Creating digital age learners through school ICT projects: What can the Tech Angels project teach us?

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Abstract

This article surveys recent work on school ICT projects. It looks at the ideas that are informing this work and surveys some of the strategies being used in the drive to turn schools into "ICT-rich learning environments". In order to illustrate how these ideas play out in "real-world" situations, the article also profiles one New Zealand school-based ICT initiative as a case study—the Tech Angels project at Wellington Girls' College, focussing in particular on how this school's experiences can help other schools considering setting up similar programmes.

Introduction

Over the last few years there has been a lot of talk about bringing New Zealand's education system into the digital age. Schools have invested significantly in ICT infrastructure and teacher professional development in ICT (from their operational grant and community fundraising), and there has been major new government spending in this area.[1] The government funding has supported many large and small school ICT projects and initiatives, including: the ICT professional development (ICT PD) clusters; the Digital Opportunities (DigiOps) initiatives; the Kaupapa ara Whakawhiti Mätauranga (KAWM) project; various online communities and videoconferencing clusters; and the laptops for teachers (TELA) scheme—to name just a few. These investments in school sector ICT are just a small part of an overall cross-sectoral drive to create a "digital future for all New Zealanders, using the power of ICT to enhance all aspects of our lives" (New Zealand Government, 2005, p. 3). The message is clear: New Zealand is moving towards a digital future, and the government expects schools to play a major role in shaping and supporting this future.

This article takes a closer look at the drive to create digital-age/21st-century learning in New Zealand schools. It begins by asking two fundamental questions. First, what are the "big ideas" that have underpinned school ICT investment? In other words, *why* is this investment necessary, and why is it thought to be a good idea? We outline four of the main arguments that are being used to support this drive, and suggest that these can be located along a continuum from minimal to radical change in current school practice. We then explore the extent to which these arguments are, educationally speaking, good ideas. Second, we look at the question of *how* schools might go about turning themselves into ICT-rich, "knowledge age" learning environments. We identify the common strategies that have been used overseas and in New Zealand schools, and consider how effective these strategies have been in promoting transformative and sustainable ICT-related changes in school practice. Finally, as a way of illustrating these ideas, we look at a case study of a New Zealand ICT initiative—the Tech Angels project at Wellington Girls' College. This project draws on—and exemplifies—many of the ideas explored in this article and raises some interesting questions. We conclude by considering some of the lessons we can learn from the Tech Angels initiative, looking in particular at what needs to be taken into account when developing ICT innovations in schools, and what this and similar projects need to do if they are to continue to develop.

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[1] In 2005–2006 the government will invest nearly $60 million in school ICT, an increase of nearly 1800 percent in the seven years since the 1998–1999 financial year (Mallard, 2005, 19 May).

What “big ideas” underpin the current investment in school ICT?

There are at least four different arguments that are being used to justify the recent major investment in school ICT. These are:

1. the “efficiency” argument;
2. the “community building/connect to the world” argument;
3. the “digital generation” argument; and
4. the “knowledge age/21st-century learning” argument.

Currently, most ICT initiatives are underpinned by a mixture of ideas taken from all of these. However, while all four arguments point to the necessity for major change in the way we do things in schools, they do this in very different ways. These four arguments have very different origins, are underpinned by very different value systems and, if taken to their logical conclusion, lead to very different outcomes. This mixing of conflicting ideas is entirely normal in educational contexts. Educational issues are invariably highly contested and politicised, and the solutions to educational problems are inevitably compromises that bring together ideas from many different sources.

In this case, however, the stakes are unusually high. School ICT projects require significant financial investment. They also require a significant commitment to change. Using digital technologies productively in schools requires a paradigm shift in educational thinking – by all stakeholders. If this investment is to be worthwhile, the ideas that are driving it need to be understood—and debated—by teachers, parents, students – and anyone else with an interest in what goes on in schools. For this reason, we think it is important to examine these four arguments closely, and to look at what it would mean if any one of the four was to be emphasised over the others. We begin this discussion with the argument that, in our view, is the *least* radical in terms of its implications for current school practice.

1. The “efficiency” argument

It is very common, when arguing for more investment in school ICT, to say that ICT helps teachers to work more efficiently or effectively, thus benefiting teachers, students, and schools. Because ICT makes communication and information management easier and more efficient in most other sectors—from farming to the film industry to global banking—it should, so the argument goes, do the same in schools. ICT allows school data (e.g., school reports, student achievement records, attendance and absenteeism records, and so on) to be collected and managed electronically, thereby streamlining teachers’ administrative work. ICT can help teachers collaborate and share teaching resources more effectively—for example, through shared online teaching and assessment resource banks or, as in several New Zealand videoconferencing initiatives, through the ability to share “expert” teachers among schools separated by distance and lacking capacity in particular curriculum areas. Within schools, shared electronic communication (such as a school email system, or school intranet) improves communication and information-

sharing among staff. It is, therefore, plain good sense to use ICT in schools, because it makes things so much easier and more cost effective.

This argument is the least radical of the four listed above, in that it involves only minimal changes to existing school practices. It does not challenge in any way the current curriculum, current pedagogical practices, and the assumptions that underlie them. If this argument is adopted as the *main* rationale for increasing ICT investment in schools, they are likely to remain more or less the same as they are now. Certain aspects of teachers' work—in particular, their administration work, their work with each other, and their access to teaching resources—could be streamlined: this is obviously a good thing. However, there is a downside. Teachers would need to spend time learning to use, and keeping up to date with, new technologies as they emerge. In the current school context, many teachers see the tasks ICT can help with as "necessary evils", marginal to their core work of working with students. As a result, they are unlikely to see the time needed to acquire and update ICT skills as being of benefit.

2. The "community building/connect to the world" argument

The second argument that is widely used to support ICT development in schools is that it builds community and connects schools to the world. In this view, ICT allows people to easily connect with each other in a range of different networked educational communities, and this is a good thing. While there is some overlap with the "efficiency" argument—since networking allows teachers to work more efficiently in some areas—the main emphasis of the "community building/connect to the world" argument is on ICT's potential for building new, different, and better *relationships*—between teachers, and between teachers, students, and people or resources outside traditional educational communities. Examples of strategies that arise from this argument include "online cluster" initiatives (where teachers/students/schools from different areas are networked to strengthen their relationships and share their learning) or "connect to the world" initiatives (where students and teachers use the Internet to connect to "real world" data or experts, or to go on "virtual field trips"). These activities, according to this view, can make classroom learning more relevant and meaningful.

The "community building/connect to the world" argument implies slightly more radical changes to current practice than the "efficiency" argument, because it introduces new ways to expand and enrich the curriculum, and because it implies that different kinds of pedagogy will evolve to fit the new modes of curriculum delivery. For example, teachers involved in the KAWM[2] online

[2] Kaupapa ara Whakawhiti Mätauranga was a series of initiatives that introduced a range of ICTs into various school clusters to: improve student achievement; improve school performance; strengthen school and community relationships; upgrade school ICT infrastructure; and improve teachers' professional capability through ICT. A key element of KAWM was the creation of a national online classroom across secondary schools (including Wharekura) using videoconferencing technologies.

classroom initiative found that familiar modes of teaching did not necessarily work well when they were teaching students at remote locations by videoconferencing (Waiti, 2005); these "e-teachers" had to experiment to find better teaching approaches.

Expanding and enriching the resources available to teachers and students is obviously a benefit, particularly for small schools in remote areas. Pedagogical change often happens as a result of approaches informed by this standpoint, and, when it does, is generally seen as being a good thing. However, exactly *why* it should be a good thing is not clear. The changes that occur are usually *ad hoc* responses—new content, new class groupings, or new methods of delivery—rather than attempts to develop new pedagogical principles. Pedagogical change is not, in fact, an essential part of the "community building/connect to the world" argument. Even more importantly, this argument does not specify *why* we might expect—or want—pedagogical change, nor does it help us to see the form(s) we might expect this change to take.

3. The "digital generation" argument

The third argument commonly put forward to justify investing in school ICT is based on the "digital generation" concept. According to this argument, *students* are demanding the shift to an ICT-rich learning environment. While students may not literally be demanding this, today's young people have ideas, experiences, and expectations of learning that are very different from those of their teachers. Today's school students are what Prensky (2001) calls "digital natives"—or, as Tapscott (1998) terms it, the "net generation". They have grown up in a digital-rich environment in which ICT—in the form of computers, the Internet, cellphones, personal game machines and mp3 players—is as normal and natural a part of their lives as books, pencils, bicycles, or soccer balls were to the previous generation. These early experiences with ICT are assumed to be formative, in that members of the digital generation think in ways that are new and qualitatively different from those of the previous generation. An important consequence of this, the argument goes, is that we need new methods of teaching and learning: the "old" ones just aren't going to work with the digital generation. To use Prensky's words, "today's students are no longer the people our educational system was designed to teach" (Prensky, 2001, p.1). Thus, if the educational system continues to *not* meet the needs of the digital generation, they may simply disengage from traditional school learning. This obviously has major implications, not only for students, but for schools, public education, and society in general.

There is a compelling element of truth to the "digital generation" argument, as anyone who has watched a 6-year-old sending text messages or a 10-year-old building a webpage will attest. However, it is easy to get carried away with this argument and suggest (for example) that the answer is as simple as teaching everything through video games, ipods, cellphones, and/or whatever other ICTs young people are using every day. In our opinion, however, this solution

misses the *educational* point. Before we discuss this, however, there is another aspect of the "digital generation" argument that we would like to address—its tendency, often based on generalisations from anecdotes like the examples above, to homogenise young people, implying that they all think and act in particular ways, As Sefton-Green (1998, p. 10) points out, "young people may not, in reality, be quite as *hyper-literate* as some theorists fantasize". While not denying that there have been significant social changes in the last couple of decades, he finds it "surprising that one social development, electronic technology, is being used to explain changes in a whole range of social domains—as if the nature of modern childhood could be attributed to a single cause" (p. 14), and suggests that much more research is needed to understand the "multiplicity of ways in which young people are utilizing and appropriating a range of new technologies in the making of youth culture in the digital age" (p. 2).

Some educators will want to argue that using video games, ipods or other digital-age devices in educational contexts is to capitulate to the "McDonaldisation" of education. This, they say, supports the multinational corporations that gave us these products, and for this reason alone these products are inappropriate in educational contexts. On the other hand, many educators see the use of digital-age devices in schools as a useful "marketing" tool for schools, arguing that these devices *are* appropriately used as a way of engaging the entertainment-oriented sensibilities of the digital generation. Others, for example, Oppenheimer (2003) and Cuban (2001), argue that such approaches, used uncritically, will "dumb down" the school curriculum with no obvious benefit in return, producing a generation of what Oppenheimer calls "flickering minds".

It seems to us that these responses to the "digital generation" argument are underpinned by the assumption that traditional curriculum and pedagogical practices do not *need* to (and *should* not) change to meet the needs of the digital generation. However, underlying the "digital generation" argument for investment in school ICT is the assumption that pedagogical change *is* necessary. In this respect this argument differs from the "efficiency" and "community building" arguments outlined above. However, there are some important gaps in the "digital generation" argument from an *educational* point of view.

The "digital generation" argument does not provide us with any grounds for deciding what the pedagogical change it implies should look like. *How* should what happens in classrooms change in response to the needs of the digital generation? Is engagement with young people and/or meeting their immediate needs *all* that matters? What about their long-term needs—or the needs of the wider community? Which aspects of traditional education do we want to keep, and which can be thrown away? What *principles* should we use to help us decide these things?

We think the problem here is the focus on the "youth culture" aspect of the digital generation. While this is obviously a consideration, youth culture—and its more-or-less compulsory "lack of fit" with education and other traditional institutions—is nothing new. We think the focus needs to be on the question of how—if at all—"digital-age" youth culture differs from the youth culture of previous generations, and how—if at all—this is significant for education. We think that what is important here is *not* how to tailor education to fit with the entertainment-oriented sensibilities of

the digital generation, but how to re-orient education so that it is capable of preparing this generation for a successful and satisfying life in a society that, it is now clear, is very different from the one our current system was designed to serve.

Prensky (2001) and Gee (2003) deal with this question to some extent. Gee quite explicitly maps out how he thinks video games can be used to develop the "new" literacies needed by 21st-century learners, and why we need strategies for doing this. Prensky (2001) and Gee (2003) both argue that video games and other digital-age devices have a great deal to teach educators about how to engage and motivate the digital generation for learning, and about how literacy and learning in general are, whether we like it or not, changing in today's world. Gee points out that substantial pedagogical change is needed if we are to engage the digital generation in learning. However, these changes are also needed for another, more important, reason. This reason is the basis of the fourth argument that is used (less commonly than the other three) to justify investment in school ICT: that recent developments in ICT are only *one* part of a much bigger set of changes that our education system has to deal with.

4. The "knowledge age/21st century learning" argument

The "knowledge age" argument is, we think, the most powerful justification for integrating ICT in schools. However, it is not widely understood. This argument *foregrounds* pedagogical change, beginning from the premise that because we have moved out of the Industrial Age context our education system was set up to serve, a paradigm shift in educational thinking is needed. ICT is one element among many in a whole set of highly significant changes in human social, cultural, and economic activity that mark the transition from the Industrial to the post-Industrial age. Since it is the role of education to help prepare learners to be full participants in—and creators of—the "digital age", the challenge is:

> to create a learning culture that keeps pace with these changes and equips people with the knowledge, skills, ideas, and values they need to become lifelong learners able to: use information effectively; adapt to changing workplace and social environments; and keep abreast of technological advances (Ministry of Education, 2003, p. 6).

The "knowledge age" argument goes beyond the previous three arguments in that its key idea is that we need to use ICT, not only to enhance curriculum and pedagogy *as we now know it* (i.e., by making it more efficient, accessible, and enjoyable for teachers and students, and more appealing to digital-generation learners), but also to help develop new kinds of curriculum and pedagogy that will both respond to and shape the 21st-century world. ICT is important and interesting for its capacity to support radical pedagogical change, but it is not the sole instrument of this change, nor the *reason* for it.

Many educationists are arguing that the school system needs a major overhaul if it is to meet the needs of the post-Industrial "knowledge age" (see, for example, Gilbert, 2005). The move away from Industrial-Age thinking involves many important developments. For schools, however, the most significant of these is probably the focus on creating *new* knowledge—as opposed to the

"old" focus on reproducing *existing* knowledge—and the associated shift in the *meaning* of knowledge. This shift has major implications for how we think about teaching and learning in schools, especially secondary schools.

According to the extensive literature on the subject, the term "knowledge society" is being used to refer to the patterns that are emerging as countries move out of the industrial age into the post-industrial age. Knowledge (or 'intellectual capital'), we are told, has replaced other more tangible assets (like labour, land and money) as the "key driver" of economic growth. Where industrial societies were based on extracting and using natural resources in manufacturing, knowledge societies, in contrast, are based on developing and exploiting new forms of knowledge. The shift from one to the other is linked with a major decline in "blue-collar" forms of employment and an increase in job opportunities in the creative, technology or service-based industries. It is also linked with new business practices and new patterns of work. The "knowledge society" is also associated with developments in ICT and globalisation. Our ability to digitise all kinds of information (including money) and to move it around the world at enormous speed has produced major socio-political change. People's understanding of time, space, and place are changing, and the boundaries between countries are breaking down. We are developing new forms of information, new ways of presenting information, and new forms of money. There are new, much more complex, forms of personal identity, and people are connecting with each other in new and different ways.

The educationally significant aspects of these developments are, however, *not* yet widely understood. Knowledge societies are *not* societies that value knowledge more than other societies. *All* societies value knowledge, and knowledge has always been important in all societies. Also, knowledge-based societies are *not*, as some people seem to think, societies that need *more* people who "know a lot", in traditional terms. Rather, they are societies in which knowledge is seen, in *economic* terms, as the primary source of all future economic growth. The key point here, however, is that the knowledge that is to drive this growth is *not* knowledge as most people understand it: it is something new and completely different. Very briefly,[3] this "new" knowledge is no longer thought of as if it were a "thing", developed and stored in the minds of "experts", and able to be organised into disciplines. Instead, it is being treated as if it were more like a form of *energy*, something dynamic or fluid, something that *does* things, or makes things happen.[4] Its value lies, not in what it *is* (or what it can explain), but in what it can *do*.[5] The "new" knowledge is a process, not a product. It cannot be pinned down or measured, but is always changing, and,

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[3] For an elaborated account of all this, see Gilbert (2005).

[4] This conception of the "new" meaning of knowledge comes from the work of Manuel Castells – in particular, his book *The Rise of the Network Society* (Castells 2000).

[5] The French philosopher Jean-Francois Lyotard calls the "new" knowledge's ability to *do* things its "performativity" (see Lyotard 1984).

importantly for educational purposes, it is produced, not in the minds of individuals, but in the interactions *between* people.

This meaning is obviously quite different from the one our education system was built on. Because of this, "knowledge society" developments are a major challenge for our schools, one that cannot be addressed by adjusting the present system, or by adding new ideas (or new technologies): a paradigm shift in educational thinking is needed. While this all seems rather daunting, there are obvious places to start. As a beginning, the current content- and assessment-driven focus needs to be replaced by an emphasis on learning and creating genuinely new knowledge. As one commentator puts it, schools need to be re-conceptualised as knowledge-*producing*—not knowledge-*consuming*—entities (Bigum, 2003). Secondary education, in particular, needs to move away from the Industrial-Age, one-size-fits-all, production-line model of education, to approaches that focus more on the learning needs of individuals. To participate successfully in 21st-century society, people need to go on learning long after they leave school. To do this, they need to know quite a lot about learning: how they themselves learn, how others learn, and how to help other people learn. They need to be able to learn in groups as well as on their own, and they need to know how to create new knowledge. It is important to note here that this does *not* mean that the "old" knowledge that is the basis of the present curriculum is no longer important. It is still important, and students still need to learn it, but in the post-Industrial Age the *reasons* for learning it are now different. Instead of learning it for its own sake, or so that it can be preserved and passed on, students need to understand "old" knowledge so that they can use it to develop *new* knowledge. If they are to do this, they need to understand it at the "big picture", "systems" level, not at the level of detailed facts. They need to understand how different knowledge systems are constructed, how they work, and what their particular strengths and weaknesses are. Traditionally, this kind of understanding was developed only in those who went on to higher education (where they were eventually trained to be the developers of new knowledge – in the context of a specific discipline). An important aspect of our move into post-Industrialism, however, is that *everyone* now needs this kind of understanding. This of course has major implications for curriculum and pedagogy, at all levels of schooling.

It is also important to note that, in this argument, the new digital technologies are important, *not* because they are driving "knowledge age" developments, but because they express and reflect them and, because of this, they can support the kinds of pedagogical change that is needed if we are to develop a "knowledge age" education system.

The "knowledge age" argument makes a challenging and exciting case for bringing digital technologies into school practice. However, saying that we need to develop new kinds of curriculum and pedagogy for the 21st century is one thing, but achieving this in practice is of course quite another. For secondary schools in particular, Industrial-Age models of curriculum and pedagogy are enshrined in everyday practice in such deep and fundamental ways that they cannot be easily changed. (A few examples: the way school days are broken up into timetabled units; the way different areas of knowledge are divided up and taught by teachers in different disciplines, operating in "departments"; the knowledge-consumption model of curriculum

delivery, which often leads to a great deal of note-taking and regurgitation of half-understood information by students; and the grouping of students according to their age, or academic ability). The "knowledge age" argument questions all this. For this reason, it is the most radical of the four arguments presented above.

In this section we have described the four main arguments that are being used to make the case for increasing the use of ICT to support the core activities of schools. In the next section of this paper we explore the practicalities of how increasing ICT use in schools might actually be achieved. We look at the range of different approaches that are being used to support the adoption and integration of ICT into school teaching and learning, and explore some of their strengths and weaknesses.

How can schools become ICT-rich learning environments — what works?

First of all, there is at least one approach that definitely does *not* successfully transform schools into ICT-rich learning environments—that of simply introducing new ICT tools and infrastructure into schools, in the expectation that they will, on their own, trigger beneficial and meaningful educational change. Many authors (Brown and Murray, 2003; Cuban, 2001; Oppenheimer, 2003; Robertson, 2003; Warshauer, 2003) have strongly criticised the kind of thinking that underlies this approach, which they call a form of *technological determinism.*[6] Case-study accounts of educationally uninspired use of computers and other equipment in many schools and classrooms certainly make for depressing reading, and highlight the vast gap between the dreams of the techno-promoters and the realities of students' everyday experiences in schools (Peck, Cuban, and Kirkpatrick, 2002).

There have been several examples in New Zealand of "technology-rich" initiatives that have struggled to produce a level of educational benefit that even approximated what was initially imagined. For example, the Notebook Valley project (2001–2003) provided laptop computers and Internet connections for 2½ years to Years 12 and 13 science and mathematics students and their teachers in three low-decile secondary schools. The project's initiators—the government and a range of business partners—hypothesised that the initiative would promote collaboration and resource-sharing between teachers in the three schools; that the laptops would improve students' attitudes towards, and retention in, science and mathematics; and that the students and teachers would use the technologies to develop and share exciting resources and new pedagogies in science and mathematics. However, a two-year evaluation of this project found little evidence that

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6 This is a form of thinking that assumes that technological developments have "a life of their own", "determining" social life in a way that is divorced from—or independent of—other social, cultural, or political forces.

these goals were being achieved and it did not appear to have been able to realise the aims of any of the four arguments listed above (Bolstad, 2004).

Professional ICT development for teachers

Another (increasingly common) way of encouraging schools to adopt ICT, integrate it into their practice, and make innovative use of it is to focus on professional development for teachers and school leaders that aims to change the way they think about and use ICT.[7] Many school ICT professional development (ICT PD) initiatives are based on a model of teacher learning that sees it in terms of "stages of adoption" (Knezek and Christensen, 1999). This widely used model conceptualises teachers' use of ICT as a series of levels or stages of adoption (see Table 1 below).

Table 1 **Stages of ICT use and adoption (Knezek and Christensen, 1999)**

Awareness
I am aware of ICT, but have not used it. Perhaps I'm even avoiding it.
Learning the process
I am currently trying to learn the basics. I am often frustrated when using computers. I lack confidence when using computers.
Understanding the process and its potential applications
I am beginning to understand the process of using ICT and can think of specific tasks in which it might be useful.
Familiarity and confidence
I am gaining a sense of confidence in using the computer for specific tasks. I am starting to feel confident about using the computer.
Adaptation to other contexts
I think about the computer as a tool to help me and am no longer concerned about it as technology. I can use it for many purposes and as an instructional aid.
Creative application to new contexts
I can apply what I know about ICT in the classroom. I can use it as an instructional tool and integrate it into the curriculum.

These approaches to ICT PD begin by focusing on teachers' ability to use basic ICT tools, on the assumption that once teachers master these they will gradually become confident in using them in teaching, perhaps even coming up with new ways to use them. This model for teacher ICT learning derives from earlier "innovation diffusion" theories, first formalised by Everett Rogers in 1962 (see Rogers, 2005), which aimed to explain how new ideas arise, are taken up, and made

[7] A few initiatives take a slightly different approach, focusing more directly on changing the way *students* use (or think about) ICT—for example, giving students their own laptop or other portable ICT devices (as in the Notebook Valley initiative, discussed above), or providing students with access to an online, after-school study support centre (e.g., WickEd).

part of a culture. Rogers came up with the concept (now widely cited) of dividing the adopters of any new idea into five categories: innovators (2.5 percent); early adopters (13.5 percent); early majority (34 percent); late majority (34 percent); and laggards (16 percent). According to Rogers, people's willingness and ability to adopt an innovation depends on their awareness, interest, evaluation, and experiences of trialling and adopting them. Rogers argued that the pattern of spread of innovations through social groups commonly takes the form of a sigmoid curve,[8] as the early adopters take up the technology first, followed by the majority, until the technology or innovation becomes common.

The "stages of adoption" model assumes that once teachers become familiar with ICT, how to use it, and what it can do, this new knowledge and skill will translate from their personal use of ICT into their curriculum and pedagogical practices. However, this model does not take into account the fact that teachers' personal views of curriculum, teaching, and learning are far more likely to influence the extent to which they use ICT for teaching and learning than their basic ICT confidence and capability. Indeed, research in ICT PD clusters in New Zealand (Ham, 2002) shows that it was the connection (or lack of connection) of ICT use with their understandings about teaching and learning that primarily determined whether or not teachers' personal competence and confidence with ICT translated into its increased use in classes with students. As Brown and Murray (2003) point out, the stage-theory model of teacher ICT learning does not factor in the importance of teachers' strategic knowledge of the "bigger picture" of ICT in education—such as the ideas discussed in the first section of this article, for example. They argue that this strategic type of knowledge is essential for critical self-reflection and the transformation of existing practice.

Fortunately, most recent ICT initiatives in New Zealand schools seem to have taken a more sophisticated view of teacher ICT learning than the stage-theory approach. In our experience, four main strategies are being used:

- **Inspiring** teachers (and school leaders) to see *new ways* of using ICT for learning. The NavCon, ULearn, and Learning@school conferences are good examples of this strategy in practice.
- Providing **enabling tools**—that is, improving the (technological) infrastructure in schools. Some specific projects that illustrate this include the Kaupapa Ara Whakawhiti Mätauranga project, the Notebook Valley project, and the Laptops for Teachers project.
- Improving teachers' **capability** in using the ICT infrastructure. The ICT PD clusters and the Te Hiringa i te Mahara ICT PD project are examples.
- **Supporting innovation**. This is often visible through small "pilot" projects, in which a few classes, a few teachers, a few students, or a few schools try out new ideas and work out on a small scale what works and what does not. When these pilot initiatives are successful, they can

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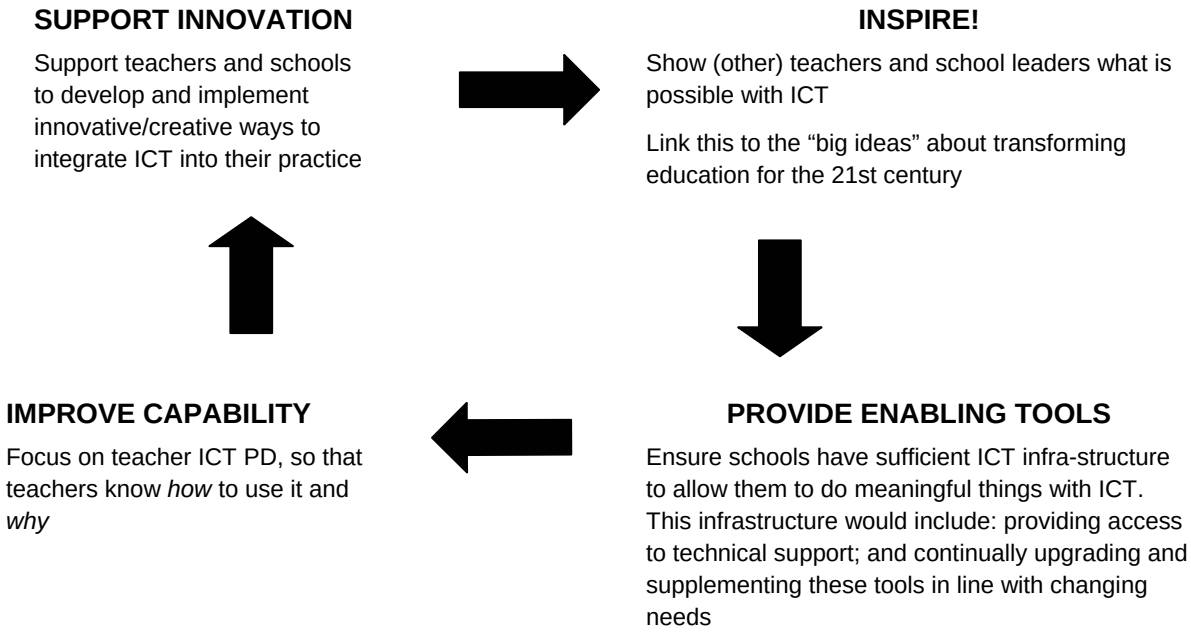
[8] This S-shaped curve is similar to the standard growth curve (familiar to biologists) that characterises a population's colonisation of a new environment. The early rapid growth slows as the environment becomes saturated, to tail off as a balance point or equilibrium is established.

serve as models for other teachers and schools. The DigiOps projects are an excellent example of this strategy.

The "loop" model of ICT innovation and change

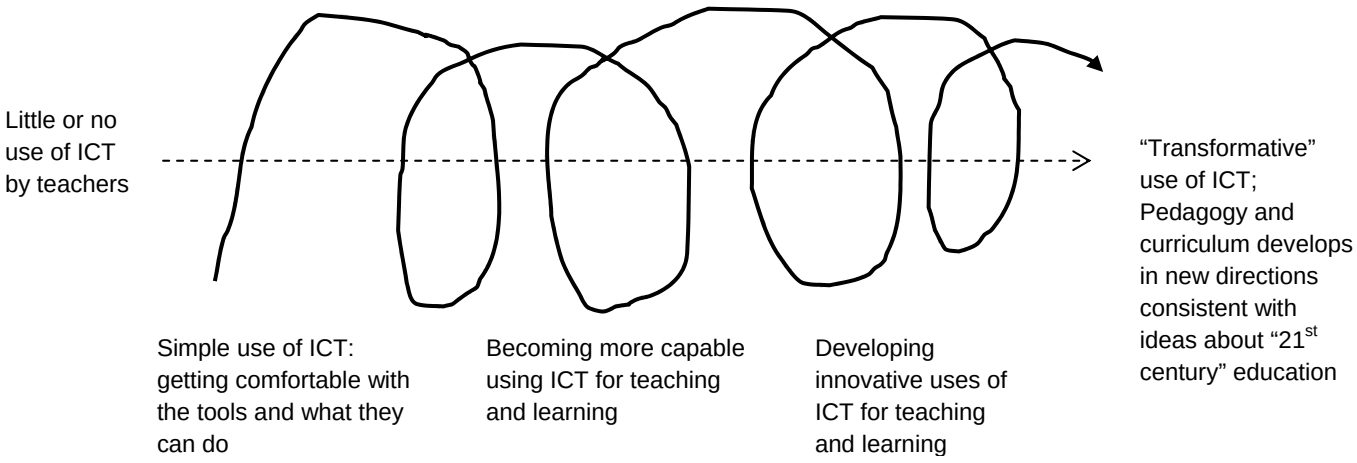
School ICT initiatives now generally include most or all of these four strategies, at least to some extent. We have found it helpful to think of these strategies as being linked together in a loop or a circle. To support ICT change in schools, the important thing is not so much where you *begin* in the loop, but that all four strategies are there, and that the right support is available at the right time. This is illustrated in Figure 1 below.

Figure 1 **Theoretical "loop" of ICT innovation and change**



A spiral might be an even better metaphor. It implies forward as well as circular movement, so that the learning from each "loop" helps us to move forward responsively towards ever better and more sophisticated use of ICT for learning (see Figure 2 below). In the ideal loop or spiral of innovation, each successful innovation serves as a model and example to others, showing other teachers or schools just what can be done with ICT, and why they should try it. The technologies that schools use also keep changing, sometimes in response to new educational ideas, and sometimes inspiring and enabling them.

Figure 2 **The loop redrawn as a spiral: ever-advancing ICT innovation and change**



Does this model work?

Does this theoretical loop of ICT innovation work? Does it change school practice? Over the last few years we have researched and read about a great many examples of interesting ICT initiatives that have *not* brought about significant and sustainable shifts towards "digital age" learning in schools. Perhaps educators have yet to work out exactly how to bring together the four strategies to achieve the kinds of change that the "digital age" rhetoric says we should be seeing in schools. Knowing what ingredients are needed to bake a cake does not mean that we know the exact quantities—or the procedures—that will produce a perfect result. However, we do know that if any one of these essential steps is missed out or inadequate, the result will be a dismal failure. In the case of the ICT change "loop" in Figure 1, we could speculate that the absence of any one of the four strategies will result in a failed cake of a slightly different *kind* (see Table 2 below).

Table 2 **Missing elements, and the results**

Missing element	Result
Inspiration: teachers and school leaders don't have opportunities to see what is possible with ICT or, if they do, this is not clearly linked to the "big ideas" about transforming education for the 21st century—that is, *why* ICT is a powerful opportunity for education	Teachers don't see *how* ICT can fit into (or change) teaching practice, nor *why* or *if* it should. If ICT is used, it is used mainly by enthusiasts, to do "old" things in "new" ways. Pilot projects might be developed, but don't get taken up in "mainstream" practice. Most practice doesn't change
Enabling tools: teachers and students do not have enough access to the types and quality of ICT tools they need to achieve their goals	Teachers and students cannot actually do what they want to do with ICT, even if they *do* see how ICT can fit into (or change) teaching practice
ICT capability: teachers don't have enough ICT PD, or enough of the right kinds of ICT PD	Teachers either don't see *how* ICT can fit into (or change) teaching practice, or *why* (or *if*) it should. If they do, they cannot actually do what they want to do (or want their students to do) with ICT
Support for innovation: innovators are left to work things out on their own. They may innovate in spite of, not because of, the wider school structures, but this is mostly done in isolation or in their spare time.	Pilot projects might be developed but not get taken up in "mainstream" practice, so that most practice does not change. Innovators are so devoted that they "don't have a life" and eventually suffer burnout

Although it is easy to see what the results will be when an ingredient is missing, it is genuinely difficult to calculate the subtleties of mixing all these ingredients together in precisely the right way to achieve the desired result. In the case of schools moving towards "transformative" use of ICT, the cake metaphor may not even be appropriate. A cake, after all, is a finished product: once baked and iced, it is done. We eat it, and it is gone. We know (or at least an experienced cook knows) what it is supposed to look like when it is finished. School change, on the other hand, is likely to be an ongoing process. Even if schools were to achieve a perfect "finished" model for ICT-rich, 21st-century education now, by 2050 this will be completely out of date. In other words, we do not know exactly what the finished product should look like, and we need to acknowledge that it will never be truly "finished". This focus on process (rather than product), continual change, and tolerating (enjoying, even) uncertainty and "not knowing" are, of course, key features of post-Industrial Age thinking.

The next section of this paper looks briefly at some international research studies that have investigated the question of why school ICT innovations so often fail to have the transformative effects intended by their initiators.

What other factors support and hinder school ICT innovation?

Zhao, Pugh, Sheldon, and Byers (2002) studied a group of American teachers in different schools who had each been given grants to carry out technology-rich projects in their classrooms. Since the grants had been awarded to the teachers in this study personally, not to the schools, most were working on the innovation on their own, or with a couple of other teachers. This is the classic "early adopter" approach to supporting ICT innovation in schools, in which innovators are supported on the basis that their experiences will later serve as an example and model to others. After tracking these projects for a year, the researchers proposed 11 salient factors that affected the success of the innovations.

Many of the factors identified by Zhao et al. were predictable, and common to other literature. For example, the innovator's knowledge of the technology and its enabling conditions, and the distance of the innovation from the innovator's current teaching practice, were both important factors. Interestingly, however, another key factor that contributed to successful projects in this study was the extent to which the innovator understood, and knew how to negotiate, the *social* aspects of the school's culture. Zhao et al. suggest at least three reasons why ICT-based classroom innovations, more than other kinds of innovation, might require teachers to be highly sophisticated socially. First, networked technologies often require resources beyond the teachers' control; they need to know who to go to for help, and what kinds of help they can reasonably negotiate. Second, these kinds of projects can make traditionally private classroom activities public, exposing students to an environment beyond the classroom walls, and disturbing well established school patterns. Third, the extra resources given to ICT projects can disturb the social harmony among teachers—colleagues may feel that other areas are missing out as a result. Similarly, a project's "distance from the school culture" affected its success. Most of the innovations departed very little from the dominant set of values, practices, and pedagogical beliefs in the schools in which they were implemented: however, those that *were* very distant from the dominant school culture tended to find themselves up against significant, sometimes insurmountable, roadblocks.

Zhao et al.'s study suggests that, even when ICT innovations are limited to a subset of teachers and students within a school, school-wide culture and infrastructure have a significant impact on their success. If this is the case, what about the next stage in the theoretical "innovation loop"—the idea that an ICT innovation, if successful on a small scale, will be picked up and developed *within and across* schools?

Four Israeli researchers developed an analysis schema to study the diffusion of pedagogical ICT innovation in schools (Mioduser, Nachmias, Tubin, and Forkosh-Baruch, 2003). Their analysis schema uses a matrix with two axes: one to describe three levels of innovation ("assimilation", "transition", and "transformation"), and the other to detail four domains and sub-domains that might be affected by the innovation ("time/space configuration", "student role", "teacher", and "curriculum"). This schema makes it possible to look at a particular innovation and determine what aspects of school life have changed as a result, and how radically (or not) each aspect has

changed. The researchers used this analysis schema to describe the levels of innovation in 10 schools that had already incorporated ICT in unique ways (Tubin, Mioduser, Nachmias, and Forkosh-Baruch, 2003). They found that, even under the most favourable conditions, the assimilation and diffusion of ICT-based innovations within schools was a complex and gradual process.[9] In many schools, the observed practices were "islands of innovation" in a "sea" of traditional practices. Accordingly, the activities in the schools that changed the most as a result of the innovations were the mostly "within-class" sub-domains: didactic solutions; student roles (for example, some students became website developers or ICT project managers); teacher–student interactions; and assessment methods. However, the more "whole-school" domains such as the physical time and space configurations of learning, curriculum content, and teacher–teacher interactions were less affected by the innovation.

In summary, while once it seemed that individual teachers' ideas about teaching and learning were the main factors influencing their uptake of ICT, it is now fairly widely recognised that a complex web of (practical and social) factors act to support or thwart the initiation and spread of innovative ICT use in schools. Peck et al. (2002) helpfully break these down into the following categories:

- **Structures.** Traditional school structures, including separate subject departments, cellular classroom arrangements, and the individualistic and isolated nature of teaching, act together to limit the spread of innovative ideas between teachers and departmental groups.
- **Time constraints.** This includes the time required for teachers to plan for ICT-based learning experiences, and time for teachers and learners to engage in project-based and student-centred learning activities incorporating ICT.
- **Technological issues.** This includes access to, and the reliability of, technology on the "micro" scale of the individual teacher and class, not just the "macro" scale of a whole school's ICT infrastructure.[10]
- **Competing educational priorities.** While there may be support for integration of ICT into teaching and learning, teachers, parents, and students may genuinely value other aspects of education above this, and decide priorities accordingly.

If transformative ICT innovation is to take place in schools, teachers need tools, capability, support, and inspiration—in a context that addresses the whole-school issues outlined above. However, these "ingredients", while definitely *necessary*, are not *sufficient* as a platform for change. If ICT is to be used in schools in ways that can foster the development of the "new" pedagogies that are needed for 21st-century learners, it is important that, as well as receiving the

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9 This is consistent with all the other (non-ICT) educational research on school change and reform—see, for example, Tyack (2003) and Tyack and Cuban (1995).

10 Some paraphrased examples of teacher comments, all taken from initiatives we have researched:
"My school might have high-speed Internet, but there are no network ports in my classroom!"
"We have three high-tech computer labs, but I can never take my class in there because they are always booked!"
"My students all have their own laptops, which they could use to analyse science data, but they can't collect data with our electronic pH probes because the plugs are the wrong type!"

kind of professional development described above, teachers are also supported to develop a sophisticated understanding of the "big ideas" driving the paradigm shift they are part of.

We have reviewed the main arguments that are being used to justify school ICT investment, and the research that looks at "what works" in supporting schools to use this investment productively. To illustrate how these ideas play out in a "real world" New Zealand situation, we turn now to a detailed discussion of an ICT innovation in one school—the Tech Angels project at Wellington Girls' College.

Tech Angels: a case study

The Tech Angels project is a "grass roots" initiative that was conceived and initiated by people working at Wellington Girls' College, with some external help.[11] It has attracted quite a lot of attention from the wider education community and there is interest in exploring whether or not the concept is transferable to other schools. There is also interest in exploring—and building on—the individual and organisational learning that has taken place through this initiative.

Tech Angels started at Wellington Girls' College in 2002. Tech Angels are students who offer time to coach and support teachers in their use of ICT, mentor their peers, and attend to computer-related problems in class or across the school. In return, the students receive specialised ICT training and technology support, both from within the school and externally, from multimedia companies and training organisations. Since its inception, more than a hundred students have been involved in the programme. Since 2005, Tech Angels has been funded in the second round of the Ministry of Education's DigiOps projects. One of the main justifications for using DigiOps funding for the Tech Angels project was to allow Wellington Girls' College to articulate and refine the Tech Angels model, and to develop resources and information that could allow other schools to evaluate the possibility of running similar programmes.

In 2005, as part of a Ministry of Education research project about Tech Angels, we (four NZCER researchers) interviewed a range of people from Wellington Girls' College. Our goal was to better understand the programme by seeing it through the eyes of some of its participants—looking in particular at its impact on learning, and the ideas and issues that had underpinned the project's development—and to offer some recommendations for the project's future development (Bolstad, Gilbert, and Hipkins, 2005). We summarise some of this research project's main findings below, in order to illustrate how the issues outlined in the first part of this paper have been realised in one reasonably high-profile ICT initiative in a New Zealand school.

[11] This sets it apart from some other ICT initiatives in schools, in which the initial idea and process for innovation comes from people *outside* the school who seek to involve schools in realising this innovation.

How did Tech Angels come about?

Like most innovations, this project came about though the confluence of many different factors. However, the enthusiasm, energy and interest of a small number of key people, and certain pre-existing features of the school's overall culture, appear to have been the most important. The school management has had a long-term interest in using ICT to support students' learning. The principal has travelled to Europe and elsewhere to research developments in future-focused education; the school has been involved in a number of teacher professional development programmes involving ICT; some staff members were early adopters of the new technologies; and its Board of Trustees is very interested in and supportive of these developments. However, at the time the Tech Angels project began to develop there was some frustration with the slow progress being made in changing teaching and learning practices in the school. It was felt that many of the school's teachers lacked the ICT skills necessary to make the most of the resources the school by then had available. A decision was made to create the position of ICT director. A new staff member was appointed to fill this position—a former primary school teacher with a strong interest in and passion for the potential of digital technologies to support learner-centred, innovative, "21st century" learning.

Out of this early mixture of ideas and needs, the notion of using a "reverse mentoring" approach to ICT PD emerged. Willing teachers would be paired up with a Tech Angel who would teach and support that teacher in the use of ICT, first to allow them to use the school's administration and communication software package, and later (it was hoped), to allow them to use this knowledge in their teaching. In the first couple of years, there was a focus on pairing Tech Angels with the teachers who had particularly low levels of experience and/or confidence with the basic uses of ICT.

In the first year of the project the ICT director worked with a pilot group of six girls to develop their ICT skills. This group was later entered in the Web Challenge (where they did very well). When the ICT director did not herself have the knowledge the girls needed, she used her personal contacts in the IT industry to find ways of providing it. These girls thus received free training in high-end computer skills, much of it from highly skilled IT professionals. They were also trained in the use of particular software packages identified as useful for teachers. In return, the girls were to be available to work with teachers in the development of their ICT skills, which, it was thought, would in turn help to embed their own learning. This was seen as being a win-win situation for all concerned, and was the beginning of what became known as the Tech Angels project. The Tech Angels also did a variety of other things in addition to mentoring teachers: for example, learning to build and maintain web pages, entering ICT competitions, creating multimedia presentations for the school or on commission, and visiting other schools and attending conferences to promote the Tech Angels concept.

Two interpretations of the Tech Angel project

The research we did at the school made it clear that the key people involved in the project, at least in its early stages, had both similar and very different ideas about what—and who—the project was for. It seemed to us that the mixture of goals and ideas that led to Tech Angels, and the way it evolved in the school, had given rise to two rather different interpretations of the project (we describe these below). What is interesting about these two different ways of seeing Tech Angels is the extent to which each fits with the ideas discussed in the first part of this paper: that is, their use of a range of different views on *why* schools need ICT, and/or *how* they can become ICT-rich environments. In this section, we look at the two different ways this project was understood, and explore the implications of each of these different understandings, if taken to their logical conclusion.

Interpretation One: Tech Angels as an ICT PD initiative

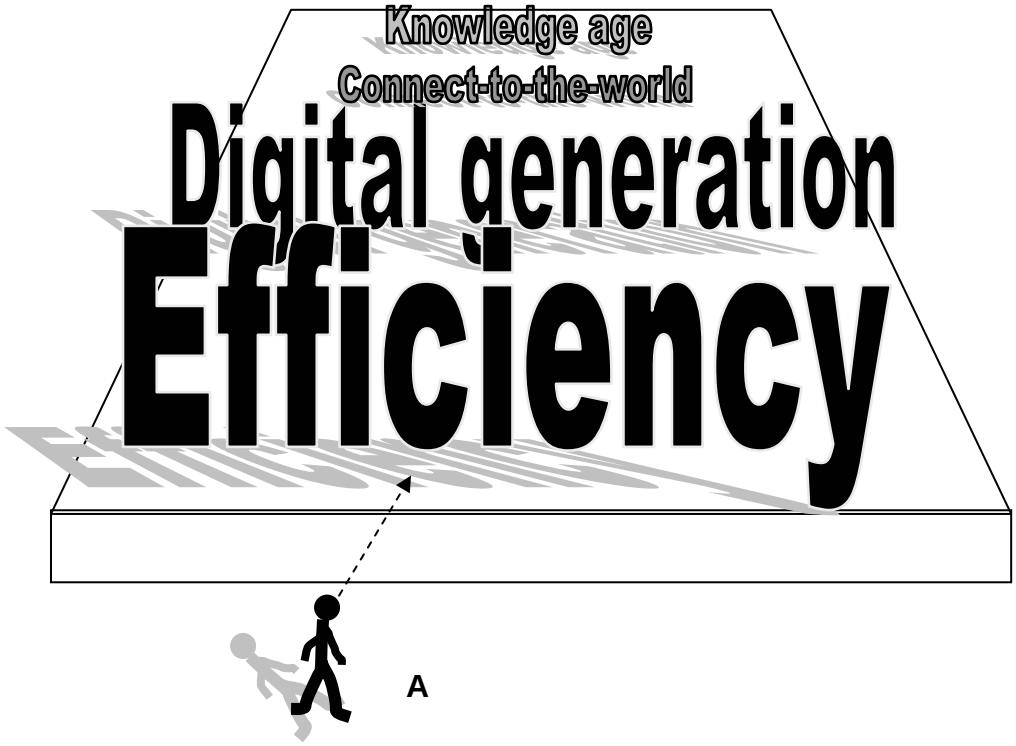
In the first of these two interpretations, Tech Angels is an innovative initiative to support the growth of teachers' (and students') ICT capability, and the effective use and maintenance of the school's ICT infrastructure—with many direct and ancillary benefits for teachers, students, and the school. We have called this first interpretation "Tech Angels as ICT PD initiative". Here, ICT is seen as a tool for making work more efficient. It is seen as an important aspect of modern life, with a central role in current and future work environments. Teachers (and students) need to keep up to date with the new and changing technologies, and know how to use them to do different things in a variety of contexts. In this view, the key issue for the school is the need for good teacher ICT PD and competent in-house ICT support to help staff use the school's ICT efficiently and productively in all aspects of their work (including administration and communication). The Tech Angels initiative appears to be an ideal solution to this problem.

This view of the Tech Angels project has elements of the "efficiency" argument outlined earlier in this paper. It also has elements of the "digital generation" argument—it assumes that, because young people are generally more fluent and comfortable with ICT, they will be able to pick up new ICT learning faster than the teachers. However, this view does not focus only on making teachers' work more "efficient". Drawing on the "stages of adoption" model outlined earlier, there is an assumption that once teachers master the basics of ICT use they will start to use this knowledge in other contexts—in particular, that they will use ICT in their teaching. However, the idea that ICT could support radical curriculum and pedagogical change (the "knowledge age" argument) is not central to this view.

If we show this interpretation of Tech Angels as a diagram, using the concepts introduced earlier in this paper, we can imagine something like Figure 3 below. In this picture, a person looking at the Tech Angels project (Person A) sees the "efficiency" and "digital generation" ideas out in front. In this case, the "digital generation" argument provides the rationale for getting *students* to learn the new technologies first: they'll learn them faster, and they'll find it engaging and exciting to have the chance to work with sophisticated multimedia technologies while at school. Although

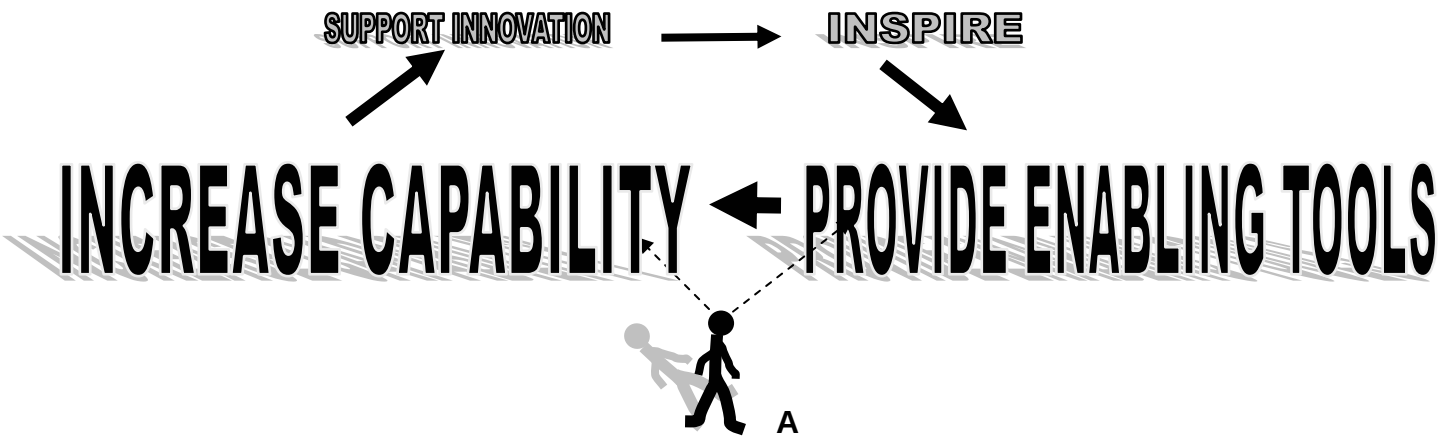
the “knowledge age” and “connect-to-the-world” arguments for using ICT in the school may be lurking in the background, they aren’t very visible – our viewer would only see them if they were actively looking.

Figure 3 **The main ideas underpinning Interpretation One**



If our viewer sees the “big ideas” like this, their focus is also likely to be on the “providing enabling tools” and “increasing ICT capability” elements of the innovation loop we described earlier. The “inspire” and “support for innovation” elements are unlikely to be visible on their horizon (see Figure 4 below).

Figure 4 **Main activities—the Interpretation One view**



Many of the teachers and students we interviewed as part of our research project held this view of Tech Angels. Most (not all) of the Tech Angels said that the programme was established in the first place:

1. to teach teachers how to use technology; and
2. to keep the school "up-to-date" with new technology; because
3. these technologies are, or are becoming, part of people's everyday lives; therefore
4. students of today need to learn how to use these technologies.

Many of the students talked about Tech Angels as a way of "killing two birds with one stone":

> Instead of just having someone come in and teach the teachers, might as well let the students have the knowledge as well. Someone just had a brainwave—why not have the students teach the teachers? (Year 11 Tech Angel)

Most of the teachers we interviewed believed that, at the start of the initiative, the school management had an agenda of specific types of ICT learning that they wanted every teacher to undertake, led by an assigned Tech Angel. Top of the list was learning the new communication system "First Class". The initiative was not, in their view, "needs driven", at least not in the first year. Several teachers spoke of a subsequent push to get teachers to learn particular multimedia programmes, which they resisted if they did not see any direct relevance for their own teaching. However, by 2005, most staff we interviewed saw the programme as a useful innovation, whether or not they had been paired with a Tech Angel.

Interestingly, teachers tended to frame the "role reversal" aspect of the project (teachers-as-learners, students-as-teachers) within their familiar roles and power structures. Even though teachers were the learners, what they told us conveyed a sense that they were taking this role primarily for the benefit of the *students*, who were to experience the "power of leadership" by becoming teachers—and learning some useful ICT skills along the way. As one person said, the

"teacher in you buys into the benefits for students", because many Tech Angels were quieter students who apparently "blossomed" once they were given this leadership role. Another teacher who saw involvement as good for students' self-confidence and relationship skills also said that the Tech Angels "solidify their knowledge" of ICT procedures in the process of teaching. One teacher worried that the role reversal aspect of having a Tech Angel might make the teacher feel a bit "vulnerable". She said involvement with a Tech Angel "doesn't necessarily lose [you] respect but it might undermine your position a wee bit". When dealing with areas where she was not confident, this teacher said she didn't try to cover this up, but as she moved back into more familiar areas she "worked a little harder to re-establish herself as the knowledgeable one".

As the teachers we interviewed saw it, the project was beneficial for students, not teachers. While the role reversal aspect of it was unsettling for some, they basically saw the project as a good thing - for *students*. Most did not recognise the project's possibilities for producing pedagogical change. Those who did were not convinced that this was a good thing. The teachers we interviewed recognised and supported the "efficiency" argument and, to some extent, the "digital generation" argument for ICT use in schools. However, they did not appear to be familiar with the "connected to the world" or the "knowledge age" arguments for bringing ICT into school teaching and learning practice.

The teachers' view of the likely future of the Tech Angels project was also consistent with their view of it as primarily an exercise in ICT PD and the development of student leadership. All of the teachers interviewed thought that the school would need only a scaled-down version of the initiative in the future. As one put it, the Tech Angels were "always going to do themselves out of a job". Or, as another said, "The younger staff don't need it [the training] and the older staff have had it". A third teacher said: "After a generation, teachers will be different anyhow". Nevertheless they all acknowledged that there would always be new things to learn, given the inevitability of future changes. Keeping the programme going meant there would always be a group of students who could initiate new teachers into the school's ICT processes. They saw this as a "narrow, if important" function. However, most teachers seemed to think that "student-led support for technology" should continue in the longer term, because it was beneficial for the *students*. One teacher acknowledged that "students will always be ahead of teachers with technology" and that it was "easier for young brains to learn" aspects such as programming.

Most of the students we interviewed thought the Tech Angels would continue to have a purpose in the school, even when teachers became good at using ICT. Their rationale was that "the technology is always changing" and "there will always be new things to learn". The students thought that things might be a bit different when a "younger generation" of teachers, already fluent in ICT, replaced the teachers who had not grown up with it. Nevertheless, most students thought that it still made sense to have a Tech Angels programme because teachers—and students—would always need to learn new things, just to keep up with the technology. In their view, if ICT-capable teachers were the norm, learning could be different and better. As one student put it:

> It would be really good if teachers knew as much as students because then they could pursue a project together. Like, "I don't know JavaScript, let's both learn JavaScript". So that would be even better, I reckon, like back and forth kind of thing. (Former Tech Angel)

The teachers we interviewed didn't seem to make this link between ICT and pedagogical change. Nor did they have anything to say about how the job of being a teacher might be different in the future.

Interpretation Two: Tech Angels as an experimental initiative to stimulate new ideas about teaching and learning

The second interpretation of the Tech Angels project is more radical than the first. This view of the project sees Tech Angels, not just as an effective ICT PD approach, but as an evolving and almost "experimental" initiative, the ultimate aim of which is to introduce new ideas about teaching and learning with ICT into the secondary school environment. One of the most important of these ideas is the necessity for a shift *away* from teacher-centred, "old" knowledge-based approaches, to student-centred, "new" knowledge-based approaches.

Viewed through the lens of the second interpretation, having students teach teachers how to use ICT is one of the project's *least* important features. Rather, the *most* valuable thing about the Tech Angels programme was the opportunities it provided for students to have learning experiences centred on ICT that they would never otherwise have had in their normal school lives. For example: using new multi-media technologies to process and package information to answer real-world questions, and communicate those answers to real people who need them (such as the multimedia presentations that were developed to help people outside the school understand the Tech Angels programme and what it was trying to achieve); or taking complex real-world problems and working as a team to develop and implement workable solutions to address these problems. In the early years of Tech Angels, one such problem that the students had to solve was the question of how to engage "reluctant" teachers to want to learn and successfully use ICT.

As former Tech Angels tell it, at the start of the project the "Tech Angels teaching teachers" concept involved a certain amount of "selling" to staff. While there was a good response from many teachers, not all responded to the offer of having a Tech Angel. The Tech Angels also found it was sometimes difficult to co-ordinate with teachers who had signed up.

> The major problem with teachers was their reluctance and making up excuses, like "I just don't have time", or "I don't need this in my classroom". (Former Tech Angel)

In the first few years, the Tech Angels and the ICT director regularly discussed ways that they could motivate teachers, and help them to recognise why learning how to use ICT would benefit them.

> We'd always say [to the other Tech Angels] "you have to think of other ways to get them interested". Like use the teachers' interests to lure them in to using the computer. Through

> that, we got to know the teachers a lot more because we had to get to know them before we could adapt the technology around them. (Former Tech Angel)

Most Tech Angels said they began by finding out what their teacher wanted to learn, and what problems they were having with ICT. The former Tech Angels said they often discussed different ways that they could work with teachers' specific interests or prior knowledge in their ICT teaching. For example, one teacher who really liked shoes was taken to "all these different shoe sites" on the web, to show her how to navigate around the web. One Tech Angel taught a biology teacher who

> … understood everything to do with biology but nothing about computers. It was very difficult. So when I explained Photoshop to her I explained everything in terms of biology. Like the layers, I'd explain that in terms of gene expression, because she already understood those concepts. So she didn't understand at first that the layers are on top of each other, and like the order affected the way they were expressed on the page. So I just told her, "that's an organism, and these are the genes" and in genetics you've got different terms like epistasis and all that, so I just explained it in terms of that. (Former Tech Angel)

The Tech Angels learned that it often required a lot of patience to teach the teacher, particularly those that had the greatest difficulty with computers. There were many things the students were so familiar with that they usually "took it for granted", but that teachers "didn't seem to get" easily. One Tech Angel described teachers as being a bit "fragile" when it came to technology. It was important for Tech Angels not to intimidate the teachers with too much at all once.

> Teachers are really good at their jobs, so they are really capable people, you've just got to transfer that confidence somehow. (Former Tech Angel)

From this it can seen that by being Tech Angels these students learned a great deal about teaching, learning, and problem solving. They learned a lot about different teaching methods; they learned a lot about teachers as people (and how best to teach them); and they learned a lot about their own learning. Many of the former Tech Angels clearly achieved longer-term benefits from this experience—in our interviews with them (a year or two after they had left school), many expressed quite sophisticated views of learning for someone of their age. For example, one of the former Tech Angels explained the development of her ideas about learning as follows:

> With the Internet and technology, and being introduced to all these people [outside school], all of a sudden it was a lot of information about everything like facts, people's attitudes, or what people were trying to say to you—but you had to read between the lines. Like there was so much information all at the same time, all of a sudden. I had to step back and say well what does all of this actually mean? I never had to do that before because every thing was like, you just have to copy down these notes that have already been ordered, the emphasis already given to you. So I had to take a step back and think about this and realise that not everything is what it seems…. Like when I did NZOOM [web challenge], I had to learn the web. I had to go onto the Internet and find stuff out for myself. If I didn't know something I had to ask people for help. Or try different ways, like trial and error. I never really learned in that way before. Mostly I used to learn by rote learning I guess. That really helped my 7th form, especially because I had a biology project. It helped me to ask

> questions, and analyse information at hand. I always just took information for granted before, I thought well it's in a book, it must be right, absorb absorb…. But now with the process of making the NZOOM, I started to question this, like "what's the value of learning this right now?", "what's the worth of knowing this piece of information?" (Former Tech Angel)

This former Tech Angel told us that she carried this new "deep" learning approach into her university studies, saying it had made her "really critical" about her learning:

> I think it makes it a bit stressful, because this analytical view takes quite a bit of time and quite a bit of thinking. So now when I study it takes me forever to consolidate the material, the lecture material, the PowerPoint, the textbook, then what they put on the intranet and other sources. Some people go "I don't care, I just won't do those". But now it's like I want to find "the truth" [in finger quotes] and it's quite stressful, I guess. There are not enough hours in the day.

According to the students, this learning was made possible largely by the approaches adopted by the first ICT director as she worked with them. Her philosophy had been that a Tech Angels-type project needed a person to work with the students who "doesn't try to manage their [students'] learning in incremental steps". In her view, it needed a person who could provide the resources and conditions students needed, but once they had started, could just "let them fly". This is a pedagogical approach that values and supports the learners' own initiative, input, and self-direction in solving complex, real-world problems. Some of the former Tech Angels talked about how this worked in practice. As one put it:

> [the former ICT director would] give me really, *really* brief instructions, like not even complete sentences, and I'd just sort of do it. Like she'd say, "this is the problem, what do you think should be done?" and I'd think about it and do it, which was quite good, because I got to problem-solve, and implement things. (Former Tech Angel)

During these conversations, the Tech Angels said, the ICT director would talk to them about "the theory behind things". These were clearly not one-off discussions, but part of an ongoing—and long-term—conversation between the Tech Angels and the ICT director, a conversation that was clearly important to the views of learning some students developed as a result of their involvement in Tech Angels. The fact that some students were able to develop these views of learning is, we think, an important finding of the research.

While the teachers we interviewed saw the project as being beneficial to the students, as we also saw in our discussion of Interpretation One, they clearly saw this in *affective* terms—building students' self-confidence, relationship, and leadership skills. The cognitive benefits to students—ICT knowledge and, more importantly, knowledge of teaching and learning, problem solving, and knowledge of themselves—do not appear to have been recognised by teachers.

Giving the Tech Angels the task of teaching teachers about ICT has (whether or not this was explicitly intended) involved these young people in solving a highly complex, real-world problem—one for which there are no pre-existing "answers". They were supported by the ICT training they received and the mentoring relationship they had with the ICT director, but in the

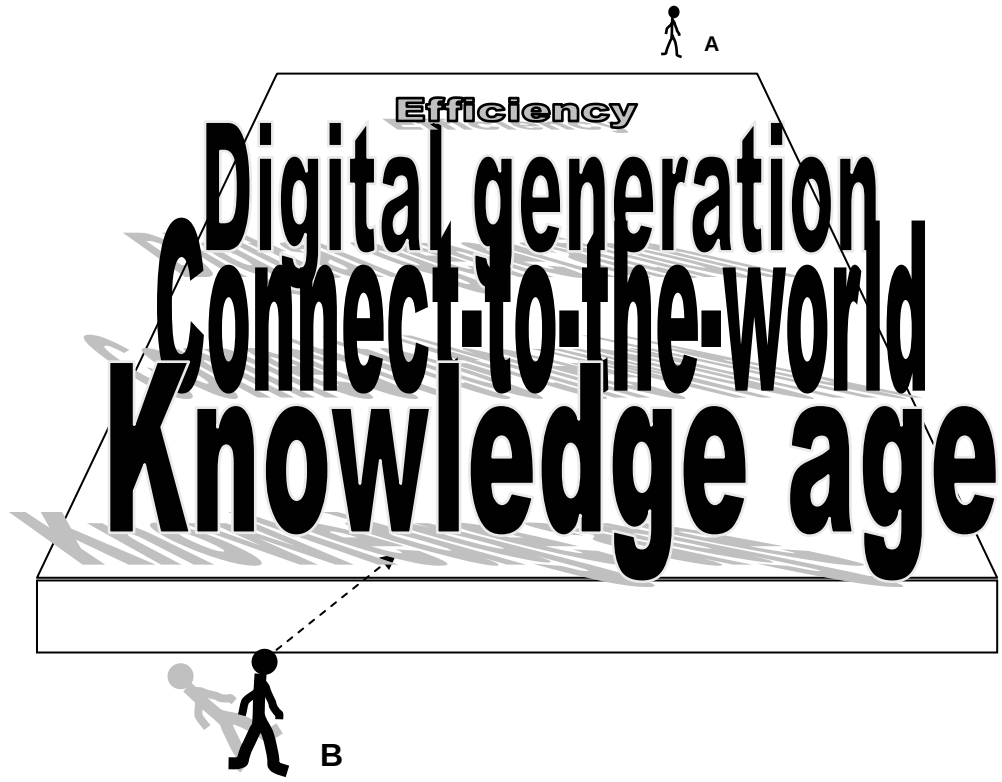
end it was up to them to solve the problem—and, in most cases, they appear to have been very successful in doing so. This experience is a very good example of the kind of "authentic" (real-world), problem-based learning that students need if they are to be prepared for successful participation in the knowledge age. The Tech Angels project shows us that this kind of learning *can* happen in schools.

This idea was the basis of the "vision" for Tech Angels as understood by the school principal and the first ICT director. Both told us that, while it is now relatively common to see the Internet being used by students in schools to collect and assemble information, it is far less common to see students using the new multimedia technologies to author and present their work in a range of media to real audiences of others with similar interests. Educational theorists argue that, because ICT allows students to work at their own pace, follow their own interests, and connect to "real-world" people and information, it has the potential to genuinely engage learners—as individuals and groups—with the subject matter, and with their own learning. This, it is argued, is inherently more motivating than the one-size-fits-all pedagogies that were a feature of Industrial Age education. In addition, and more importantly in terms of the "bigger" aims of education, the availability of these technologies frees teachers to focus on developing the intellectual skills required to do this work well—skills such as: designing research questions; critically evaluating and analysing information; synthesising and organising it to make a case or solve a problem; and designing a presentation that can effectively communicate the results of this work to the target audience. This, while always important, is now an absolutely essential part of the work of any post-Industrial Age education system.

When the Tech Angels project is viewed through the lens of Interpretation Two, actual ICT skills—learning about ICT or how to use ICT—become much less important. Similarly, the idea of using ICT to "extend" the kinds of things we do now" takes a back seat. Instead, ICT is revealed as being important for its ability to support the kinds of pedagogical changes that are needed if we are to develop Knowledge Age schools.

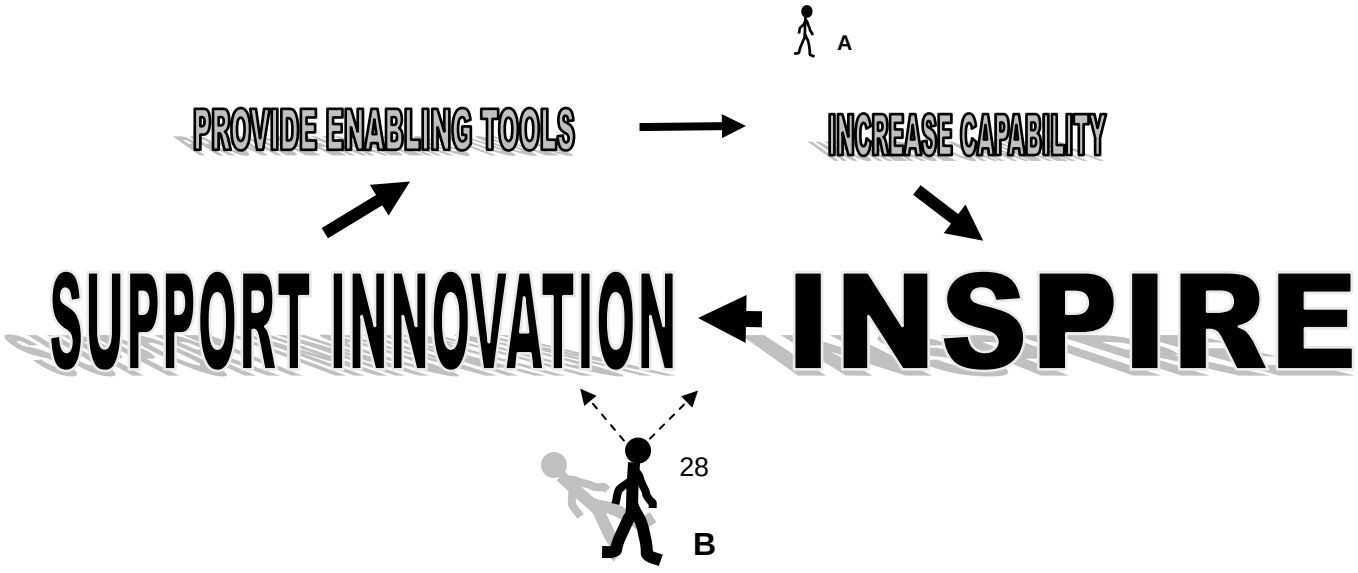
We could represent this interpretation of Tech Angels diagrammatically, as in Figure 5. This time, our imaginary viewer (person B) would look at the project and see the "knowledge age", "digital generation", and "connect to the world" arguments for using ICT in school. The "efficiency" argument is of secondary importance, and sits quietly in the background. Notice the relationship between person B and person A in Figure 5: they are looking at the same project, *but each sees it quite differently.*

Figure 5: The main ideas underpinning Interpretation Two



If we think of the innovation loop described earlier, we would similarly expect our viewer to see mainly the "inspiring" and "supporting innovation" elements (see Figure 6 below). While they would also see the "enabling tools" and "capability" elements, these would appear very much in the background. The viewer's focus is likely to be on what is *possible* with new multimedia technologies, what students are capable of doing when they are given the space and opportunity to use these, and/or on pairing willing teachers up with ICT-savvy students in an environment where they can develop ICT-based solutions to real-world problems.

Figure 6: Main activities—the Interpretation Two view



Summary

As an ICT PD initiative—an innovative way of teaching teachers how to use ICT in their teaching—Tech Angels has been reasonably successful. However, it has also been able to lay some foundations for the pedagogical changes that are needed as we move from the Industrial Age into the Knowledge Age. This idea (Interpretation Two) was the basis of the Tech Angels "vision" - as understood by the principal and first ICT director. When interviewed, both told us that, while it is now relatively common to see the Internet being used by students in schools to collect and assemble information, it is far less common to see students using the new multimedia technologies to author and present their work in a range of media to real audiences of others with similar interests. Both talked about the idea that, because ICT allows students to work at their own pace, follow their own interests, and connect to "real-world" people and information, it has the potential to genuinely engage learners—as individuals and groups—with the subject matter, and with their own learning. This, they said, is inherently more motivating than the one-size-fits-all pedagogies that were a feature of Industrial Age education. In addition, however—and more importantly in terms of the "bigger" aims of education—the availability of these technologies frees teachers to focus on developing the intellectual skills required to do this work well—skills such as: designing research questions; critically evaluating and analysing information; synthesising and organising it to make a case or solve a problem; and designing a presentation that can effectively communicate the results of this work to the target audience. This part of the work of teachers, while always important, is now absolutely central as a foundation for developing a Knowledge Age education system.

This section has looked at the different elements of Tech Angels in terms of the extent to which they fit with one or the other of two different views of the project. In the final section of this paper, we draw some key principles out of these elements – as a way of summarising the Tech Angels "model" for other schools interested in developing similar projects. Following the original Tech Angels "vision", we have emphasised Person B's view of the project (as primarily a future-focussed and transformative initiative) over Person A's view of it (as primarily an ICT PD initiative).

Adapting the Tech Angels model: lessons for other school ICT innovations

Tech Angels "worked" at Wellington Girls' College because the following key elements were present during its development:

- A culture that expects and encourages individual excellence and student leadership/service to the school;
- A strong interest in creating a 21st century learning environment;
- The availability of a mentor/coach for the Tech Angels who aimed to provide students with the resources and conditions for independent learning;
- School investment in high-end ICT infrastructure;
- Student access to training in high-end ICT skills - on an as-and-when-needed basis;
- A dedicated physical space for Tech Angels work;
- The "reverse mentoring" concept for working with teachers.

It is now time for the school to decide where it wants to take this project in the future. If the project is looked at from Person A's point of view, the following alternatives emerge:

- The project could be phased out or scaled down the project as most teachers reach satisfactory levels of ICT confidence and capability.
- The project could continue much as it is now. Students who participate could receive training as needed, and engage in a variety of in-school ICT support activities (including supporting teachers, technical troubleshooting, hardware support, and so on). Some students could use their training to work on various extracurricular ICT-related projects (building and maintaining school websites, competing in the NZOOM web challenge, working at TKI, for example). Tech Angels' work could extend to peer teaching—supporting other students learning about ICT.
- Tech Angels work could become part of the school's core IT curriculum.

These three alternatives are based on a "business-as-usual" view of education's future, in which the purpose of ICT is mainly to extend and improve existing services. However, if the project is viewed from Person B's perspective, a fourth alternative emerges, one that sees what has happened so far as the first steps of what is needed to support the shift to 21st-century teaching and learning.

Two things are needed to support the further development of this view of the project:

- The development of a shared, school-wide "vision" for the project: in particular, its role in mainstream school activities;
- The continued growth and development of the school's interest in innovation, continuous professional development, and creating a 21st century learning environment.

The question of how to go about developing a "shared vision" in schools is the subject of a fast-growing area of educational research, much of which draws on ideas developed in non-educational contexts. To take one example: in a recent evaluation of the Curriculum Innovation projects (CIPs) in five New Zealand secondary schools, (Boyd et al., 2005) suggest that a key ingredient for supporting and sustaining pedagogical and curriculum change in the secondary school environment is "shared ownership of the vision"—that is, a set of shared beliefs, understandings, and clear goals (Russell, 2003; Stoll and Fink, 1996). The development of an initial vision, for both students and teachers, which could then be adopted or adapted by a team, was crucial to the success of the CIPs. However, those who developed the initial vision were not necessarily the same people as those who enacted it, and some teachers who were not involved in the conceptualisation of the projects were not clear about what "the vision" was, were unsure whether the vision was practicable, and were uneasy about their involvement. Most of the schools found they needed to develop systems that allowed teachers to debate the beliefs and practices underpinning the vision and have input into the form of the projects. Staff needed time to contribute their experiences, debate their beliefs about learning, discuss their concerns, and adapt the vision if necessary to reflect their reality (Boyd, 2005).

According to (Fullan, 2005; Hargreaves and Fink, 2004; Harris, 2002), school leadership is central to developing, nurturing, and sustaining change, and plays a crucial part in the development of a shared vision. The CIP evaluation found the support of the principal to be absolutely essential for success, as was the ongoing pedagogical leadership provided by staff who had the ability to influence school structures and resourcing. The CIP research also suggests that different leverage points (curriculum, pedagogy, and/or assessment) can be utilised to effect change, and that planning for change needs to incorporate understandings about how to manage a change process. An explicit awareness of the interplay between pedagogy, curriculum, and assessment, and how these interact with other school structures to support or inhibit change, is important at the school level. The research also highlighted the need for coherent messages to be given at the national level to ensure that attempts to transform the ecology of schooling towards practices and systems that promote a lifelong learning orientation are deliberate and planned for.

Putting this research and the Tech Angels "vision" together, in the tables that follow we list the principles that have driven Tech Angels so far, along with some that are needed to drive its future development. These principles are intended to serve as a guide for other schools interested in developing Tech Angels-type projects. They are presented in table form for easy reference, grouped under the following headings:

- School culture and leadership
- Teacher professional development
- ICT infrastructure
- Teacher-student interactions
- School-community-business partnerships.

Table 3 **Key principles of the Tech Angels "model"**

A. School culture and leadership principles	Why are these important?	How can they be achieved?
School leadership and a school culture that supports: • innovation and continuous professional development • critical thinking and discussion among staff about the purposes and practices of curriculum and pedagogy • student leadership/service • teacher-student co-responsibility for learning (and a view of learning as a two-way process) • a commitment to developing a "21st century learning culture".	Ultimately, the leadership and culture of a school are key determinants of whether an initiative like Tech Angels succeeds. If the leadership is not absolutely committed to the intentions of the project, it will founder. If the school culture works against the intentions of the initiative, it will only ever succeed in small isolated "pockets", and innovators are likely to get burned out and move on. The initiative will not be sustainable.	School leadership needs to focus on developing a shared vision of the future development of curriculum, pedagogy and assessment in the school. The school needs an explicit strategy for supporting the development - and diffusion - of curriculum and/or pedagogical innovations.

B. Teacher professional development principles	Why are these important?	How can they be achieved?
Teacher ICT professional development that: • links teachers' ICT learning to their understandings of teaching and learning; • takes into account individual needs and understandings – that is, starts where teachers are "at"; • introduces ideas about the roles of digital technologies in a 21st century "knowledge age" learning environment • emphasises a view of ICT not as a "tool", but as an "environment" for learning • challenges teachers to reflect on their existing ideas about curriculum and pedagogy, and to compare these to ideas about 21st century curriculum and pedagogy	In order to support a "shared vision" for the use of digital technologies in schools in ways that are consistent with "21st century/knowledge age" aspirations, it is critical that teachers' ICT PD be firmly grounded in these ideas. For example, there isn't much point in teaching teachers how to use multimedia software unless they also have the opportunity to understand how and why such technologies can provide valuable learning opportunities for students. ICT PD must also be designed with a recognition that some *current* curriculum and pedagogical practices in secondary schools do *not* align with a 21st century view of teaching, learning, and curriculum. Teachers must have the opportunity to compare their existing ideas and practices with "21st century" ideas, to debate these ideas, and to accept constructive challenges to their own ideas and practices. This is likely to be a slow process requiring ongoing shared professional learning among staff.	Individualised PD programmes need to be replaced by co-ordinated programmes that are designed to develop the school as a professional "learning community".[12] One of the aims of this learning community should be to develop a *collective* sense of the "way forward" for the school. The school needs ongoing professional development that foregrounds exposure to - and opportunity to engage with and debate - "new" approaches to pedagogy and curriculum. This is likely to be time-consuming (and expensive). In addition, because it will challenge many teachers' sense of professional identity, it will be cognitively and affectively demanding for some teachers.

[12] See, for example, Senge et al (2000) *Schools that learn*.

C. ICT infrastructure principles	Why are these important?	How can they be achieved?
Schools need • reliable, high-speed internet access in all teaching areas, and a reliable school network. • prudent investment in high-quality, flexible, upgradeable, multimedia-capable hardware. • an emphasis on purchase and use of software that allows students to be authors and creators, has the potential to encourage creativity and higher order thinking skills, and enables students to do more than they could by any other methods. • investment in other digital equipment that supports the authoring and sharing of knowledge by students and teachers – visually, aurally, and textually. (e.g. digital cameras or video cameras, data projectors, sound equipment, etc.) • at least one "multimedia" room in the school which is accessible to all students and teachers.	Fast internet and a reliable network enable students and teachers to produce, store, and share digital information, both *within* the school, and with audiences *outside* the school. Computers that are too slow or not powerful enough may not be suitable platforms for good multi-media software: the kind that supports students to be creators and authors of new ideas. As the amount of digital material produced by students and teachers grows, it is likely that a school will encounter issues connected with digital storage and archiving capacity (multimedia items require large storage capacity), and issues regarding intellectual property rights over material created for the purposes of teaching and learning, and finally, personal privacy issues related to the storage and use of these materials beyond the contexts in which they were created These issues will become increasingly common for schools, tertiary institutions, and other kinds of learning institutions, and is part of the process of moving towards a 21st century learning environment. This has implications at the level of national policy and funding, as well as for individual institutions. Over time, collective solutions may emerge, as educational policy and funding adapts to this changing environment.	To make wise decisions about investment in ICT, schools need people who have sufficient technical knowledge to purchase equipment and software that are capable of supporting the learning intentions of a 21st century school, and to be able to achieve this within a reasonable budget. It may not be possible to fully equip all the learning spaces in a school; therefore, decisions about how to prioritise infrastructure investments are likely to be needed. Investing in at least one "multimedia" learning environment in the school, accessible to all students and teachers, means that teachers will have opportunities to at least see what *can* be done in such a learning space. When more money is available, teachers and students will have a more informed idea of what a 21st century classroom could look like. They can also introduce their own design requirements into the development of new teaching spaces.

D. Teacher-student interaction principles	Why are these important?	How can they be achieved?
Schools need to provide • opportunities for two-way learning, and co-learning between teachers and students. • an emphasis on student-led, self-paced learning with teachers as mentors, coaches, and guides to student knowledge-building. • recognition and valuing of students' interests, prior knowledge, and experiences (including their experiences as a child of the "digital generation") in the development of curricular and pedagogical planning.	A "21st century/knowledge age" learning environment should foster the development of students' critical thinking, their ability to find and evaluate knowledge, their ability to communicate their ideas to other people, and their deep understanding of how knowledge is constructed, tested, and used in various subject domains and disciplines. They need to know how they and others learn, and how to work together with all kinds of other people to achieve their goals. Educationists argue that in order to develop these understandings and abilities, students' school learning should provide opportunities for them to develop and practice these in authentic, "real-world" contexts which are engaging and relevant. Creating such a learning environment means re-examining current pedagogies and critically questioning the extent to which they serve the goals of a 21st century learning environment. One powerful way to do this is to unsettle familiar patterns – for example, by creating opportunities for "reverse mentoring", and/or by promoting the idea of students learning in teams, and/or encouraging teachers to step back and make observations and reflections on the characteristics of learners, groups of learners, and the dynamic processes of learning.	21st century schools need to be professional learning communities. These can be initiated within the traditional subject areas, across the school, and/or in groups with membership from within and outside the school. Students and people from the school's community need to advise, participate in, and be part of these groups. These people, in partnership with the school's teachers, need to participate in the process of making the school as a whole a "learning organisation", a knowledge-*producing*, not knowledge-*consuming*, entity.

E. School-community-business partnership principles	Why are these important?	How can they be achieved?
Schools need to build • relationships between the school and community and/or business partners who can support the aims of "21st century" learning within the school	The shift to a "21st century/knowledge age" school system should include the recognition that schools will need to seek new relationships in order to provide all the knowledge, learning opportunities, and experiences that students need to prepare them for life in the 21st century. Some of the most important learning experiences for Tech Angels have come about because of their engagement with a wide range of groups and people from *outside* the school. In these encounters, students encounter new knowledge and ideas and must accommodate these into their overall understandings. Community and business groups can provide knowledge and expertise that may not be available within a school, and in turn these people and groups become a "real" audience to whom students must learn how to engage and communicate. People and groups outside the school can provide authentic and engaging learning contexts (including real problems to solve).	The school needs to be able to move beyond the Industrial Age model of a specialist "silo" – a place that, because it is recognised as having certain expertise, is left alone to get on with the job of educating the next generation. Knowledge Age schools will form partnerships and collaborations with a range of other agencies, organisations and individuals – some educationally based, some not. To be successful the partners will need to be genuinely committed to working towards common goals, and to recognising and using each others' strengths. These collaborations are likely to be a good source of "real world" knowledge generation tasks for students.

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