required for CS**, including developing a healthy curiosity. (Bell et al., 2012, p. 2)

We think Bell et al.'s unplugged education example is provocative and exciting. If a discipline like computer science can be taught "unplugged", with the explicit intention that some of the deeper thinking aspects of the discipline can thus move into the foreground, could the same thinking be applied to e-in-science?

For us, this question opens up a new way of thinking about the "e" in "e-in-science". Rather than thinking in terms of what kinds of *digital tools or technologies* teachers or learners might use in the course of their science learning, the "unplugged" scenario offers a way to think about how to bring in "e" *ways of thinking* into science learning. This might be about CS ways of thinking, software engineering ways of thinking, social media ways of thinking or any other ways of thinking that are connected with contemporary use of digital technology.

Whether the tools used to do this kind of learning in the classroom are electronic or otherwise becomes secondary to the question of what kinds of ideas, ways of working, ways of thinking, relationships and so on are in the foreground of learning experiences, and why.

Reference

Bell, T., Fellows, M., Rosamond, F., Bell, J., & Marghitu, D. (2012, June). *Unplugging education: Removing barriers to engaging with new disciplines.* Berlin, Germany: Conference of the Society for Design and Process Science (SDPS).

What if…?

What if resources weren't seen as a constraint?

What are the beliefs that we have about teaching that we don't even question?…that you go through school and you do well, then you go to university and do well and you get an MA, then you go on to a PhD, and somewhere between the MA and the PhD you're allowed to ask your own questions. We assume you can't do that kind of thinking, that kind of questioning, that kind of research, at a secondary school level.

It's just one of these things that we all just accept as true—even if it isn't.

Yes. Another thing that I hear from people is the belief that you need a whole lot of resources to do it. They say 'Oh, it's different for you [as an engineer] because you have a lot of resources.' But my boss might say something like, 'I need you to make one of these, and we have a broken toaster, and some other things, and oh by the way you have two weeks. You can't spend any money but I want you to spend some time making something with duct tape, just to see if it's even going in the right direction.' You want to have that kind of mindset in schools.

That was one of the criticisms I got when I was having my students doing their own inquiries. I was asked 'Where are the resources going to come from, who is going to pay for this?' But it was completely irrelevant—we were building things out of cardboard. We built an airplane out of cardboard. And this year they are going to get an old bicycle wheel and a pedal, I have a student who is interested in making a model of the space station…

You can source a lot of things like that in the community—you have to create the need first, not the resources. You have to create the need to engage with the community. It's not about, 'Let's go to a lab and see what they are doing in the lab.' It's 'I want to find this out. Oh, they have that apparatus here, or they have that workshop there.' When you have the incentive to do it, the practicalities come into place afterward.

What can we do within our current curriculum?

The New Zealand Curriculum currently offers a broad framework within which teachers can support students to develop some of the additional skills and dispositions that will be needed to contribute effectively to the complex challenges—and opportunities—of the 21st century.

Of course, this is not a simple task.

- Schools need access to the expertise and resources of the science community and wider community.
- Students' funds of knowledge (the knowledge and ways of thinking that students bring with them into the classroom) need to be acknowledged, built on and valued.
- The assessment system and the community expectations (including schools, parents, universities) need to support with 21st century learning goals.
- Examples of innovative practice need to be celebrated and shared.

> The Nature of Science strand gives me so much scope when planning a unit for my Year 5 students.

> We're playing around with different combinations of achievement standards to create new kinds of science courses.

> Our school is placing a strong emphasis on the principles in the *Curriculum*, especially *cultural diversity* and *inclusion*. We're required to think about this each time we plan a unit.

Questions:

- Could school science learning focus on developing science understanding through interactions between people (learners, teachers, the science community and the wider community) and knowledge (scientific data, science ways of problem solving, science contexts in the community)?
- How can we work to better include our students' and our communities' interests and values in our science programmes?
- Are students, teachers, schools, the science community and the wider community ready to work in these ways?
- Are our curriculum and assessment systems adaptable to these ways of learning and teaching?

What makes a future-oriented science teacher?

Our research suggests future-oriented science teachers have many of the following characteristics:[9]

- They enjoy science and the possibilities that it offers to all students. This includes helping students develop a scientific way of understanding their world.
- They seek out and embrace opportunities for their own ongoing learning. They wonder "What if?" and are open to experimentation and finding new ways of doing things.
- They have a robust understanding of the nature of science as a dynamic, cultural enterprise. They also understand the purposes of school science in the context in which they are teaching (e.g., primary, junior secondary, senior secondary).
- They make decisions based on what they perceive to be the "big picture" of science learning—that is, their focus is on the end purposes for learning science, not just on "covering" particular bits of science teaching.
- They reflect critically on their classroom programmes. This includes:
    - the learning objectives and why these are important to students both while they are at school and for their future lives
    - what students are capable of emotionally and cognitively, and the knowledge they bring with them into the classroom
    - which tools and activities enhance learning, recognising that these might be different for different students
    - classroom interactions that will support learning, including encouraging students' metacognitive awareness and self-efficacy (belief in their abilities)
    - how learning will be assessed, and what the purpose of this assessment will be (e.g., to guide ongoing learning or to conclude a unit of work and provide summative data).

> It takes a lot of time and effort, but I do it for the students.

> 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.

> Our pedagogy needs to move to putting the student at the centre. Because the student has such easy access to up-to-date information, that in itself should catalyse some changes in what we do.

[9] Also relevant here is the Ministry of Education's Best Evidence Synthesis Programme report *Quality Teaching for Diverse Students in Schooling: Best evidence synthesis*, which identifies 10 generic characteristics of quality teaching for diverse students: http://www.educationcounts.govt.nz/__data/assets/pdf_file/0019/7705/BES-quality-teaching-diverse-students.pdf

- They explore their thinking with others in professional conversations.
- They create a network of relationships that allow them access to relevant knowledge and resources. This could include the local community as well as contacts specifically in science-related areas of work.
- They have robust digital literacy and enjoy finding out about new digital technologies and how they might be used in the classroom.
- They are resilient, determined and motivated—sustaining innovative practice is challenging and time consuming.

As teacher in charge of ICT at my school, it's my job to help others integrate ICTs in their teaching. It really helps that I come at it from a pedagogical angle—that I know about computers, but especially that I know about teaching.

What can school leaders do?

Shifts in school culture will require a shared vision of the purposes of using digital technologies. School leaders can support teachers by encouraging thoughtful risk taking and ongoing reflection. School leaders also need to make strategic decisions. Often this involves resourcing—purchasing hardware and software, paying for technical support and prioritising professional learning opportunities for staff.[10]

My school has a culture of valuing deep learning. Summative assessment criteria are seen as only one part of students' school learning experiences. The culture of learning also stretches to staff. Professional discussions are expected and valued.

You learn more about what you can do through PD, but then you want the infrastructure to be able to do it.

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.

Questions:

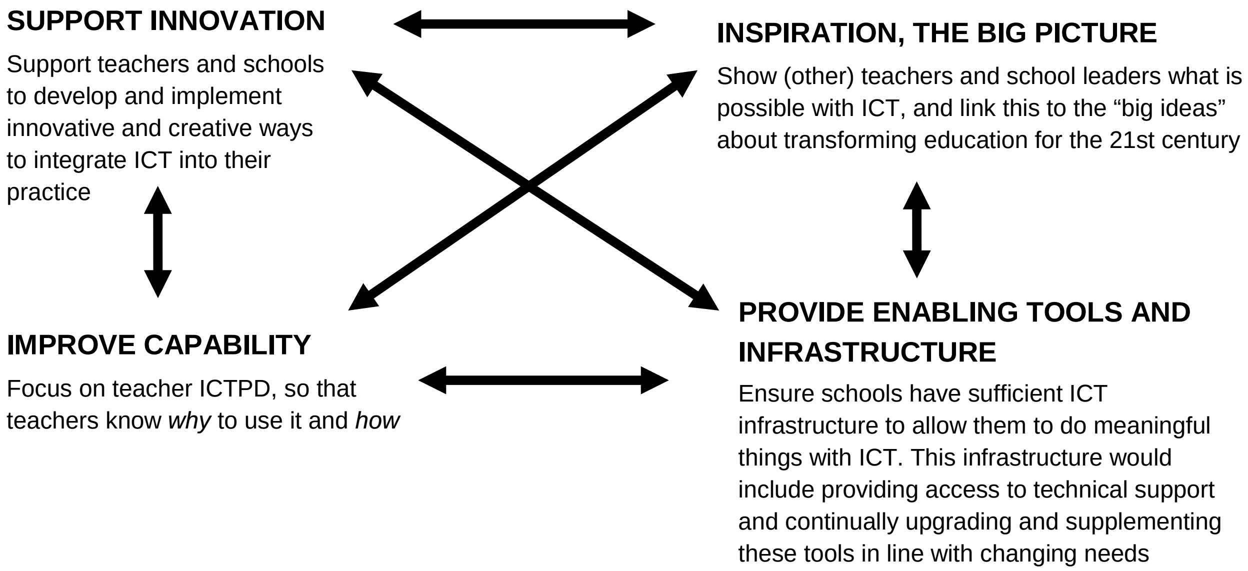
- Who leads innovation in your school, and how are they supported?
- How is innovation celebrated and shared?
- Do you learn from and share ideas with other schools in your networks?

[10] New Zealand research on the Laptops for Teachers provides recommendations for school leaders. (See page 53.) www.educationcounts.govt.nz/__data/assets/pdf_file/0006/22947/879_TELA_Y9-13-v2.pdf

What are the implications for school structures and the wider system?

Thinking about what education might look like in the future includes thinking critically about digital technologies and how they might be used—to increase student engagement, enhance learning and maybe even change what and how learning occurs. Shifts in school-wide use of digital technologies need to be supported by structures within schools and across the wider system. Research indicates that educational ICT innovation requires a combination of linked strategies, including those shown in the figure below.

Linked strategies needed to support educational ICT innovations[11]



Did you know…

The Ministry of Education's previous research reports on ICT and e-learning in education are available to download for free: www.educationcounts.govt.nz/publications/ict

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[11] Reproduced from Bolstad, R., & Gilbert, J. (2012). *Supporting future-oriented learning and teaching: A New Zealand perspective.* Wellington: Ministry of Education. www.educationcounts.govt.nz/publications/schooling/supporting-future-oriented-learning-and-teaching-a-new-zealand-perspective

A final word from the authors

Thinking about the future of science education is not easy, but it is important. While aspects of curriculum and assessment are unlikely to change dramatically in the near future, we can change what science learning looks like in our classrooms. We can involve students in making decisions about how they learn. We can and should work to ensure that school science reflects contemporary science practice. We can think about what roles digital technologies might play in this. Finally, we can wonder, we can be creative, we can take risks.

Teaching is a complex task that requires commitment, courage, tenacity and large amounts of energy. One of the rewards is knowing that students are better equipped for making thoughtful, informed decisions because of time they have spent in your classroom.

Suggestions for further reading

Reference details and links to further reading are footnoted throughout this document. Below are three readings that are particularly useful for teachers and school leaders who are interested in the future of science education.

Inspired by science was a paper commissioned by the Royal Society of New Zealand and the Prime Minister's Chief Science Advisor in conjunction with the Ministry of Research, Science and Technology to encourage debate on how better to engage students with science. Available from: www.nzcer.org.nz/system/files/inspired-by-science.pdf

Principles and big ideas of science education is an online report developed by 10 international experts in science education. It argues that students should be helped to develop "big ideas" *of* science and *about* science that will enable them to understand and make informed decisions about science. Available from: www.ase.org.uk/documents/principles-and-big-ideas-of-science-education/

Jane Gilbert's (2012) analysis of contemporary science and what this might mean for school science was published in *New Zealand Science Teacher*, *131*, 5–9 and is a provocative read. Available from: www.nzcer.org.nz/system/files/science-2-0-and-school-science.pdf