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Building Innovation: Learning with technologies

Kathryn Moyle

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Foreword



The first criterion for a successful monograph is to pick the right topic. On this *Building Innovation: Learning with technologies* hits the mark. Innovation may well be the most important educational issue of the day. In 2010, schools exist in a world radically different from the world that existed when the system of schooling currently in place was invented. Information Communication Technologies (ICT) have played a critical role in worldwide changes that have occurred in the last few decades. The World Wide Web provides a volume of information and learning resources unimaginable a few decades earlier. Most recently, Web 2.0 applications, such as social networking, collaborative work and play spaces, blogs, and publication places for creative products, are being extensively used by children and adults. These developments have resulted in a chasm between the world of information, knowledge production and dissemination, and learning as it exists outside of the schools, with what is happening within them.

The second criterion for a successful monograph is for it to successfully accomplish the development and execution of its argument. Kathryn Moyle's monograph is a lucid, comprehensive and thoughtful analysis of the topic. It provides a very good basis for understanding the challenges we face in securing a full measure of benefit from the incredible opportunities that digital media provides for creating relevant and vibrant learning environments in our schools.

The changes generated by ICT have had deep and broad impact on all sectors of society such as business, health care, journalism and publishing, entertainment, government, and the sciences. Studies cited by Kathryn Moyle show a high percentage of young people making use of computers at home and at school. Since teenagers are particularly peer oriented it is no surprise that they make abundant use of social networking and other Web applications that involve participation and collaboration. While young people make use of computers in schools, apart from notable exceptions in classrooms here and there, the nature of teaching and learning in schools has been little affected. Success with regard to the integration of various technologies such as computers, whiteboards, etc. has often been defined by how extensive or prominent the use of such equipment has been in schools, rather than whether such use was providing new, better, and more relevant learning experiences.

There are two dimensions to the school innovation issue. The first pertains to the capabilities required by young people to have a successful life and also to contribute to economic, social, and their individual wellbeing. The second dimension pertains to what needs to be done to align the nature and structure of school with contemporary culture. The first four sections of Moyle's review paper focus on the first dimension, with the last two sections focusing on the second dimension.

With regard to the first of the two dimensions, the need for changes in the competencies of school is generally linked to the recognition of the importance of ensuring nations have the type of

workforce necessary to enable them to be competitive in the global economy. Over the past few years in nations around the world there has been a proliferation of policy statements, speeches, and commentary in the media, calling for schools to do a much better job in cultivating students with a high level of skills, creativity, problem solving, and self-directed lifelong learning. In the United States of America the rationale for developing those capabilities in students is typically linked to national economic viability. The *Melbourne Declaration* recognises the importance of making substantial changes and improvements in the capabilities of graduates for national economic competitiveness. But it also takes a holistic approach, identifying goals for Australian education that relate to the intellectual, physical, social, emotional, spiritual, and aesthetic wellbeing of young Australians. Moyle contends that the full scope of the goals of the Declaration are not being taken seriously in Australian school reform; rather, in actuality the rationale for school reform is national economic viability. Without challenging the importance of national economic viability, one may still wonder why in many nations, my own included, there is far less attention given to the need for the graduates of our schools to have the competencies required for citizenship in a world beset by complex problems that transcend national borders. We need a generation of young people more capable of resolving those problems than have been their parents and grandparents. As important as economic viability is, it is still contingent on social stability and human survival. There is something sadly impoverished about educational policy and practice that sees the young people of the nation only as economic assets.

Well-conceived policy statements such as the *Melbourne Declaration* are valuable since they provide a framework for action but, intentionally or unintentionally they can become ‘window dressing’, providing the semblance rather than the reality of change and progress. Moyle asks the right question: How does fostering innovation and creativity advance from being an abstract goal to a concrete reality in school programs? No matter how well a policy document on this issue is conceived and expressed, policy words, in and of themselves, cannot cause change. At best they can motivate change agents, who must confront all of the thorny problems of implementation.

It is at this point where the two dimensions of innovation coincide. Creativity and innovativeness cannot be taught as a discrete school subject. The cultivation of such qualities needs to be infused through the entire educational process. To a degree that many of us may not wish to acknowledge, creativity, innovativeness, and self-directed learning are too often acquired by our students despite, rather than because of, what is happening to them in school. The schools as they currently exist – even with heroic efforts of school personnel – can only have a modest level of success in accomplishing what the *Melbourne Declaration*, and the other policy documents referred to by Moyle, seek to accomplish.

A learning environment that promotes the development of creativity, innovativeness and capability for self-directed lifelong learning in students will have a strong flavor of constructivist learning, rather than one of teacher-dominated declarative learning. Students will be active agents in the construction of their own knowledge, rather than passive recipients of that knowledge from teachers. Moyle’s description of the characteristics of the 21st century school reveals the learning situation required to promote those capabilities in students, and shows it is not compatible with the existing traditional school structure. Such a learning environment is not tidy and does not follow a preset script. Students involved in self-directed learning make mistakes but in a 21st century school the mistakes are considered a natural and valuable element in learning. Wrong answers and the sense of being lost in a problem are not qualities generally welcome in schools. Those who accept the existing paradigm of school practice would likely see this type of classroom as one that is out of the control of the teacher. They are also likely to be dismayed by a perceived waste of time. Time is a scarce commodity in schools, so from the standpoint of time usage it may seem more efficient ‘to tell’ students the knowledge rather than to have them be participants in achieving the knowledge. But, taking time to enable students to be active participants in their

learning is a requisite if the goal is to foster creativity and self-directed learning. The fostering of creativity and self-directed learning occurs when students are given tasks or problems that challenge them to 'think outside the box' and to 'own the problem'. Constructing such learning tasks also challenges the creativity of curriculum developers and teachers.

As Moyle indicates, accountability requirements have been a serious inhibiting factor in the development of innovative capability of students. Accountability mandates, per se, are not the problem, but when accountability requirements for schools focus on quite traditional testing of predominately recall information, school personnel are under no illusions as to which educational goals are being privileged. To paraphrase a familiar saying: 'He who shapes the assessment calls the tune'! Politicians and other policy leaders who express the need for students to be creative, self and lifelong learners, and be adept at using existing knowledge resources, while at the same time calling for accountability that focuses on traditional achievement tests, may not be duplicitous. They may just lack the background and experience required to recognise that their policy mandate and their accountability prescription are out of sync.

While many of the conversations about how the learning environment needs to be changed have focused on pedagogy or how we teach, it is vitally important that we disengage from a lock-step, discrete subject matter curriculum. The perspectives of Australia's *National Curriculum* and the *Partnership for 21st Century Skills Framework* in the United States of America are responsive to the establishment of multi-discipline syntheses of curriculum content. The impact of the *Skills Framework* in generating widespread curriculum reform is still to be seen, and many of us will be watching with great interest to see what progress Australia's *National Curriculum* generates.

Any effort to connect schooling with the realities of the 21st century should be informed by the realities of the use of ICT by young people of school age. If there is any doubt about the way ICT has become infused into their lives, Section 4 of this AER will remove those doubts. That section contains a useful portrayal of how ICT is being used by young people - particularly in their lives outside of school. The empirical research reported in this section is a good antidote to the stories of terrible use of social networking, cell phones, etc., as reported in the mass media.

In Sections 5 and 6 of the review paper, Moyle deals in more detail with the second dimension of the school innovation problem: the creation of a new system of schooling. Information and communication technologies challenge many of the long-standing conceptions about schools beginning with the most fundamental question: What is a school? The school in the 21st century is no longer necessarily a place; rather, as Moyle says, 'Now schools can be considered more as environments that consist of physical, online, or simulated learning spaces, or they can be environments that consist of any combination of these environments.' (p.42)

The belief that schools need to do a much better job in fostering creative, self-directed, lifelong learners is not new. There is a long line of champions of educational reform who disparaged passive, spiritless, 'learn just to pass a test' type schooling. What is new is that ICT has provided resources that make such learning environments in schools incredibly more plausible than has ever previously been possible. The good news is that the World Wide Web has turned the idea of more vibrant learning into a reality, and one can easily see countless examples of children and teenagers taking advantage of these resources. And it is certain that young people will find and use an ever-increasing array of effective learning opportunities, via the Internet. For many of them, this activity is happening in their lives outside of school. The key question for our schools is: Can school personnel take a full measure of benefit from these resources to make our schools work better for our kids? My sense of the matter is that the required transformation of schools is not inevitable. How distressingly perverse it will be if our young people experience a richer learning environment when they are not in school than when in it!

Much discussion about the needed transformation of schools focuses on professional development as the basis for creating new schools. Certainly, pre- and in-service professional

development is an important component in school transformation. However, it is clear that professional development cannot, in and of itself, accomplish the transformation of schools on any widespread basis. It is the system and the learning objectives that need to be aligned with their best practice. Teachers, principals, and other school personnel who have acquired new techniques, and who function within the existing structural context of schools, are often discordant elements – aberrations. If they are sufficiently motivated and persistent, they may be able to make good use of their capability, despite incompatibilities with the existing situation. But to expect them to move the school system into harmony with their preferred practice is to expect too much. Their good work may last only until they burn out or move on.

The task then is to make the structure of schools compatible with teachers who embody state-of-the-art teaching capabilities and perspectives. Moyle recognises that the task of building 21st century schools requires direct attention to the existing nature of schools. She identifies three elements: physical infrastructure, technological infrastructure, and organisational infrastructure. The physical structure of the school building, and the furnishing of it, along with the nature and extent of the ICT hardware and networking, can serve for the students and teachers in those buildings as assets, but in reality but they are far too often liabilities. As challenging as it is to obtain the funds necessary for the physical and technological infrastructure, contending with the organisational infrastructure is an even greater challenge, since changes in the nature of the organisation entails deeply-held beliefs, not easily changed, about the proper way for schools to function and schooling to occur.

In Section 6, Moyle brings into full focus her position on the undue impact of economic interest on Australian education. She contends that the educational technology industry has had much too strong a hand in shaping the content of schooling. She makes the case for open source, non-proprietary applications. Since open source applications are free, cost, which confines options in many schools, is less of an issue when open source applications are used. However, the case for open source/open education is not only about money; it is fundamentally about a philosophy, and the philosophy is a more potent force than the money. Open education (and open source as an element in such) constitutes an effort to make the process and benefits of education available to all, by minimising social, political and economic barriers. This is a theme of great importance but, as valuable as is open source/open education, it would be unfortunate if it were seen as a panacea. The existing structure of schools has good capability in getting new developments to fit into the existing scheme of things, and to not really challenge the status quo. Thus, to bring schooling up-to-date, it is important to place implementation of open source within the context of the constructive policy and organisational structure changes that Moyle presents in Section 5. Whether one agrees or disagrees with Moyle's position, it serves a valuable purpose by putting the issue on the table. Nothing better subverts attempts to make real and substantial change than allowing unrecognised 'givens' and unchallenged assumptions to shape the proposal for change.

Building Innovation: Learning with technologies raises the right issues and should provoke valuable dialogue among those seriously concerned about educational reform. It will be a valuable source of information for anyone committed to bringing the full measure of the powerful learning capabilities provided by ICT to the lives of our children in our schools.

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Introduction

Building innovation with technologies in school education is providing Australian educators with the opportunity to reconceptualise teaching and learning in the 21st century. Inquiry-based, project-based and personalised learning pedagogies that include technologies aimed at building innovation capabilities in students are emerging in Australian schools, and they are being promoted through government policies.

In 2008 all the Ministers of Education in Australia endorsed the *Melbourne Declaration on Educational Goals for Young Australians*. This policy statement draws links between building innovation and teaching and learning with technologies. It provides the following context for Australian school education, stating in the *Preamble* that:

In the 21st century Australia's capacity to provide a high quality of life for all will depend on the ability to compete in the global economy on knowledge and innovation.

(Ministerial Council for Education, Early Childhood Development and Youth Affairs (MCEECDYA), 2008, p. 4)

As a foundation for success in all learning areas, it states that students will have:

... the essential skills in literacy and numeracy and [be] creative and productive users of technology, especially ICT.

(MCEECDYA, 2008, p. 8)

This Declaration also indicates that successful learners:

... are creative, innovative and resourceful, and are able to solve problems in ways that draw upon a range of learning areas and disciplines.

(MCEECDYA, 2008, p. 8)

These policy statements provide a 'window' into official views about the types of teaching and learning advocated for Australian school students in the 21st century. Underpinning these directions is the philosophy that education is socially constructed and consists of more than simply getting students to learn information. In the 21st century, Australian policies such as the *Melbourne Declaration* promote pedagogies that encourage students to learn how to take information and turn it into knowledge applicable to their own circumstances. Such approaches require teachers to support students to learn how to work with others in face-to-face settings, and also how to use the Internet to communicate with others in different times and places, in order to collaboratively create new knowledge. Such approaches represent fundamental

changes to the way teachers and students are often positioned in schools and with each other. Teachers have to be experts in their fields, as well as mentors and coaches. They must now be a knowledge expert with skills in the facilitation of groups of students, where those activities include the meaningful use of technologies.

The opportunities afforded by mobile, laptop and desktop technologies to aid or add value to the learning students undertake has, and continues to be, investigated by researchers around the world. This research includes investigating what types of teaching and learning support the development of foundation skills such as literacy, numeracy and technological literacy, and includes the generic capabilities of creativity and innovation (see, for example, Papert & Caperton 1999; Naismith, Lonsdale, Vavoula & Sharples, 2006; Resnick, 2007, 2008; Dede, 2009).

At the same time as the links between technologies and learning are providing opportunities for educational practices to be reconceptualised, so too the links between building innovation and teaching and learning with technologies are providing lenses through which national policy-makers are connecting economic and education policies. Australia's education policy priorities are being driven by national and international economic priorities that are consistent with the directions being taken by many countries around the world, including those that belong to the Organisation for Economic Co-operation and Development (OECD). It is the intersections between the national and international economic policies aimed at building innovation, and the implications of these policies for teaching and learning with technologies in Australian schools that are discussed in this review paper.

Policy meanings of 'ICT'

A range of official documents that are labelled as 'policies' can include party political election platforms, new government legislations and amendments to existing legislations, white papers, government departments' statements labelled as 'public policies', departmental strategic planning documents and budget statements. These are all types of public policies, but they are more than official documents; they are also the authorised 'talk' of the state (Taylor, Rizvi, Lingard & Henry, 1997). Policies:

... always have a prior history of significant events, a particular ideological and political climate, a social and economic context – and often, particular individuals as well – which together influence the shape and timing of policies as well as their evolution and outcomes.

(Taylor et al., 1997, p. 16)

Policies gain their meaning through processes of authority and legitimation, interpretations of which make selected meanings possible. Government policies and associated budgets provide insights into some of the world views legitimated through the policy language used.

One of the challenges to understanding policies concerning teaching and learning with technologies arises from a lack of shared understandings of commonly used words in policies, locally and globally. This is not to suggest that a shared language should be put in place, but rather to acknowledge there are different interpretations used in different countries for the same policy language.

Australia, and several countries throughout Asia and Europe, use the phrase 'information and communication technologies' or the label, 'ICT' (MCEECDYA, 2008; MCEECDYA & Ministerial Council for Tertiary Education and Employment (MCTEE), 2008). These policy statements either focus upon devices such as computers, the Internet and mobile devices of various kinds, or refer to an area within the curriculum, or both. For example, the label 'ICT' can be used as a global or catch-all term that refers to computers linked to the Internet, through telecommunications services, including broadband and satellite services. And it can refer to subjects at school in which the technical aspects of technologies are emphasised. In comparison, in the United States of America, a more common term for these is 'educational technologies' (United States Department of Education, 2009a). 'One to one' programs in the United States of America generally refer to the use of laptop computers by students (One-to-One, 2009).

Around the world, newer technologies, online resources and social networking sites tend to be labelled by their respective collective names.

The range of devices now available for students' learning, and the variety of purposes to which they can be put, however, is seeing the emergence of different meanings about what the label 'ICT' is intended to cover. There is a lack of clarity about what is intended by the label, and what the phrase 'information and communication technologies' means and encompasses in educational contexts. As such, 'ICT' is becoming an inadequate label for describing the multiplicity of technologies used by students.

One of the tensions that arises when bringing together the fields of policies and technologies is that both are socially constructed. Innovations such as new technologies are artefacts that result from the outcome of negotiations between individuals, groups and institutions, where the cultural meanings of the technologies can be seen in the language and symbolism that are created around them (Wyatt, Henwood, Miller & Senker, 2000). Policy questions about technologies tend to focus on the control and use of 'ICT' in schools. These are questions about what human, organisational and physical models ought to be adopted; the nature of decision-making exercised; and who has access to the skills, facilities and knowledge essential to design, implement and employ technologies for teaching and learning purposes.

Given there are now varying interpretations of the meaning of 'ICT', understanding what is intended in any specific policy has to be developed by drawing upon the context and processes surrounding the use of the phrase. For the purposes of this review paper, the terms 'technologies' or 'digital technologies' will be used where an encompassing term is implied, and when it refers to networked computers linked to the Internet. The phrase 'information and communication technologies' ('ICT') will be used in this review paper, where its use is consistent with other references and with the context in which it is being used, such as when discussing national, state and territory policy documents. Where software or hardware other than networked computers linked to the Internet or combined services are intended, reference will be made by name to that process or specific piece of technology.

Technologies in Australian schools

The computing infrastructure provisions of Australian schools usually include the hardware, software, Internet services, networking and connectivity requirements necessary for the teaching and learning and for the administration of schools (Grimes, 2008). Wireless access to the Internet, personal digital assistants (PDAs), and other mobile devices, such as notebooks and laptops, are all examples of common technologies found in schools and labelled as ICT (see for example, Australian Bureau of Statistics (ABS), 2008).

A broad range of school activities are supported through an information technologies (IT) or a technological infrastructure, such as:

- teaching and learning in classrooms, in computer laboratories and at home (for example, through using computers and the Internet to support the use of interactive whiteboards; learning and content management systems; real-time, social learning software; virtual learning environments such as Second Life; and Web 2.0 applications)
- administration and record-keeping (for example, with databases that record students' attendance, students' family background and contact details, student achievement outcomes, finance and asset management)
- information provision within and outside the school (for example, through online daily bulletins, newsletters and media releases)
- communication to teachers, students and parents (for example, using email, SMS messaging or the announcements functions of learning management systems)
- simulations and knowledge-building activities (for example, using Web 2.0 and Web 3.0 functionality)
- online content provision (for example, through the use of publicly and privately developed materials accessible over the Internet such as learning objects and online books)
- borrowing books (for example, through the use of online school library services).

The devices (or hardware) that support these respective school activities each employ different sorts of software applications. Both synchronous and asynchronous software is used to support face-to-face and online learning. Synchronous software enables learning to occur with students and/or educators taking part in activities at the same time and sometimes in the same place. Examples of synchronous software include the group facilitation and team-building software *Zing*; the voting software that supports ‘clickers’, which are devices designed to allow students to anonymously answer multiple-choice questions during lectures and gain instant feedback on their own response in relation to their classmates; and software systems that support both real time and asynchronous learning such as *Elluminate* and *Centra*. Asynchronous software enables learning to occur at any time and in any location that has computers with access to the Internet. Learning management systems such as *Moodle*, *Blackboard* and *WebCT* are common software applications used to support asynchronous learning.

Emerging challenges

Technologies offer educators and students alike opportunities for creating meaningful learning environments. Technologies enable different types of social interaction, provide ready access to information and can overcome some of the difficulties presented by time and space. Students can create new materials, artefacts and new knowledge with the media tools now available to them. These tools are constantly evolving as individuals and companies create and refine new software. The futurist Alvin Toffler is reputed to have predicted some 30 years ago that ‘... the illiterate of the 21st century will not be those who cannot read and write, but those who cannot learn, unlearn, and relearn’.

Including technologies in teaching and learning requires a reconceptualisation of the curriculum and how it can be taught. Using technologies to simply replace blackboards with whiteboards and pens with computers and word processors does not constitute a reconceptualisation of teaching and learning, nor the nature of school education. Such an approach will not support students to ‘learn, unlearn, and relearn’.

Studies over the past decade have tended to show that using technologies to improve students’ learning outcomes is difficult to demonstrate. Indeed, in the United States of America a recent, large-scale study found that, even with good hardware and educational software, little learning benefit for students was identified (Dynarski, Roberto, Heavyside, Novak, Carey, Campuzano, Means, Murphy, Penuel, Javitz, Emery & Sussex, 2007). Furthermore, Cuban (2001) described how the use of computers in classrooms did not result in improved learning opportunities for students. Such studies demonstrate that using technologies to support a pre-existing curriculum is of contested effectiveness. Instead, they point to some of the challenges facing teachers as they shift to student-centred teaching and learning approaches that include technologies. Other studies point to the potential of technologies to address the complex set of challenges facing the world: addressing issues such as climate change and feeding the planet (Puttnam, 2009). Rather than simply trying to slot technologies into the curriculum, however, educators are now afforded an opportunity to rethink the ways in which they carry out their work. This shift calls for more demanding professional pedagogical repertoires than those that have been required in the past (Johansson, 2000).

One of the promises of integrating technologies into classrooms, a promise commonly made in the United Kingdom and increasingly in Australia, is that technologies enable teachers and schools to become ‘learner-focused’ (Hargreaves, 2004; Higham, Hopkins & Ahtaridou, 2007; Puttnam, 2009). There is an increasing emphasis on designing schools for personalised learning, and as a result, school leaders and policy-makers are considering how schools can approach capital works projects to successfully implement personalised learning; and how best to include technologies in physical environments created to assist in enabling personalised learning opportunities at school (Higham, Hopkins & Ahtaridou, 2007).

The trends towards standardisation of school curricula and the often large numbers of students in classes, however, can make the transition to more personalised forms of learning difficult. One of the ways in which schools are working to achieve personalised learning for

students is to use technologies. 'Virtual learning environments', provided through learning management systems such as *Moodle* and *Blackboard*, are seen to offer students and teachers the capacity to personalise students' learning opportunities, and to put students in control of the pace of their learning. Personalised learning strategies place an emphasis on self-direction and self-reliance. Trust is placed in the learner to make thoughtful and meaningful choices about what they learn and how they will learn it (United Nations Educational, Scientific and Cultural Organization (UNESCO), 2009). One of the leading educational software applications used in over 80 countries to personalise students' learning has been developed in Australia. The Learning Activity Management System (LAMS) provides teachers with simple software tools to design, post and manage online, self-paced learning activities. It provides teachers with visual authoring tools for creating sequences of learning activities, which can range from individual tasks and small group work to whole class activities (LAMS International, 2009).

While there is a certain attraction to promoting personalised learning opportunities through using technologies, Australian school leaders and Australian students have indicated that students not only enjoy working individually on personalised activities, but also value working together on collaborative activities (Moyle & Owen, 2009; Moyle, 2006). Students want to be taken seriously as individuals, and to be excited and challenged by ideas (Moyle & Owen, 2009). In the attempts by educators to make students' learning more meaningful to them personally, care has to be taken not to lose sight of the fact that much learning occurs through dialogue with others and through working in teams to solve problems.

Young people are surrounded by moving images of many kinds, and sorting the good from the bad and the useful from useless requires the assistance of educators. More than ever, students require an extended awareness of narrative in order to understand the power of moving images (Puttnam, 2009). They require teachers to assist them to develop their own understandings of their world, so that they can frame thoughtful and informed responses to sites such as *YouTube* and other social networking sites. With the support of their teachers, ignorance and prejudice can give way to thought and rationality, and as this happens young people become informed, imaginative, critical and literate digital participants. The challenges for educators in the 21st century can then be summarised as requiring fresh thinking about what is taught, how it is taught and why it is taught.

Structure

This review paper begins by discussing the national and international policies that influence school education in Australia, especially those concerning the two intersecting national school education policy priorities of how to meaningfully include technologies into teaching and learning, and how to build innovation capabilities in students.

The education and economic policy contexts for digital education in Australia, their intersections with international economic priorities and the role of markets, are discussed in Section 2. That section is context for Section 3, which discusses Australia's education policy priorities which focus upon using technologies to support students to build both their discipline-based and general capabilities, including their abilities to be creative and innovative. Section 4 looks at students' current common practice when using technologies for learning and communicating and collaborating with each other, inside and outside of school. Then, in Section 5 the discussion moves to focus on the physical and human characteristics that are required to make a 21st century school. Finally, in Section 6, the discussion challenges existing paradigms of technology use in schools, and focuses upon the implications for teaching and learning with technologies arising from the current national and international policy directions concerning education.

National and international policy agendas

A common theme in many countries' national policies is that innovative, knowledge-based economies driven by talent and creativity are the way to build sustainable societies in the future. Innovation within nation-states is highlighted in both economic and education policies, as fundamental to regional, national and international competitiveness as countries reposition and re-structure in response, not only to the global financial crisis, but also to climate change, demographic changes, and increasing energy and food prices (OECD, 2009a; Australian Government, Department of Innovation, Industry, Science and Research (DIISR), 2009).

To improve countries' international competitiveness and to address the global financial crisis, political and government leaders in countries in the OECD, such as Australia, have argued that innovation, technologies and education are fundamental to generating sustainable, productive and competitive national economies. Further, they have argued that such economies have to be supported by local and regional knowledge systems, well-educated people and public policy that fosters innovation activities (Australian Government DIISR, 2009; Bradley, Noonan, Nugent & Scales, 2008; Cutler, 2008). As a result, there are symbiotic interrelationships between Australia's education, economic, innovation and technologies policies, and at the end of the first decade of the 21st century, these relationships are being strengthened. Underpinning these relationships, the following propositions tend to be put in documents such as the Australian Government's response to the 'Productivity Group' at the 2020 *Summit* (Australian Government, 2009), and in policies such as *Powering Ideas: An innovation agenda for the 21st century (Innovation Agenda)* (Australian Government, DIISR, 2009). These texts indicate that:

- Using technologies is contributing to the development of globalised workforces.
- High-performing economies' productivity is underpinned by high levels of post-school education participation.
- Having an increased proportion of the population with higher level skills is a critical advantage to respective regions' and countries' competitiveness.
- Links between productivity and human capital are leading to the restructuring of education and training systems.

The links between a country's economic competitiveness and the knowledge, skills and capabilities of its people, including their capacity to use technologies and to innovate, are woven tightly together by policy-makers, economists and multinational companies, which result in the intersections of these policies focusing on the education and training systems of a country, as the following statement illustrates.

The economy of leading countries is now based more on the manufacture and delivery of information products and services than on the manufacture of material goods and even manufacturing depends upon innovative uses of information and communication technologies [ICT]. ... These economic and social trends have implications for education.

(Cisco, Intel & Microsoft®, 2008, p. 1)

The notion of basing economies on information products and services is often referred to as the 'knowledge economy'. Drawing relationships between educating people in Australia and the requirements of a knowledge economy, Bradley et al. (2008) outlined in the *Review of Australian Higher Education* that:

As the world becomes more interconnected and global markets for skills and innovation develop even further, it will be crucial for Australia to have enough highly skilled people able to adapt to the uncertainties of a rapidly changing future.

(Bradley et al., 2008, p. xi)

In the schools sector, the backdrop of globalisation and technological change provides the context for education, as the *Melbourne Declaration* states:

Globalisation and technological change are placing greater demands on education and skill development in Australia and the nature of jobs available to young Australians is changing faster than ever.

(MCEECDYA, 2008, p. 4)

Both the *Review of Australian Higher Education* and the *Melbourne Declaration* recognise the pressures from global markets, acknowledge international pressures on national economic policies and foreshadow the implications for education and training systems, including schools.

Australian education policy context

What happens in schools and school systems is deeply social and political (Apple, 2004). Relationships between education and Australia's economic priorities can be seen in current national policies. The relationships between the economy and education are not new (Wyn, 2009). Rather, the policy directions of past decades are being reinforced. Ways of understanding these dynamics and directions in school education policies can be found in the nature of the discourses through which policies are framed and how the debates around them are expressed (Reid, 2000). Through what is published in policies and what is taught, schools symbolically and practically capture what is considered to be of value to a society at any given time.

In Australia the responsibilities for school education sit within multiple policy contexts at local, national and international levels. Legislative responsibility for school education rests with state governments, while the Australian Government has the capacity to exercise power and control through the financial grants it provides to the states and territories (see, for example, Council of Australian Governments (COAG), 2009). As a member of the OECD, Australia participates in the *Programme for International Student Assessment* (PISA). How Australia's PISA test results compare with those from other countries is used to inform policy directions in Australia (Gillard, 2008a; Graham, 2008).

Digital education

With the Australian Labor Party winning the 2007 federal election, promises of a *Digital Education Revolution* (Rudd, Swan & Conroy, 2007) became Australian Government policy. The aim of the *Digital Education Revolution* is to:

... contribute sustainable and meaningful change to teaching and learning in Australian schools that will prepare students for further education, training, jobs of the future and to live and work in a digital world.

(Australian Government, DEEWR, 2008a, p. 1)

Current policy directions concerning teaching and learning with technologies build upon the policy *Learning in an online world: School education action plan for the information economy* (Education Network Australia (EdNA) Schools Advisory Group, 2000) and its associated suite of documents. The economic role of schools is unashamedly advocated in *Learning in an online world*, which states that:

School education provides the foundation for the information economy and the knowledge society.

EdNA Schools Advisory Group, 2000, p. i)

This policy also emphasises that all students should leave school with the:

... employment-related skills needed in the information economy and [that] an increased percentage [of students should] commence pathways to employment in the ICT industries.

(EdNA Schools Advisory Group, 2000, p. 5)

Almost a decade later, a central focus of the \$2.2 billion *Digital Education Revolution* is to provide computers to all secondary school students in Years 9 to 12, over the five years to 2012 (Australian Government, DEEWR, 2008a). Computers are being provided through the *National Secondary School Computer Fund*. This is the first time in Australia's history the federal government has directly funded the provision of computing hardware and software to schools. There are some parallels though, with the introduction of science laboratories by the Menzies Government. During the November 1963 federal election, Menzies announced that, if re-elected, his government would make use of Section 96 of the Constitution, which allowed the federal government to make specific purpose assistance in the form of grants, for science laboratories in government, and controversially, in non-government schools (Wilkinson, 2008). In 1964, all secondary schools, both public and private, were granted funding from the Australian Government, through the introduction of the *States Grants (Science Laboratories and Technical Planning) Act No. 50 of 1964* (Stapleton, 1998).

The *Digital Education Revolution* policy also commits the Australian Government to provide broadband connections to schools (Australian Government, DEEWR, 2008a). One of the primary purposes of providing increased bandwidth to all schools is to support the introduction of a national curriculum.

National Curriculum and the Melbourne Declaration

In 2008, the Australian Government passed legislation to establish the Australian Curriculum, Assessment and Reporting Authority (ACARA) to:

... develop and administer a national school curriculum, including content of the curriculum and achievement standards, for school subjects specified ...

(Australian Government, 2008, p. 5)

It is intended that the *National Curriculum* is to be developed, taking into account the student learning outcomes identified in the *Melbourne Declaration*. These outcomes include the development by students of:

... deep knowledge within a discipline, which provides the foundation for inter-disciplinary approaches to innovation and complex problem-solving, ... and the development of practical ICT, design and technology skills, as these are ... central to Australia's skilled economy and provide crucial pathways to post-school success.

(MCEECDYA, 2008, p. 13)

The development of the *National Curriculum* along with the *Melbourne Declaration* are seen to be not only beneficial to individual students, but also fundamental to achieving increased productivity in the Australian economy.

From 2011, the *National Curriculum* is to cover the year levels Kindergarten to Year 12 in specified learning areas. Aligned to the *National Curriculum*, ACARA is to oversee a national assessment program that measures students' progress on specified outcomes (ACARA, 2009). The first phase of the *National Curriculum* development involves the preparation of curricula for implementation from 2011, in the learning areas of English, mathematics, science and history. A second phase of curriculum development in languages, geography and the arts is expected once the first phase of development is complete. Consistent with the *Melbourne Declaration*, the curriculum in each learning area is to be based upon a continuum of general capabilities, including literacy, numeracy, creativity and ICT skills (ACARA, 2009). The general capability of 'creativity' is seen as being closely linked to innovation and enterprise, where 'creativity' requires young people to exercise:

... intellectual flexibility, open-mindedness, adaptability and a readiness to try new ways of doing things.

(National Curriculum Board, 2009, p. 12)

It is intended that the curriculum documents for each learning area will specifically outline how these general capabilities will be included in each learning area, and how links will be made between the respective learning areas (National Curriculum Board, 2009). In addition, at an aspirational level, the *Digital Education Revolution*, the *Melbourne Declaration* and the development of a *National Curriculum* are intended to intersect. In policy development and practice however, these intersections are currently still under development.

Intersections of policies

Along with the interplays occurring between education and economic policies, technologies are seen as one of the ways in which innovative capabilities in students can be built. Current and past policies emphasise several interrelated initiatives aimed at building the education and therefore the 'innovation base' of Australia's population.

Intersections between Australian national education and economic policies are located within a globalised setting. Government and non-government policies and reports around the world for the past couple of decades have proclaimed the importance of including technologies in education and training for the benefits of both individuals and their communities (see, for example, Commonwealth Schools Commission, 1984; Cuttance, 2001; Dutta & Mia, 2009; MCEECDYA & MCTEE, 2008; OECD, 1998; Papadopoulos, 1994; Standards Council of the Teaching Profession, 1998; United Nations ICT Taskforce, 2003). Furthermore, in 2009, Klaus Schwab (Executive Chairman, World Economic Forum) argued that education and technologies are critical for countries to continue innovating their processes and products and to thereby maintain a competitive advantage in the global economy. The intersections between Australia's economic performance and school education are outlined here, not to justify this approach to policy, but to illustrate the strong policy links between economic and education policies, a topic also discussed in the most recent *Australian Education Review* (Wyn, 2009).

Organisations such as the World Economic Forum and the OECD use household access to and use of computers, and the population's access to and use of telephony and the Internet,

as indicators of socio-economic progress and of economic productivity (Dutta & Mia, 2009; OECD, 2003, 2005, 2006, 2007). According to the World Economic Forum, in 2008–09, for the third consecutive year, Denmark and Sweden were assessed as the world's most networked economies (Mia, Dutta & Gieger, 2009). The Australian Bureau of Statistics (ABS) also uses computer and Internet access by households and businesses as one of the indicators of Australia's progress (ABS, 2009). The ABS data shows that over the past decade Australians have increasingly used the Internet and computers at home and at work. Indeed, between 1998 and 2004–05, access to the Internet from home grew to 56 per cent of Australian households (ABS, 2009, p. 1), and since 2006 the adult mobile phone market has become almost saturated (Australian Mobile Telecommunications Association (AMTA), 2008; Roy Morgan Research, 2006). In 2008, the most common way contact was made by the public with the Australian Government was through the Internet (Australian Government, Department of Finance and Deregulation, 2008).

Implications of the global financial crisis

Since 2007, the governments of many countries have struggled to handle the impact of the global financial crisis. Stock markets have collapsed, banks and other financial institutions have become insolvent, and governments, in response, have created rescue packages to avert economic and associated social crises from the fallout of the global financial crisis (International Federation of Accountants (IFAC), 2009; International Monetary Fund (IMF), 2009; Shah 2009). The OECD recommended strategies by which countries might alleviate the effects of the financial crisis (OECD, 2009b), suggesting that national and local governments put in place economic stimulus packages which include investments in education and educational infrastructure as a way of building economic demand (OECD, 2009a).

The OECD also argued that the global financial crisis presented countries with an opportunity to raise their levels of investment in people, or human capital, by including education and training initiatives, together with new education infrastructure, in their respective stimulus packages (OECD, 2009b).

Many countries face challenges regarding school buildings. Renovating the school infrastructure (e.g. integrating ICT and building more ecologically-friendly schools) can foster more innovative and effective learning environments.

(OECD, 2009b, p. 14)

The OECD further argued that there are multiple benefits to be gained from investing in a nation's human and physical infrastructure, as innovation is a key driver for economic growth.

Many of the stimulus packages being introduced in OECD countries include components to support innovation, entrepreneurship, infrastructure, human capital and green investments, to foster more efficient and sustainable economic growth.

(OECD, 2009b, p. 15)

Several OECD countries have chosen to invest in education and education infrastructure as part of their economic stimulus packages (OECD, 2009c), and in Australia, the \$16.2 billion school infrastructure program *Building the Education Revolution* initiative, of which \$14.1 billion was allocated to rebuild primary schools for the 21st century, was introduced specifically as an economic stimulus package (Australian Government, DEEWR, 2009b). Similarly, as part of the overall US government economic stimulus package in the United States Recovery Act, \$US650 million was allocated to fund the *Investing in Innovation Fund* (or the i3 program), of which \$US100 million was earmarked for use in 2010 to fund, on a competitive basis, the scaling-up of:

... educational practices with significant evidence of success in improving student achievement and support [the] development, implementation, replication, and further evaluation of promising innovative practices.

(United States Department of Education, 2009b, p. 1)

Innovation

Together then, innovation, education and technologies are constructed in policies in Australia and overseas, as the foundational requirements for sustainable 21st century economies. But if innovation, technologies and education are fundamental to creating sustainable economies, then what does this mean for Australian school educators and their students? How can innovation be built? And what does ‘innovation’ mean in the context of school education? Indeed, how can students’ innovative capabilities’ be developed? Further, how do the respective policies concerning school education, including technologies in teaching and learning, and building a creative and innovative workforce, interface? These are questions school educators have to address if they are to build students’ innovative capabilities with technologies.

Defining innovation

The word ‘innovation’ and the concept of being ‘innovative’ are liberally used throughout various individual countries’ and international agencies’ policies and reports (see, for example, Australian Government, DIISR, 2009; MCEECDYA, 2008; OECD, 2009a, 2009b). In the Australian policy context, the dominant use of the term ‘innovation’ mainly has economic meanings, which relate to improving the productivity and competitiveness of national and local economies (Australian Government, 2009). Interpretations and applications of the word ‘innovate’ can vary depending on the individual’s frame of reference. Rarely, however, are the economic concepts of ‘innovation’ reviewed in the context of current national school education policies.

Research and innovation, and science and innovation are often linked together in Australian policy documents, as are the concepts of innovation, building knowledge-based economies and using technologies to build innovative organisations (Bradley et al., 2008; Cutler, 2008; Australia Government, DIISR, 2009). Given the different contexts in which the concept of ‘innovation’ is used, a brief review of some descriptions attributed to the concept of ‘innovation’ will be provided here. This discussion informs our understandings, so that the concepts of ‘innovation’ in policy documents have meaning in the context of school education.

Dictionaries define ‘innovation’ as ‘introducing something new’: the Latin stem ‘innovare’ refers to altering or renewing, and is derived from ‘novus’, meaning ‘new’ (Little, Onions & Friedrichsen, 1973). That is, an innovation is something that is new, is positively different, or is better than what was there before. Innovations however, do not exist objectively or in an unchanging sense. Concepts of newness or reformation are viewed differently by different people, and to categorise something new as ‘innovative’ places additional meaning on its value or relevance. As such, to be ‘innovative’ is an affirmative description of an artefact or a process.

In Australia, the *Review of Australian Higher Education* placed research and innovation together.

Research and innovation play a pivotal role in Australia’s international competitiveness and ongoing prosperity. Universities contribute through their research and innovation efforts to the nation’s economic growth and productivity.

(Bradley et al., 2008, p. 11)

Implicit in the concept of innovation is that creativity and imagination underpin innovative capabilities. At the turn of the 21st century, policy-makers drew links between developing

the imaginative capabilities of the population and the economic priorities of Australia, as the following excerpt from *Learning in an online world* illustrates:

For educators, the challenge is how best to change and improve the quality of teaching and learning in order to contribute to Australia's development as an equitable, imaginative and economically strong knowledge society.

(EdNA Schools Advisory Group, 2000, p. 1)

While encouraging students to be creative involves encouraging them to use their imaginations and to be innovative, it also involves teachers and students learning how to constructively learn from making mistakes. Building innovation and creativity requires educators to move beyond rewarding students for providing correct answers to problems, to also rewarding them for their effort and ideas. This requires the processes of learning to be valued as well as the outcomes. This is not new. Children learning to play with a computer game like SimCity or a flight simulator will try out ways of completing the tasks required. Inevitably they will come across tasks that they fail to successfully complete. They will try again and again until they succeed. This is how human beings learn, and the tasks have to be sufficiently engaging to keep students motivated to learn.

But such approaches to learning, where success and failure are intermingled, are counter-intuitive to the way many educational environments are currently set up. This is partly because the stakes associated with failure for students and teachers are often too high for failure to be an option. In many schools, accountability requirements put pressure on both teachers and students to provide the right answers to problems and to achieve highly on external tests (Robinson, 2001; Sahlberg, 2009). An irony of Australia's education policies is that they place an emphasis on achievement, yet the fostering of creativity and innovation is stifled where there is a fear of failure. This fear reduces the capacity of both students and teachers to take risks, and therefore impedes their abilities and opportunities to be creative and innovative (Sahlberg, 2009). As such, some of the critical conditions required for creativity to flourish are environments where there is trust between teachers and students, and where the consequences for students and teachers of making mistakes are reduced.

Some of the literature on innovation distinguishes between the concepts of innovation and inventions, where an invention is a new idea that becomes an artefact, and an innovation is a new idea or set of ideas successfully applied to processes or practices (Davenport, 1993). That is, innovation can be conceptualised as an organisational phenomenon, where to be innovative refers to putting in place practices that are substantively different from, or have more desired outcomes than what has gone before.

In an education context, the United States Secretary of the Federal Department of Education illustrates the distinctions between invention and innovation as follows:

Educational innovation should not be confused with just generating more great ideas or unique inventions. Instead we need new solutions that improve outcomes – and that can, and will, be used to serve hundreds of thousands of teachers and millions of students.

(Duncan, 2009, p. 1)

Duncan is making the distinction between an invention and an innovation, indicating that innovation requires going further than a single invention. Inventions are conceptualised as a first step towards an innovation. Such a view links the concept of innovation with that of 'scalability', where an innovation takes an invention to scale, making the invention an innovation. Some economists argue, however, that inventions and innovations are no more than artefacts placed along a continuum of product commercialisation (Fagerberg, 2003), where invention is considered to be the discovery of something new, and innovation is the commercialisation of that invention. Equating commercialisation with innovation, however, is a narrow view of innovation. More recent economic approaches to the concept of innovation take a systemic view, often Keynesian in nature, which includes the field of education.

Economic innovation

In an economic sense, ‘innovation’ is seen as fundamental to building a productive and competitive economy (Australian Government, 2009; Australian Government, DIISR, 2009). Some early work linking economics and innovation was undertaken by Joseph Schumpeter. In his book, *The Theory of Economic Development* (1934), he described innovation as being constituted by one or more of the following characteristics:

- the introduction of a new good or of a new quality of a good
- the introduction of a new method of manufacturing
- the creation of a new market
- the identification of a new source of supply of raw materials or partly manufactured goods
- the organisation of new processes within an industry.

Views such as Schumpeter’s have led to understandings that equate innovations with patents of new products and/or processes.

More recently, the Harvard Business School’s Michael Porter is attributed with conceptualising innovation as a tool of economic regeneration linked to the notion that competitive advantage is achieved by adding value to products and services (that is, by being innovative), through research, development and design (von Prondzynski, 2009). Porter argues that the location of where value is added is the variable that is likely to create competitive advantages in the global marketplace (Porter, 1998). To illustrate Porter’s thinking by drawing on Australian work, Cutler (2008) has argued to the Australian Government, that:

... through advances in ICT and efficiencies in production and logistics, global supply chains are becoming more disaggregated and open to greater competition. A country which understands and specialises on specific parts of the supply chain can grow in competitiveness and gain access to new markets.

(Cutler, 2008, p. 21)

Porter’s research has also informed work undertaken by the World Economic Forum, which publishes annual reports of countries’ global competitiveness. The World Economic Forum draws on the work of the Global Competitiveness Network, which produces the annual *Global Competitiveness Reports*. The reports provide an analysis of countries’ competitiveness based on the *Global Competitiveness Index* (GCI). This *Index* is used to measure national competitiveness, using both microeconomic and macroeconomic foundations of national competitiveness, where ‘competitiveness’ is defined as:

... the set of institutions, policies, and factors that determine the level of productivity of a country.

(Porter & Schwab, 2008, p. 3)

On the overall index for global competitiveness, of the 133 countries measured for the 2009–10 *Global Competitiveness Report*, Australia was ranked 15th behind Switzerland (first), the United States of America (second), and Singapore (third) (Schwab, 2009).

Measuring innovation

The *Global Competitiveness Network* uses ‘12 pillars’ of economic competitiveness to evaluate global competitiveness. These 12 interrelated pillars include primary and higher education (which includes secondary education); technological-readiness of the nation’s population, government and businesses; and measures of innovation (Schwab, 2009). The authors of the *Global Competitiveness Report* separate technological-readiness from innovation, although innovation and technological-readiness measures are highly aligned. Indicators of innovation include the capacity within a country for innovation, and the quality of the country’s scientific

research institutions. Education and training, therefore, are seen as fundamental to economies rapidly restructuring in line with innovation agendas.

The authors of the *Global Competitiveness Report* also identify characteristics they consider underpin different sorts of economies, indicating that ‘innovation driven’ economies, such as Australia’s, are the most highly competitive and require higher levels of education, and sustain higher wages and associated standards of living. On average in 2009–10, the performance of all countries operating as ‘innovation economies’ fell, with Australia ranked 20th in the world (Schwab, 2009). Furthermore, of the 15 most problematic factors identified for doing business in Australia, an ‘inadequately educated workforce’ was rated 7th out of the 15 variables identified (Schwab, 2009). The OECD has also observed that Australia’s Year 12 retention rates are still marginally below the OECD average and well below the top six performing OECD countries (OECD, 2008). This data provides strong motivation for both politicians and policy-makers to put into place strategies to increase the quality of students’ outcomes on international benchmarks, and to keep students in school longer, as outlined in the *Melbourne Declaration*.

Innovation, science and technologies

The World Economic Forum’s *Global Competitiveness Index* also links innovation with science, technologies, and research and development for measurement purposes. Of the 133 countries included in the 2009–10 *Global Competitiveness Index*, on the single measure of the 12th pillar concerning ‘innovation’, Australia was ranked as follows on each of the indicators:

• <i>Capacity for innovation</i>	26th
• <i>Quality of scientific research institutions</i>	10th
• <i>Company spending on research and development</i>	20th
• <i>University–industry collaboration in research and development</i>	14th
• <i>Government procurement of advanced technology products</i>	42nd
• <i>Availability of scientists and engineers</i>	34th
• <i>Utility patents</i>	15th

(Schwab, 2009, p. 75)

It can be seen that although Australia rated 15th overall on the *Global Competitiveness Index*, performance on the ‘innovation’ indicator reflects a lower achievement on this measure compared to other countries in this *Index*.

Related to this 12th pillar measuring ‘innovation’ is the measurement of the 5th pillar – higher education and training, which includes both secondary and tertiary education. Indicators of the 5th pillar include participation rates in secondary and tertiary science and in maths education, and take into account the availability of the Internet in schools (Schwab, 2009). In 2009–10, although Australia was ranked 14th of 133 countries for the overall quality of its education and training systems, it was ranked 30th for the quality of its post-primary maths and science education, and 25th for the provision of Internet access to schools (Schwab, 2009). These World Economic Forum comparative rankings provide some insights into why science and technologies are seen as key parts of Australia’s *Innovation Agenda*:

... investment in science and technology is critical to the growth of knowledge-based economies ...

(Australian Government, DIISR, 2009, p. 3)

The World Economic Forum also annually produces *The Global Information Technology Report*. The most recent of these is the 2008–09 Report, which aims to provide data to the international community on countries’ ICT networked-readiness and about the principal drivers for increasing the national deployment of technologies. The authors of this report argue that technologies are an enabler of socio-economic progress and development, and enhance productivity and economic growth (Dutta & Mia, 2009). As such, they indicate that high-speed broadband

networks form a basic infrastructure component of a country and are one of the foundations of a nation's knowledge economy (Dutta & Mia, 2009).

In Australia, initiatives such as the *National Broadband Network* and the associated school bandwidth initiatives, supported by a contribution of \$100 million from the *Digital Education Revolution* to roll out high-speed bandwidth connections to Australian schools (Australian Government, DEEWR, 2009a), create alignments between these national policies and the international measurements used to judge countries, international competitiveness and technology-readiness. Furthermore, school education policy initiatives such as the *Education Revolution* are also consistent with approaches to measurement used by the World Economic Forum education policies, as can be seen from the Australian Government's *Innovation Agenda* (2009):

Investment in Australian innovation is supported by investments in infrastructure to sustain the innovation process – including the National Broadband Network – and the Education Revolution, which is transforming every stage of the learning journey from pre-school to post-doc.

(Australian Government, DIISR, 2009, p. 2)

Good education systems, high levels of technological-readiness and innovation, are seen as essential engines of economic growth. These characteristics are considered necessary if countries' economies are to overcome the recent financial crisis (Dutta & Mia, 2009).

The Global Information Technology Report 2008–2009 (Geiger & Mia, 2009) also includes an index of countries' IT 'networked readiness', which is determined against indicators assessing the market, political, regulatory and infrastructure environments; individual, business and government readiness; and individual, government and business ICT usage. On the overall *Networked Readiness Index* of the 134 countries measured for the most recent 2008–09 report, Australia was ranked 14th behind Denmark (first), Sweden (second), and the United States of America (third) (Dutta & Mia, 2009). One of the indicators used to measure the infrastructure environment is expenditure on education. Australia ranked 48th out of the 134 countries assessed on this measure (Dutta & Mia, 2009).

Internationally and in Australia then, the interrelationships between education, science, technologies and innovation policies within an economic paradigm are evident. These interrelated policies are promoted in order to build and sustain national economies, including Australia's, in a global context. It is unlikely these interrelationships in Australian policies are accidental or coincidental, especially since it was the Deputy Prime Minister, and Minister for Education, Employment and Workplace Relations, Julia Gillard, who has represented Australia at recent World Economic Forums (Gillard, 2009). Given the interrelated nature of innovation, education and technologies policies, however, a challenge for educators is to determine the implications of such policies, by asking 'What do these priorities mean for the work of educators and the studies undertaken by school students? How can innovation in students and educators be built?'

Building innovation and the role of schools

Since knowledge creation forms a part of almost all types of work (Porter & Schwab, 2008), school education is being constructed by policy-makers as the engine of a knowledge economy. Indeed, as national and international reports, policies and strategic plans emphasise the intersections between economic, scientific, technologies and innovation policy agendas, it is not surprising that the economic language of innovation has permeated Australia's and other countries' school education policies.

Australian Government policies and reports suggest that school education is considered a fundamental part of building the productivity of the Australian workforce. At the 2020 *Summit* held in 2008, school education was considered part of the 'Productivity Agenda' which dealt with education, skills, training, science and innovation (Australian Government, 2009). The Australian Government's ten-year reform agenda outlined in its *Innovation Agenda* (Australian

Government, DIISR 2009) has the aim to make Australia ‘more productive and more competitive’ (Carr, 2009, p. iii), and this includes schools along with training and higher education. The Australian Government’s report of the 2020 *Summit* outcomes illustrates this aim, stating:

The Government recognises that addressing issues of education, productivity and innovation will require investment in all levels of education, increased participation in the workforce and the implementation of best practices to stimulate and harness innovation.

(Australian Government, 2009, p. 8)

One of the key goals of the *Digital Education Revolution* is to ensure that innovative uses of technologies underpin all students’ learning, and that these approaches gain a strong foundation in all Australian schools (Australian Government, DEEWR, 2008a).

The *Building the Education Revolution* (Australian Government, DEEWR, 2009b), the Australian Government’s *Nation Building, Economic Stimulus Plan* (2009), the *National Curriculum* (ACARA, 2009), the *National Secondary Schools Computer Fund* which is a part of the *Digital Education Revolution* (Australian Government, DEEWR, 2008a; 2008b), and the teaching of maths and science, together form an interconnected base which is seen by policy-makers as central to achieving a more innovative Australia. The following extract from the Australian Government’s *Innovation Agenda* (2009) highlights how the Australian Government conceptualises the interconnections of these policies:

Most important of all, ... is the Commonwealth’s multi-billion-dollar Education Revolution. It is preparing young Australians for the future by giving them the skills they will need to participate fully in a knowledge-based economy and a democratic society. A national curriculum in the seven key learning areas – English, mathematics, science, history, geography, languages, and creative arts – will be implemented in 2011. It is particularly important that we build technology skills – as the Commonwealth is doing through the National Secondary School Computer Fund and related initiatives. It is equally important that we reverse the historic decline in the study of science and maths.

(Australian Government, DIISR, 2009, p. 40)

It is interesting to note that while policies such as the *Melbourne Declaration* and the *Innovation Agenda* indicate that students and teachers are to be producers of knowledge in a knowledge-economy, the *Innovation Agenda* above refers to:

... giving them [that is, students] the skills they will need to participate fully in a knowledge-based economy ...

(Australian Government, DIISR, 2009, p. 40, author’s emphasis)

This language suggests a tension in the policies, between the notions of students building their innovation capabilities with guidance from teachers, and the didactic concept of delivering existing content skills and knowledge.

In the context of an *Innovation Agenda* (Australian Government, DIISR, 2009), much is made of building students’ creativity and innovation capabilities in Australian official documents (Australian Government, 2009; Bradley et al., 2008; Rudd & Gillard, 2008; OECD, 2009a, 2009b). The main emphasis in these policies and reports, however, tends to be utilitarian, focusing upon the overall economic benefits of the human capital of the country being innovative and creative. Individual benefits are also constructed in utilitarian terms, highlighting that people who demonstrate innovative and creative characteristics have the skills profile required by the Australian workforce (Wyn, 2009). It is further argued by policy-makers that, as the competition for skilled workers becomes increasingly global, innovative and creative workers will have the skills necessary to set them apart from other workers (Bradley et al., 2008).

Arising from these policy directions there are implications for teachers if they are to create opportunities for students to learn knowledge-building strategies. Teaching and learning practices in school education have to provide opportunities for students to learn knowledge-building strategies (Zhang, Scardamalia, Lamon, Messina & Reeve, 2007). Schools then are being asked to develop the creative and innovative capabilities of students, not as a good end in itself, nor for artistic pursuits per se, but for the utilitarian and economic purposes of preparing students for work in the 'knowledge economy' (MCEECDYA & MCTEE, 2008).

The emphases in Australian policy documents and reports, like those in comparable countries around the world, reflect their economic purposes. Authors such as Robinson (2001) argue it is not a bad thing for countries to emphasise that students should develop creative and innovative capabilities, since it makes no sense for individuals not to do so. Indeed some argue that for too long teaching and learning in schools has focused on 'teaching to the test', rather than on the development of a broader range of capabilities, including creativity and innovation (Ballantyne, McLean & Macpherson, 2003). An implication for teachers, though, is that they now are to both teach to the test and to build students' general capabilities. This represents a deepening of the 'professional toolkit' teachers require to be effective educators in the 21st century. Educators require the capacity to include in their repertoire classroom strategies that build the innovation and creative capabilities of students, and to do so using technologies. At the same time, school leaders have to be able to foster innovative practices, which will enable innovative outcomes to be achieved by teachers and students in their schools.

Influence of markets

The provision in the 21st century, of school education where technologies are central to emerging demands, requires additional infrastructure and resources to that of the past. Attendance by students in physical spaces called schools remains a fundamental characteristic of Australian school education. However 21st century schools not only require the physical infrastructure of the past be maintained, but in addition, the present and future physical infrastructure of schools has to support teaching and learning with technologies. As such, 21st century schools are places where the choices made about technologies reflect both the technical requirements of the schools and the philosophical priorities of those directing these choices.

As previously mentioned, schools deploy a wide range of software for teaching and learning and administration purposes. At present, technologies' products and services are mostly provided to schools by the private technologies market. It is here that the provision of school education and the markets intersect. As a result, digital spaces used in schools are commercialised. Some time ago now, Kenway, Bigum, Fitzclarence, Collier & Tregenza (1994) argued that technologies:

... are becoming integral to the targeting and marketing projects of those who wish to cultivate consumers through schools.

(Kenway et al., 1994, p. 322)

They went on to suggest that:

... this has led to one particular manifestation of the market – a relatively new triad consisting of education, markets and information technology.

(Kenway et al., 1994, p. 322)

Kenway et al. saw this emerging 'market triad' as problematic, suggesting that educational democracy is being redefined:

... as consumer democracy in the education 'industry'. Investors are encouraged to see education as a site worth cultivating for various sorts of profit, and consumers are encouraged to seek the competitive edge.

(Kenway et al., 1994, pp. 321–322)

It should be remembered, however, that markets are not inanimate ‘things’. Rather, markets are behavioural constructions (Marginson, 1998), where there are social and economic interactions between vendors in the marketplace, and in this case, people in schools. Manufacturers of technologies start growing their customers around the time they enter school (McNeal, 1999). Companies target their products at children to establish and build brand loyalty (Beder, 2009). But the intentions and motivations of schools within a community, and those of private technologies companies in a market, are different. The role of vendors is to make profits in a competitive market environment. The roles of schools include providing students with educational opportunities that enable them to achieve to their fullest potential and preparing them to take their place in society. Both roles are legitimate, but different, and this tension should therefore be acknowledged. Unlike the intentions of most schools, however, markets construct powerful relationships based on dominance, submissiveness and control (Marginson, 1997). The construction of a ‘market’ is:

... determined by the political and the discursive, including economic knowledge joined to power ... [where] economies are never innocent of power. They are constituted by systems of domination-subordination and control, and help to contribute such systems in return.

(Marginson, 1997, p. 15)

Over a decade later, the views of Marginson and Kenway et al. seem to be almost prophetic. Schools are now firmly entrenched in IT markets. In Australia, the overwhelming majority of computer hardware and software used in schools is manufactured by companies owned by commercial interests located overseas. This means that the profits made from the sale of these commodities (bought with public money through programs such as the *National Secondary Schools Computer Fund*) are not always directed into Australian-owned enterprises or directly into schools, but instead go overseas through Australian branches of transnational and multinational companies such as Microsoft® Corporation, IBM, Apple, Cisco and Intel (see, for example, Department of Education and Early Childhood Development (DEECD), Victoria, 2009a). Given the amounts of money involved, there is surprisingly little debate in Australia about how taxpayers funds should be used to purchase various technologies for use in schools, and often only scant and dismissive consideration is given to alternative software and hardware solutions. These issues are explored further in Section 6.

Markets, furthermore, are not neutral places where buyers’ choices are unfettered. One strategy used by vendors constructing schools as markets is product branding. Advertising and branding of products are deliberately used by vendors to influence buyers’ choices, or in the case of children in schools, to influence parents’ choices through their children. These strategies are pervasive. Both Michael Apple (2001) and Naomi Klein (2001) have published books which include sections on product branding and schooling, particularly in the United States of America and Canada. They indicate that in those countries the product branding of goods and services provided to schools is a deliberate part of the marketing to students, parents and teachers. In Australia, the use of product branding occurs in schools through (for example) simply turning on a computer and waiting for the operating system to begin working. Doing this means that students and teachers are exposed, almost subliminally, to the software-maker’s branding. In Australian schools, this branding is most likely to be that of the Microsoft® Corporation. It is a potent mix of state and private sector policies that sees schooling as compulsory between the ages of five or six and fifteen or sixteen, and at the same time these students are treated as markets for various technologies by vendors.

Since markets are associated with unequal power relations, constructing students and parents within education markets places them into subordinate positions of power. Consider the case of the Microsoft Office® productivity software. Almost all Australian schools provide Microsoft Office® on their computers. Individual schools and most of the Australian state and territory departments of education have signed contracts with the Microsoft® Corporation for the provision of operating systems and other software. The recurrent costs to taxpayers,

for school students to simply boot-up a computer at school is, nationally, millions of dollars each year (Moyle, 2003). This widespread deployment of Microsoft® products establishes a 'commonsense' view (Gramsci, 1971) of the necessity for its products. At the same time the company receives legitimization and authority through the state for its products, given they are considered suitable for use in Australian schools. This acceptance of the commonsense value of particular software products over others then puts pressure on parents to have and maintain compatible software at home: the marketing strategy is circular, complete and self-sustaining.

Australia's heavy reliance on proprietary software over all other options is at odds with much of the rest of the world. The United National Educational, Scientific and Cultural Organization (UNESCO) maintains a free and open source software portal (UNESCO, 2005). European national governments such as France, Spain and Portugal are deploying open solutions for schools (see European Commission, 2008). This is also the case across much of Latin America, Africa and India (Free and Open Source Software Foundation for Africa, 2003; Free Software Foundation of India, 2002; Free Software Foundation Latin America, 2009). Schools in the United States of America are also deploying open source solutions, as is the US National Aeronautics and Space Administration (NASA) (NASA, 2009).

Unlike in Australia, Microsoft®'s dominance of the school education IT market in the United States of America has not gone uncontested. Indeed, as a result of findings against Microsoft®, arising from an extensive class-action lawsuit filed by 19 US states in the late 1990s and settled in 2006, over \$US1 billion has been made available by Microsoft® for schools in those states participating in the class action, to purchase hardware and software (see, for example, Department of Education, State of Vermont, 2009; weau.com, 2009). The person who initially led this US anti-trust case against Microsoft® was Mr Joel Klein when he was the US Assistant Attorney General (Klein, 1997; New York City Department of Education, 2009). In this position, he provided his views on Microsoft®'s behaviour in the market, and on the role of competition and anti-trust cases, to the Committee on the Judiciary in the United States House of Representatives. His testimony provides some insights into market competition in the US context. The following is an extract:

Sound antitrust enforcement is vital to America's economic health. American consumers and businesses benefit from a free market economy with antitrust enforcement. Protecting against anticompetitive actions helps consumers obtain more innovative, high-quality goods and services at lower prices and enhances the worldwide competitiveness of American businesses by promoting rivalry, encouraging efficiency, and ensuring a full measure of opportunity for all competitors. Indeed, contrary to the suggestions in some quarters, I believe that, as markets increasingly become global in nature, vigorous antitrust enforcement will help to ensure that American businesses will have the necessary incentives and ability to compete successfully on a global scale.

(Klein, 1997, p. 1)

Interestingly, Joel Klein is now the Chancellor of the New York Schools system, and it is this system's approach to teacher and school accountability which the Rudd Government seems to wish to emulate in Australia (Gillard, 2008b). Rather than adopting the accountability mechanism of this school system, however, it would arguably be of more value to draw on Klein's anti-trust work on behalf of American schools, and apply it to the Australian context. Competition and markets are not the direction in which many Australian or American educators wish to go (Beder, 2009). Yet in the United States of America, unlike in Australia, the anti-trust mechanisms of the state are working to ensure the monopolistic power of multinationals such as Microsoft® are to some extent mitigated against, in the schooling sector.

Concluding comments

There are international pressures then for building innovation in school education. The policy directions in Australia and overseas have stressed the importance to simultaneously:

modernise, professionalise and innovate while also placing reforms directed at effective learning.

(OECD, 2009d, p. 17)

It is against the economic backdrop of the effects of the global financial crisis, with the heightening of issues of international competitiveness, productivity and economic demands, that the economic roles of schools have been elevated to levels of pre-eminence over all other purposes of education. Sometimes the processes of innovation and creativity challenge past practices. Policy-makers are emphasising the necessity for changes to be made at multiple levels to structures and administrative systems of schools, but also to the culture and practices of teaching and learning.

To address these pressures, policy measures and implementation strategies have been and continue to be constructed to foster innovations in curriculum and in teaching and learning. These initiatives are aimed at building students' capabilities, making schools more innovative, and thereby making Australia more innovative, competitive and productive. But schools tend to be 'risk-adverse' and so putting into place policies and processes that actually support students to learn the characteristics of flexibility, risk-taking, innovation and creativity represents significant challenges for education systems. While employers argue that many jobs will require educated young people who have the ability to improvise, be innovative and creative, these abilities are neither taught nor prized in many schools (Johnson, Levine, Smith, Smythe & Stone, 2009). Sahlberg (2009), however, argues that creativity and risk-taking are not being fostered in teaching and learning because competition and the market are being seen as the best ways to improve education. Many educators do not approve of interventions by markets in schools, and are resistant to implementing their propositions. (Apple, 2004; Ashbolt, 2009).

Australia's education and economic policies promote the development by students of their innovation capabilities with technologies. These policies and priorities are consistent with directions being taken by comparable, developed countries. Unlike some of the countries akin to Australia, however, the influence of IT vendors and markets in schools is not left unfettered to the same extent as it is in the Australian schools sector.

Software, by its nature, structures the way students and teachers can frame their learning, and so it is likely there are interrelationships between the dominance of certain types of software, and the nature of teaching and learning that is possible. The ways in which software structures the way students can present their knowledge in assignments, and the implications of this for students' learning, however, requires more research. Section 3 investigates different curriculum approaches to building innovation in school education and the role of IT vendors in curriculum and assessment approaches in schools. Section 6 will invite further consideration of ways in which open education activities may be able to position students and teachers to be more in control of their learning with technologies.

Pedagogies and technologies

Educating students is the central purpose of those who work in schools and associated support services. While international and national policies and reports provide a context for understanding the current economic and education emphases placed on building innovation through school education, technologies provide us with a conceptual lens through which to rethink the emerging characteristics of school education (Moyle, 2006; Puttnam, 2009). Educational possibilities are presented as new technologies emerge and old ones become more powerful. As children and young people's uptake of technologies for use in their daily lives increases (Australian Communications & Media Authority (ACMA), 2009a), educators are reconsidering the nature of school education and the ways in which learning can become more technologically enabled.

Integrating technologies into teaching and learning is seen by many educators as affording opportunities to shift from teacher-centred to student-centred learning (Moyle, 2006). Placing students' learning requirements as the central focus of the work of a school was conceptualised almost half a century ago by John Dewey (1966), and with the diffusion of various technologies into classrooms, notions of child-centred learning are being revisited (Delaney, 1999; Resnick, 2007). Furthermore, in Australia and overseas, the curricula of schools are also being reconsidered to take into account the predicted future labour market conditions it is expected students will face on leaving school, with a view to raising the Australian population's overall level of qualifications by increasing the numbers of students retained in education or training (Bradley et al., 2008). The overarching Australian national schools policy, the *Melbourne Declaration*, for example, states:

To maximise their opportunities for healthy, productive and rewarding futures, Australia's young people must be encouraged not only to complete secondary education, but also to proceed into further training or education.

(MCEECDYA, 2008, p. 4)

Since current and future students will be leaving schools or other educational institutions to take up jobs that may not exist yet and are increasingly likely to be competing globally for work, policy-makers argue that students must be equipped with the generic competencies that underpin lifelong learning, where the concept of lifelong learning is assumed to include technologies (Wyn, 2009). That is, there is recognition that while subject-specific content is important, so are general capabilities.

Among the general capabilities proposed as important for students to develop, the capacities of being both innovative and creative are seen as fundamental. The benefits of developing these

capabilities underpin the Australian Government's response to the 2020 Summit held in April 2008, which reports the Australian Government is considering:

... a fundamental change in education to support innovation and entrepreneurship from the earliest years of schooling.

(Australian Government, 2009, p. 35)

But building innovation and creativity, or the 'creative capital' of Australian school students, is complex. Simply conceptualising notions of 'innovation' and 'creativity' as content areas that can be taught using technologies is not sufficient in itself. Rather, a widespread understanding is required by teachers and school leaders of how the processes of creativity and innovation can be developed in students, and how and where those processes can include technologies. It is against the policy backdrop outlined earlier, and in light of the emerging views about the relationships between pedagogies and technologies, that recent trends in curriculum, teaching and learning with technologies, and assessment are discussed in this section.

Innovation and the purposes of curriculum

It is through the functions of curriculum, teaching and learning, and assessment that views are afforded into the purposes of school education. During the mid to late 19th century, school education moved away from the province of the Church to that of the State (Hyams & Bessant, 1972). At that time, one of the purposes of schools was to prepare young people to be able to take their place in an industrial society (Wyn, 2009). In the 21st century, as outlined in Section 2, schools are now required to prepare workers for a 'new economy' that is dependent upon the production of knowledge (Australian Government, DIISR, 2009; Bradley et al., 2008). Indeed, the ability to innovate is now seen as one of the key capabilities of the knowledge economy (Committee for the Review of Teaching and Teacher Education, Commonwealth of Australia, 2003).

One of the ways proposed by the Australian Government to encourage innovation in schools is to mandate the creative arts (Australian Government, 2009). Many observers applaud this direction, suggesting it is long overdue. Others are concerned to have recognised that creativity is not limited only to the creative arts (McWilliam & Haukka, 2008). As such, creativity has a double meaning: while 'creativity' relates directly to the creative arts, it can also be considered to be a necessary general capability appropriate across discipline boundaries; that is, it is possible to be creative in all disciplines (Robinson, 2001). The generic nature of building students' creativity can be linked with the concept of creating something: either an artefact or a process. As Resnick (2003) indicates:

... in order to really develop one's creativity, one needs to develop the ability to create and a lot of times we both express ourselves most creatively and develop our creativity best, when we are in the process of designing things, creating things.

(Resnick, 2003, p. 1)

Students can learn to be creative and innovative working in social contexts on concrete tasks (Robinson, 2001). Therefore, even though the lever for including innovation and creativity into teaching and learning in policy contexts is economic, the consequences for the student of learning to be creative in social settings, and of getting feedback more broadly from their peers, can nonetheless be beneficial for all students in and across a range of subjects, and more generally in life.

General capabilities and the Australian curriculum

Underpinning the *National Curriculum* developments are the use of 'general capabilities' (National Curriculum Board, 2009). The *National Curriculum* is being based upon the

Melbourne Declaration (MCEECDYA, 2008), which indicates that young people are to develop a range of general employability skills that have particular application to the world of work, and to further education and training (MCEECDYA, 2008). The general employability skills identified in the *Melbourne Declaration* are:

... planning and organising, the ability to think flexibly, to communicate well and to work in teams ... the capacity to think creatively, innovate, solve problems and engage with new disciplines.

(MCEECDYA, 2008, p. 13)

The notion of general skills or capabilities to underpin students' learning originally gained some credence in the 1990s in Australia, when the (then) ministers of education endorsed seven 'key competencies'. These were:

- 1 *Collecting, analysing and organising information*
- 2 *Communicating ideas and information*
- 3 *Planning and organising information*
- 4 *Working with others and in teams*
- 5 *Using mathematical ideas and techniques*
- 6 *Solving problems*
- 7 *Using technology.*

(Mayer, 1992)

These competencies were identified, developed and agreed upon by a national Committee chaired by Eric Mayer who reported to the respective state and federal ministers of education (Mayer, 1992). In 2009, curriculum reform has returned to the concept of 'general capabilities' (National Curriculum Board, 2009), based upon the requirements of the *Melbourne Declaration*. Not so dissimilar to the 'Mayer key competencies', the new general capabilities to be covered in the *Australian National Curriculum* will be:

- *Literacy*
- *Numeracy*
- *ICT*
- *Thinking skills*
- *Creativity*
- *Self-management*
- *Teamwork*
- *Inter-cultural understanding*
- *Ethical behaviour*
- *Social competence.*

(National Curriculum Board, 2009)

The *National Curriculum* will also include the following cross-curriculum perspectives:

- *Indigenous perspectives*
- *Sustainable patterns of living*
- *Skills, knowledge and understandings related to Asia and Australia's engagement with Asia.*

(National Curriculum Board, 2009)

While this range of general capabilities and cross-curriculum perspectives is listed in the papers prepared to assist writers developing the respective national curriculum statements, there is not as yet any detailed outline of what constitutes these capabilities or perspectives. There are only superficial statements about their desirability, but no insights are provided about what constitutes the 'content' of each capability or perspective, nor how these respective capabilities and perspectives will be or ought to be sequenced across year levels and across discipline

boundaries. There are no indications either of how the knowledge of the respective disciplines and the capabilities and perspectives identified are to intersect and integrate, nor whether the general capabilities will be assessed and reported upon (Reid, 2009).

21st century skills

In the United States of America there is also considerable interest in building general capabilities, which are described in that country as '21st century skills'. This interest is particularly promoted by several multinational technologies and publishing companies such as Pearson Publishing, Microsoft®, Apple, Cisco and Intel. There is a degree of self-interest in their doing so. The more technologically literate students in schools become, the more justification companies have for marketing their products to those children, and for increasing the functionality and sophistication of technologies targeted to children and young people.

The Internet is now recognised as a common part of everyday lives of children and adults alike (see, for example, ACMA 2009a; Puttman, 2009). Studies suggest there are social and cultural drivers for the diffusion of technologies such as the Internet (Downie & Glazebrook, 2007; Roy Morgan Research, 2006). These are consistent with Rogers' *Diffusion of Innovations Theory*, originally published in 1962. According to Rogers (2003), the spread of technological innovations occurs over time, through particular social channels and through the members of a given social system. Educators and students within an education system or sector then, provide ready-made social groups for the introduction of new technologies. Educators however are finding that, in general, their students take up and diffuse new technologies (both hardware and software) more readily and rapidly than they do (Moyle & Owen, 2009). Indeed, students comment on the ICT skill levels of their teachers:

... most [of] the time we teach the teachers about IT. Well, it depends on the teacher, we don't teach the IT teachers.

(Moyle, 2008, data file)

In the 21st century, vendors are well aware that technologies such as the Internet and mobile phones are highly valued and fashionable to young people, and as such are very important to children's and young people's self-perceptions, identity and the practicalities of their lives. Indeed, in 2006, a survey by Roy Morgan Research found that 62 per cent of Australian children between the ages of 9 and 17 agreed with the statement that 'the way a mobile phone looks is important to me' (Roy Morgan Research, 2006). Furthermore, vendors are keen to make links between students' formal and informal lives and take market research about children's use of technologies and purchasing patterns, and link these to education. These approaches provide vendors with highly effective marketing strategies.

Constructing children and young people in schools as marketplaces, however, is not a new idea. James Rorty made the following observation in 1934:

... a democratic system of education ... is one of the surest ways of creating and greatly extending markets for goods of all kinds and especially those goods in which fashion may play a part.

(Rorty 1934 in Klein, 2001, p. 87)

In the 21st century though, technology vendors are going beyond treating school students as markets for their products, to actively lobbying on the nature of curriculum and assessment that should be undertaken in schools and by school systems. The *Partnership for 21st Century Skills* and the international *Assessment & Teaching of 21st Century Skills Project* are illustrative of how large multinational companies, at national and international levels around the world, are providing curriculum and assessment guidance to governments.

Partnership for 21st Century Skills

The *Partnership for 21st Century Skills* is a US-based advocacy organisation which is comprised mainly of senior members of the US technologies business community, along with a small number of educators. The Strategic Council for the *Partnership for 21st Century Skills* consortium includes representatives from big companies such as Microsoft®, Intel, Cisco, Blackboard, Adobe, Apple and Dell. An organisation comparable to the *Partnership for 21st Century Skills* does not exist in Australia.

The *Partnership for 21st Century Skills* website (2009a) indicates that generic skills or capabilities are essential for students to develop at school. This position has been developed against the backdrop of the US policy *No Child Left Behind* and limited resources being made available in the United States of America, between 2000 and 2008, for technologies in schools. As such, the *Partnership for 21st Century Skills* consortium has developed a curriculum framework for American education, and they use it to lobby US state and federal departments of education to adopt their *Framework for 21st Century Learning* (2009a).

This *Framework* comprises a set of core subjects or disciplines steeped in ‘21st Century Themes’, which consist of global awareness, financial literacy, civic literacy and health literacy. These themes are underpinned by the following ‘21st century skills’:

- Learning and Innovation Skills (for example, creativity and innovation, critical thinking and problem solving)
- Information, Media and Technology Skills (for example, information literacy, media literacy, ICT literacy)
- Life and Career Skills (initiative and self-direction) (*Partnership for 21st Century Skills*, 2009a).

The *Partnership for 21st Century Skills* further suggests that to build creativity and innovation, students have to learn how to think creatively, work creatively with others and implement innovations (*Partnership for 21st Century Skills*, 2009b).

The *Partnership for 21st Century Skills* (2009b) proposes that thinking creatively requires:

- Use of a wide range of idea creation techniques (such as brainstorming)
- Create new and worthwhile ideas (both incremental and radical concepts)
- Elaborate, refine, analyze and evaluate their own ideas in order to improve and maximize creative efforts.

(*Partnership for 21st Century Skills*, 2009b, p. 3)

The approach to the Australian *National Curriculum* developments share similarities with the approach used by the *Partnership for 21st Century Skills*, but unlike the Australian *National Curriculum* ‘shaping papers’, the writers of the papers for *Partnership for 21st Century Skills* have unpacked the concepts sitting behind their generic capabilities, and have suggested that to work creatively with others, students have to be able to:

- Develop, implement and communicate new ideas to others effectively
- Be open and responsive to new and diverse perspectives; incorporate group input and feedback into the work
- Demonstrate originality and inventiveness in work and understand the real world limits to adopting new ideas
- View failure as an opportunity to learn; understand that creativity and innovation is a long-term, cyclical process of small successes and frequent mistakes.

(*Partnership for 21st Century Skills*, 2009b, p. 3)

Partnership for 21st Century Skills also argues that for students to develop creative and innovation capabilities requires that they have to implement their innovations. This means that students have to act on their creative ideas, in order to contribute in tangible and useful ways to the field in which their innovation has been developed (*Partnership for 21st Century Skills*, 2009b).

In an interview, Resnick explained his views concerning how to promote creativity in students as follows:

... when you're in the process of creating something ... it's often taking a model that you have in your mind and playing out that model with a new creation in the world. But as soon as you create something in the world, it's not necessarily going to live up to exactly the model that you had in your mind. It will disagree in certain ways or surprise you in certain ways. So by creating things in the world, it leads you to revise the models that you have in the mind. And as you revise the models you have in the mind, it leads you to create new things in the world. So I think that we think about this constant cycle back and forth that, taking our ways of thinking about the world and using that to express ourselves and create things in the world, and through that activity of creating, it gives us an opportunity to test out, to try out, to play with the models we have in our mind and continually iterate back and forth between the two.

(Resnick, 2003, p. 1)

While the iterative nature of creativity is being conceptualised by academics such as Resnick, the interactions between discipline or content knowledge and general capabilities, such as innovation and creativity, still require further thought by education researchers and practitioners, to determine their implications for classroom practices, and also for assessment and reporting purposes.

Assessment & Teaching of 21st Century Skills Project

Until 2009, one of the gaps in education policy and practice in Australia and overseas has been the lack of consensus about how to assess and report on students' abilities to perform generic skills. In addition to contributing to the *Partnership for 21st Century Skills* initiative, the three large technology companies – Microsoft®, Intel and Cisco – are also funding an international assessment project which is being managed through the University of Melbourne. Interestingly, the Project Director for this project is Barry McGaw, the inaugural Chair of the National Curriculum Board in Australia and a former Executive Director with the OECD.

The purpose of the *Assessment & Teaching of 21st Century Skills Project* is to investigate how to specify in measurable terms the understandings and skills required by 'productive and creative workers and citizens of the 21st Century' (Cisco, Intel & Microsoft® 2008, p. 1). The main task of the project is to develop a computer-based assessment system to test students' analytical, creative, innovative and adaptive abilities, and their ability to solve problems and to work cooperatively. One of the extended aims of the project is to inform the assessment items used by the OECD for international student tests in 2012 (*Assessment Teaching of 21st Century Skills Project*, 2009).

Consistent with OECD and World Economic Forum policy statements outlined in Section 2, the *Assessment Policy Brief* prepared by Cisco, Intel and Microsoft® justifies this project by stating that:

In the 21st century economy and society, the ability to respond flexibly to complex problems, to communicate effectively, to work in teams, to use technology and to produce new knowledge is crucial.

(Cisco, Intel & Microsoft®, 2008, p. 1)

This assessment project was formally launched in January 2009, with Australia, Portugal, Finland, Singapore and the United Kingdom, as founding participant countries.

It can be seen then that the work being undertaken in the United States of America, by the *Partnership for 21st Century Skills*, and internationally, through the *Assessment & Teaching of 21st Century Skills Project*, share similarities with the work recently commenced in Australia on the *National Curriculum*. At one level, this consistency of curriculum and assessment

initiatives will serve well the economic interests of OECD countries as they compete with each other to demonstrate the quality of their next generation of human capital. At another level, the homogenisation of curriculum and assessment approaches globally may suggest that governments, together with markets, are creating the types of approaches to learning and testing that meet the requirements of the dominant international vendors, and in some cases fills the void where impoverished curricula have previously been in place. But what might be lost at the local level, by implementing standardised curricula, is yet to be seen.

ICT literacies

Throughout the history of education in Australia, emphasis in policies has been placed on the development of literacy and numeracy skills:

Unless a child can read fluently, spell correctly, add up and multiply columns of figures with quickness and accuracy, he (sic) is mentally crippled, not merely in the ordinary business of life, but in the pursuit of higher scholarship.

(Parliamentary Paper, 1884 in Ling, 1984, p. 48)

With the introduction and use of technologies in school education and in the daily lives of young people generally, educators now recognise that students encounter multiple kinds of texts to read and interpret:

One of the great contemporary challenges is equipping students ... for life-long learning through effective use of information technology and online services. With the advent of the Information Economy, 'IT literacy' is becoming the '4th R' of the basic competencies every individual needs.

(State Government of South Australia, 2000, p. 44)

ICT literacy is now being accorded the same policy status previously allocated only to literacy and numeracy (see, for example Commonwealth (then) Department of Education, Training & Youth Affairs (DETYA), 2000; EdNA Schools Advisory Group, 2000; MCEECDYA, 2008). As discussed earlier, the *Melbourne Declaration* indicates that as a foundation for success, students will have to develop:

... the essential skills in literacy and numeracy and [be] creative and productive users of technology, especially ICT.

(MCEECDYA, 2008, p. 8)

Again, one of the major policy drivers for this emphasis is economic:

... information and technological literacy are now essential pre-requisites to work in almost any career.

(EdNA Schools Advisory Group, 2000, p. 5)

Over time, understandings of ICT literacy have developed and now ICT literacy has various meanings. One interpretation of ICT literacy brings into focus the way literacy, technology and learning interact with each other. Back in 1995, Tinkler, Lepani and Mitchell argued that the use of technologies necessitates a new form of literacy, indicating that students require the ability:

... to use information and information technologies effectively to find, select and effectively use information to create knowledge and insight.

(Tinkler, Lepani & Mitchell, 1995, p. xiii)

Subsequently, Lankshear, Bigum, Green, Morgan, Murray, Synder and Wild (1997) and Kenway (1998), drawing on Green (1988), made similar points, proposing that for students and teachers

to develop ICT literacy, three dimensions of ICT literacy are required: the operational, cultural and critical. Furthermore, as Kenway (1998) states:

... in order for teachers to teach their students to use technology, to teach through and about new technologies and to do so in the most competent and creative ways, they must be skilled, informed and critical users themselves.

(Kenway, 1998, p. 83)

Lankshear et al. (1997) also indicated that while there can be an advocacy for both sophisticated or higher order intentions to the phrase 'ICT literacy' in policies, there can also be a back to basics flavour associated with the phrase, when it is taken to refer only to the technical capability of using the technologies. More recently, 'ICT literacy' has also been used to describe how technologies can be employed to interpret and understand information. For example, 'ICT literacy' was defined for the national *ICT Literacy* assessment program as:

... the ability of individuals to use ICT appropriately to access, manage, integrate, and evaluate information, develop new understandings, and communicate with others in order to participate effectively in society.

(MCEECDYA Performance Measurement and Reporting Taskforce, 2008, p. 2)

The purpose of the national ICT literacy assessment program is to assess the ICT literacy skills of a sample of students in Years 6 and 10, every three years. The third cycle in this national assessment will be conducted in 2011. The assessment is based upon determining students' technical or computer literacy skills, along with their traditional literacy and communication skills (MCEECDYA Performance Measurement and Reporting Taskforce, 2008).

In the 21st century, there are complexities to linking the phrase 'ICT' with the concept of 'literacy'. Section 1 included a discussion of the difficulties associated with developing shared understandings about what technologies are encompassed by the phrase 'ICT'. The concept of 'literacy' also brings with it its own tensions (Freebody, 2007). Several associated 'literacies' are linked with 'ICT literacy': media literacy, digital literacy and visual literacy. Careful use of this terminology is important, especially given the context of the operational, cultural and critical dimensions of ICT literacy which research has revealed.

While teaching students to evaluate information is encouraged in policies, it is difficult to translate this into practice. To develop students' abilities to be able to take a socially critical view (Habermas, 1991) to the use of technologies, requires teachers and students to not only take an operational view, but also to approach learning with technologies from cultural and critical perspectives (Lankshear et al., 1997; Green, 1988). As has previously been stated, teaching and learning with technologies involves more than simply 'giving' students skills, but rather requires students to be able to learn by creating their own views. It is crucial students realise that all technologies, and the practices employed to use them, are socially constructed. They are designed and built by people who have their own views about what is good or preferable in certain circumstances (Wyatt et al., 2000). Consequently, there is no ultimate truth about how technologies in schools ought to be constructed or used. This lack of ultimate truth, however, is a double-edged sword: educators have the freedom to develop the operational, cultural and critical dimensions to students' ICT literacy, but at the same time they are constrained by the external curriculum, assessment and accountability requirements placed on schools.

Curriculum challenges

There are several curriculum and pedagogical issues that arise from the concurrent promotion of both general capabilities and discipline knowledge. Through the work undertaken in the United States of America by the *Partnership for 21st Century Skills*, and based on the experiences in Australia in the 1990s from introducing the 'Mayer Key Competencies' in the 21st century context, two related questions arise:

- 1 In what ways do general capabilities and knowledge interact?
- 2 How can teachers support students to learn to transfer their general capabilities across discipline boundaries?

Linking discipline knowledge and general capabilities

What the interactions between discipline knowledge and general capabilities mean for classroom practices requires further discussion. Solving problems, for example, does not happen in isolation from a body of knowledge of some kind, and often that knowledge-base is interdisciplinary. It is essential that educators understand and are able to articulate what constitutes capabilities such as ICT, creativity and innovation, and how discipline knowledge, general capabilities and cross-curriculum perspectives intersect and can be developed across discipline boundaries. Without such understandings, educators will not appreciate what is required of them. Without these understandings, the types of learnings espoused in the policies, which aim to enable students to meet the emerging challenges of the 21st century, will not be achieved. In such circumstances, educators again will face the criticisms about their failure to appropriately prepare students for the likely futures they face. Insights into some of the issues that arise from linking discipline-based and general capabilities can be gained, however, from earlier work undertaken on the Mayer Key Competencies.

One of the problems identified with the implementation of the Mayer Key Competencies, and contrary to the conceptualisation of these competencies, was that it was common practice to think about the competencies as discrete independent skills, to be taught and assessed singly (Hager, 1996). Such an approach, however, showed a limited notion of relationships between generic competencies and the content knowledge that is critical to identifying the underpinning nature of a problem. In order to address and solve a problem, an understanding of the nature or the 'content' of the problem itself is required. To illustrate the implications of this for teaching and learning in schools, consider project-based and inquiry-based approaches to learning, such as those in which students investigate and propose solutions to questions, for example, how to recycle rubbish at school. Approaching this task requires students to develop an evidence base of information and knowledge about the school environment, the current behaviours of students, what materials can be recycled and so on. This task also requires the students to sift and sort information, to exercise critical thinking, analytical and problem-solving skills, and probably to work in teams. As such, solving problems requires the combination of content knowledge and generic capabilities. Furthermore, solving problems with technologies requires not only an understanding of the interactions between generic capabilities and the specific nature of the problem, but also requires an understanding of the functionality of technologies, so that appropriate selections of particular technologies can be made and applied to specific contexts in order to assist in gaining solutions to problems.

Students have to learn that critical and analytical thinking in one discipline of knowledge may not operate in the same way as in another discipline. Students now have to learn how to move rapidly from being a generalist to a specialist, and this requires the development of their research capabilities and their abilities to check the veracity of information. Technologies can assist students to creatively and productively learn knowledge-building practices. For example, students can learn creativity and knowledge-building strategies by being involved in social interactions that engage them in multiple processes. In such contexts, the achievement of goals emerge from learning within complex networks of people and ideas (Valsiner & Veer, 2000), and against the backdrop of an informed knowledge base, students develop critical thinking, teamwork and problem-solving skills. Teachers therefore have to develop their own generic capabilities, if they are to support students' development of general capabilities that can be applied within the context of background knowledge and understandings.

Supporting students to build their critical thinking, teamwork and problem-solving skills, however, requires creating learning environments in which students can take risks and experiment. These characteristics are not easily found in the current culture and practices

of most schools. Indeed, as the world becomes more complex, it is increasingly necessary to teach students to deal with problems in different ways. The problem-solving models ought to be ones that bring people together and draw on the expertise of the many by leveraging their small efforts, rather than relying on the large efforts of a few (Resnick, 2003): to collectively use discipline knowledge and general capabilities in practical and meaningful contexts.

Transferring capabilities across discipline boundaries

Related to the question of how discipline knowledge and general capabilities interact is the question of how best to support students to learn to apply general capabilities across discipline boundaries. Indeed, one of the big debates in education during the introduction and implementation of the Mayer Key Competencies revolved around how students could learn to transfer their use of key competencies to new situations (Drew, 1994; Hager, 1996; Ryan, 1997). Questions were raised about how teachers could support students to move from the take-up phase of learning to successfully transfer knowledge, skills and understandings to new contexts. One of the problems identified at that time concerned how the key competencies were taught. Reports suggested that the key competencies would gain a life of their own, and students would learn these competencies in isolation in specific situations, rather than learning how to transfer the competencies to new situations (Down, Martin, Hager & Bricknell, 1999; Hager, 1996). This was impractical and untenable, as is still the case.

It was proposed at the time that instead of teaching the key competencies as separate entities, they should be taught in an holistic and integrated way. Furthermore, there were debates about whether the extent of transferability of general competencies was as a result of becoming better at implementing specific competencies, or whether the person became more confident in recognising what was required in new contexts. There is still a lack of common understanding on these matters and, as such, it seems timely then that these debates be revisited, given the silence of considered educational debate on these issues in the 21st century, and especially in light of the proposed place for general capabilities in the Australian *National Curriculum*.

Concluding comments

Integrating technologies into teaching and learning, and building students' innovative and creative capabilities with technologies, is now seen, in Australia and overseas, as necessary for preparing students for the unknown futures they face. National curriculum developments in Australia are focusing on the dual priorities of students acquiring discipline knowledge, and developing general capabilities such as ICT, innovation and creativity capabilities. The role of IT vendors in curriculum and assessment approaches in schools is evident and pervasive. In the absence of specific government-funded work on the relationships between assessment and teaching of general capabilities within and across disciplines, large IT vendors have stepped into the breach. It is unclear at this point in time, however, what the implications arising from the curriculum and assessment work being undertaken at a national level in Australia will mean for what happens locally, in classrooms.

Both the *Melbourne Declaration* and the work that Australian educators are currently undertaking in developing a *National Curriculum*, which includes learning with technologies, espouse benefits students should gain from learning with technologies. However, to date, the development work on the *National Curriculum*, has appeared to neither take into account nor question how some students are already using technologies in complex and critical ways. Yet by reviewing recent research, it is possible to piece together a picture of how Australian school students are currently using technologies, such as computers, the Internet and mobile phones, to assist in their learning. The discussion in Section 4 aims to review the evidence of school-based use of technologies and fill in some of these gaps in this picture.

Students' uses of technologies

Students' lives are imbued with technologies: they do not separate their lives according to 'without technologies' and 'with technologies' as adults often do (Green & Hannon, 2007; Moyle & Owen, 2009). Indeed, most Australian children born in the 21st century will grow up not knowing life without technologies. Children will play with toys such as Lego's programmable bricks, watch television that is becoming increasingly interactive, and play online games with other young people located around the world. A majority of Australian children over the age of 12 are now more likely than not to own a mobile phone (ACMA, 2009b; Moyle & Owen, 2009; Roy Morgan Research, 2006), and they use it to perform a range of functions including to access the Internet, to navigate their way to new destinations using Global Positioning Systems (GPS), to video friends and relatives, to take photos and to listen to music. From time to time, they may use their mobile phone or others', to make phone calls (Moyle & Owen, 2009). Some of these young people will spend their leisure time living online in other worlds, living out several identities, some of which will be of a different gender and age to the ones they have in the real world. Indeed, the US-based IT research company, Gartner Inc. predicts that by 2011, 80 per cent of active Internet users will have a 'Second Life' (Gartner Inc., 2007).

The world of hyper-adoption

In 2006, the United States of America, Japan, China and Germany were home to more than half of all the world's personal computers (Worldmapper.org., 2006). At June 2009, it was estimated that there were over 1.6 billion Internet users around the globe (Miniwatts Marketing Group, 2009). A sense of the scale of the use of the Internet can be gleaned from the number of registered players of online games. As of August 2009, approximately 11.5 million people were registered worldwide to play the massively multiplayer online game (MMOG) *World of Warcraft*, which it is claimed, represents 62 per cent of the online game market (*World of Warcraft*, 2009). In 2007, in its first four months of operations, Nickelodeon's virtual community for children, *Nicktropolis*, reportedly attracted 4 million registered users, with 14 million visits during that time (PRNewsWire, 2007). *Nicktropolis* provides children between 8 and 13 with the opportunity to use online spaces to play games, watch videos, and explore Nickelodeon-branded online environments (PRNewsWire, 2007).

Mobile phone technologies, however, seem to be the technology becoming most ubiquitous. Between 1990 and 2007 it is estimated that the number of mobile phone users worldwide increased from 11.1 million to 3.2 billion. It is estimated that the number of Internet users during

the same period grew from 2.6 million to 1.2 billion (Geiger & Mia, 2009). Future watchers predict that over the next couple of years the number of people using mobile technologies will continue to grow, especially given the adoption of a recent new feature that allows mobile phones to run third-party applications. This capacity represents a fundamental change in the way mobile phones can be used and opens the door to even wider uses of mobile phones for education purposes (Johnson et al., 2009).

By 2012, if the rollout of computers supported through the *Digital Education Revolution* (Australian Government, DEEWR, 2008a) goes to plan, a conservative estimate suggests there will be over one million computers in Australian secondary schools. And this suggests classrooms in the second decade of the 21st century will be different to those in the first decade and for the past century. In *Disrupting Class*, Christensen, Horn and Johnson (2008) predict that by 2019, 50 per cent of all high school classes in the United States of America will be provided online. In Australia, online learning in schools is currently small, but with the widespread deployment of computers and the Internet to Australian secondary schools funded through the *Digital Education Revolution*, it is possible that such a trend will be adopted here too. But currently there are disjunctures between many Australian school students' experiences of technologies use in their personal lives and that which they experience at school. In this section, school students' current patterns of technologies use will be examined, and the implications of these for building students' innovation capabilities in formal learning environments will be discussed.

Young people's patterns of usage of technologies

Australian children have access to and use a wide range of technologies. Data from the 2003 Programme for International Student Assessment (PISA) *ICT Familiarity* survey indicates that Australian students' access to computers at home and at school is among the highest in the world and above the OECD average (Ainley & Enger, 2007). Indeed, over 90 per cent of children aged between 7 and 8 have a computer at home (Australian Institute of Family Studies, 2008). Australian research suggests that access by children and young people to technologies is comparatively high, and that they use these technologies for a range of purposes (see, for example, ABS, 2008; 2009; Ainley & Enger, 2007; Moyle & Owen, 2009).

Internet use

Australian children generally have high levels of access to computers and the Internet from home. In April 2006 the ABS (2008) investigated the use of computers by young people aged between 5 and 14, in the 12 months prior to April 2006. The results showed that in total, 92 per cent of the children surveyed used a computer either at home or at school. Of these young people, 89 per cent used a computer at home; 90 per cent accessed a computer at school; 37 per cent accessed a computer at another person's house and 12 per cent reported using a computer in a public library (ABS, 2008). Of those students who reported using a computer, 70 per cent also reported accessing the Internet (ABS, 2008). Results similar to these were also found in 2008 in an Australian study, which showed that about 78 per cent of children aged between 9 and 11 accessed computers and the Internet from home at least 1–2 times per week, and that 77 per cent of students aged between 14 and 16 accessed computers and the Internet from home daily (Moyle & Owen, 2009).

Children and young people use personal computers and mobile phones to access emails and the Internet (Moyle & Owen, 2009). Younger and older Australian children, however, show differences in the ways in which they use the Internet. Primary school students' regular use of the Internet is higher at school than at home, and secondary school students' use of computers and the Internet is more regular at home than at school (Moyle & Owen, 2009). In a study conducted by the Australian Communications and Media Authority (2009a; 2009b), children between the ages of 8 and 11 reported using the Internet primarily for playing individualistic games (ACMA, 2009b). Older children between the ages of 12 and 17, however, reported more

interest in using the Internet for social networking, and playing multiplayer games (ACMA, 2009b).

Australian research also shows that children and young people aged between 8 and 17 already use the Internet to find information, to assist in educational activities such as preparing assignments, and to access social networking sites. According to ABS data, the most common activities reported for using the Internet at home or at school were for educational activities (82 per cent) and for playing online games (51 per cent) (ABS, 2008). Children over the age of 8 also reported that the Internet 'is important to them', and 74 per cent of children aged between 8 and 11 also reported that the Internet was a highly important part of their lives (ACMA, 2009b). Similarly, 91 per cent of 12- to 17-year-olds also reported that the Internet is somewhat, very or extremely important to them. Furthermore, the extent of use of the Internet and social networking sites by children appears to increase with age (ACMA, 2009a; Moyle & Owen, 2009). Market research suggests this trend does not look like stopping, neither in Australia, nor in other comparable developed countries (Lenhart, 2005; Roy Morgan Research, 2006; Williamson & Payton, 2009).

Mobile phones

Mobile phones are also an important part of 21st century children's lives in Australia and in other comparable countries (Lenhart, 2009). As with Internet usage, young people's mobile phone use and attachment increases with age (ACMA, 2009a; 2009b). Drawing on research by Roy Morgan Research (2006), research by Downie and Glazebrook (2007) concerning the attitudes of Australian children aged between 6 and 13 towards mobile phone use shows that, in 2006, 23 per cent of children in this age cohort owned a mobile phone. Of these young people, 55 per cent of the 12- to 13-year-old boys and 65 per cent of girls of the same age, indicated they owned a phone (Roy Morgan Research, 2006). It is unclear, however, why there is a slight gender difference in phone ownership among children aged between 12 and 13, although these gender differences are also in evidence in other Australian studies concerning adult use of mobile phones, which indicate that about two-thirds of women in the age group 22–40 years, own a second mobile phone compared to 38 per cent of men (Mackay & Weidlich, 2006; 2008). Locating reasons which explain these gender differences in mobile phone ownership and use will require further research.

Consistent with the above findings by Roy Morgan Research (2006), data collected in 2008 from over 500 primary school students in Australia also shows that 55 per cent of children aged between 9 and 11, and 96 per cent of young people aged between 14 and 16 indicate they own a mobile phone (Moyle & Owen, 2009). Both these studies show that as school-aged children get older, it is more likely they will own a mobile phone (Roy Morgan Research, 2006; Moyle & Owen, 2009). Interestingly, however, the main socio-economic group to which children with the highest mobile phone ownership belong, are in families with incomes of less than \$30,000 per year (Roy Morgan Research, 2006). The children with the second-highest rate of mobile ownership and use come from families with annual incomes of over \$120,000. Again, it is unknown at this stage why Australian children from the poorest and the richest families have the highest rates of child ownership of mobile phones in Australia, and more research is required to shed light on this phenomenon.

Common ways in which Australian children and young people use mobile phones are to text message, make phone calls and take photographs, while about a third of teenagers share files using their mobile phones (Moyle & Owen, 2009). As children get older, their mobile phone use increases in importance to them, with 43 per cent of young people aged 16 to 17 years of age indicating their mobile phone is extremely important to them (ACMA, 2009b). These findings suggest that mobile phones are important to young people's lifestyles and to their identities.

Insights into links between identity and technologies can be gleaned from research into young people's consumerism of mobile phones. Drawing on a range of studies of mobile phone ownership by Australian children aged between 6 and 13 years of age, Downie and Glazebrook

(2007) show that many in this group of young people have the following characteristics. They tend to:

- watch a lot of television
- be very concerned with appearances – theirs and others
- be responsive to advertising, especially if it includes celebrity endorsements
- be very brand aware, and capable of a high degree of brand recognition
- be interested in keeping up-to-date with the market in new and emerging technologies.

Investigating the attitudes of the children who own mobile phones, Roy Morgan Research (2006) shows that for the majority of these children, beyond appreciating the functionality of mobile phones, they also show signs of using mobile phones as status symbols. This research shows that while just over half the children agreed that 'having a mobile phone with the latest technology and features is important to me', just over half of the child mobile phone owners also agreed with the statement that 'the brand of mobile phone is important to me' (Roy Morgan Research, 2006). A challenge for educators then, is to understand the relationships between technologies and identity, which is presently an under-researched area in Australian education, while taking into account the potential benefits of such mobile technologies for building communities of learners.

Social networking

Along with mobile technologies, social networking sites have been increasing in popularity with young people. A social networking site is an online site or website that allows people to create personal pages and to display online their social contacts. Young people communicate using messaging, email, video or voice chat. They share photos and videos and they post comments in online forums, wikis, blogs and discussion groups. Personal sites may contain personal information, such as real-life photos and descriptive comments about the person (ACMA, 2009b).

There were over 250 million profiles in social networking sites globally as at October 2007, and on a monthly basis, in Europe, social networking sites are the third most popular online activity (Pascu, 2008). Surveys in the United States of America have found that 55 per cent of teenagers who use the Internet have created a personal profile online and have used social networking sites such as *MySpace* or *Facebook*. In addition, young people in the United States of America aged between 9 and 17 years of age report spending almost as much time online, including on social networking sites, as they do watching television (Attwell, 2007; Lenhart & Madden, 2007; Childnet International, 2008).

Research by ACMA (2009b) suggests that like their overseas counterparts, the majority of Australian teenagers aged 12 to 17 years, and half of children aged between 8 and 11, use social networking sites (ACMA, 2009b). Children and young people's preferences for a specific social networking site varies according to age: younger children prefer Club Penguin and MSN, whereas older teenagers nominate *Facebook* and *MySpace* as their preferred social networking site. The most popular site across the age range of 8 to 17 years is MSN (ACMA, 2009b; Moyle & Owen, 2009). It is unclear why there are differences in the social networking preferences of young people according to age, and more investigation into these reasons is required.

Playing online and computer games

Children and young people around the world play online and computer games. The best of these digital games offer opportunities for learning that the physical world cannot offer. Students, for example, can trial various responses to ethical and moral questions and they can play and replay different scenarios within games to see the consequences. The free, online, multiplayer game *PowerUp* for example, challenges students to help save the fictitious planet Helios from near ecological disaster. Using avatars, young people compete alone or together in timed missions to rebuild solar panels, wind turbines and dams using basic engineering principles. They make

choices that help them understand energy efficiency, climate change and conservation (see <http://www.powerupthegame.org/home.html>).

There is much debate, however, about the value or not for young people of playing digital games, and much of this debate tends to be polarised. At one end of a continuum, playing digital games can be regarded as a harmless diversion, and at the other, a corruptor of youth (Seely Brown & Thomas, 2006). Yet understanding the nature of online game playing is important for educators to grasp, in order to understand how children and young people enjoy and can learn from such activities.

Studies undertaken in the United States of America show that teenagers play online and computer games frequently. Most US teenagers aged between 12 and 17 play computer, web, portable, or console games, often daily. Research undertaken on behalf of the commercial research company Pew Internet indicates that:

- 86 per cent of teens play on a console like the Xbox, PlayStation, or Wii.
- 73 per cent play games on a desktop or a laptop computer.
- 60 per cent use a portable gaming device like a Sony PlayStation Portable, a Nintendo DS, or a Game Boy.
- 48 per cent use a cell phone or handheld organiser [such as PDA] to play games.

(Lenhart, Kahne, Middaugh, Rankin Macgill, Evans & Vitak, 2008, p. i)

Contrary to the myth that young people's online game playing is an isolating activity, for most teenagers from the United States of America, playing online and computer games is a social activity that forms a major component in their recreation time. Indeed, nearly 3 in 5 teenagers (59 per cent) indicate they play games in multiple ways: with others in the same room, with others online, or by themselves (Lenhart et al., 2008). Young people are also mobile users of technologies. They report they are just as likely to play games online with others, whether they are at home or away from home, on computers, consoles, or on a mobile phone.

Children and young people also indicate they use and adapt a variety of different devices in order to play games, including mobile phones, PDAs, and other portable devices not purpose-built for gaming. About half of the teenagers in this US study (Lenhart et al., 2008) indicated they had played games on a mobile phone or PDA, with girls being more likely to report playing games on a mobile phone than boys. Lower-income teenagers (from families earning under US\$50,000 per year) were more likely than higher-income teenagers to play racing games, adventure games, or horror survival games. Nearly a third of boys who reported they play online games also reported they had played a MMOG, compared with 11 per cent of the girls (Lenhart et al., 2008).

Less is known of the trends in Australian children's and teenagers' use of online and computer games. Australian students however, do report they are interested in and have played one or more computer or online game, usually outside of an educational setting (Moyle & Owen, 2009). Most Australian children who have a computer at home, however, report that they play games on it (Australian Institute of Family Studies, 2008). Furthermore, according to ACMA (2009a), 40 per cent of young Australians consider it is a 'low risk' activity to play online games with other people they do not know (ACMA, 2009b), which is a view probably at odds with that of their teachers and parents.

Consistent with research findings from overseas, a recent Australian study, *Listening to students' and educators' voices* (Moyle & Owen, 2009) indicates that there is little agreement in Australia about the educational value of computer and online games. On the one hand, educational computer games are seen to be able to keep students' interest in learning, but on the other, there is a lack of surety by educators about the value of such games (Moyle & Owen, 2009). School students however, report that they think if their teachers could play online games it would assist their teaching, and enable them to include technologies more effectively into their classroom activities (Moyle & Owen, 2009). Despite some concerns about possible distractions, over half of student respondents in this study indicated that educational games should be more widely used in schools because of their motivational and educational benefits. Consistent with findings from other studies, primary-aged children reported most interest in individual action, sport, driving and

strategy games, while secondary students indicated more interest in more collaborative games (ACMA, 2009b; Moyle & Owen, 2009).

Given this profile of children and young people's use of technologies, it is timely to now consider the educational possibilities of mobile phones and other technologies for building students' innovation capabilities.

Students learning with technologies

There are disjunctures between the ways in which students use technologies at school and the ways in which they use them in their personal lives, for school work and for recreation (Levin & Arafeh, 2002). These disconnects between the real lives of students and their experiences of schooling are reported in several countries, including the United States of America, the United Kingdom and Australia (*Project Tomorrow*, 2009; Green & Hannon, 2007; Moyle & Owen, 2009). In the United States of America it is argued that this disconnect is symptomatic of a larger issue, where the vision students have for their learning today is very different to the vision being implemented in schools (*Project Tomorrow*, 2009). Furthermore, several studies have now reported that students find the quality of their learning that includes technologies to be poor and uninspiring (Farris-Berg, 2005; Levin & Arafeh, 2002; Valdez, 2005).

Students around the world report regularly they would like to be assigned more complex and engaging activities that involve technologies, and that such activities should be relevant to their lives (see, for example, *Project Tomorrow*, 2009; Green & Hannon, 2007). Indeed, many students in these studies assert that such uses of technologies would significantly improve their attitude toward school and learning.

One of the challenges for educators is to bridge the divide between formal and informal learning that students undertake. As Green and Hannon explain:

One of the key differences between learning that goes on outside the classroom and learning in the classroom is that informal learning is driven by the interests, enthusiasms and passions of the individual. This is the opposite of the approach in schools; too often teachers assume they know what children are interested in.

(Green & Hannon, 2007, p. 55)

Students also report they feel like they are stepping back in time when they go to school. They indicate that while many education institutions are experimenting with a diverse range of digital tools, the approaches used are not always creative or innovative. Insights into the differences between how technologies are used by students in their daily lives, and the ways they are encouraged to use technologies in their studies, can be gleaned from reviewing what is considered to be best practice in schools. The National College for School Leadership (NCSL) for example, indicates that in the United Kingdom:

Our very best schools have children able to research using ICT, and to present their interpretations of their learning through a range of multimedia packages.

(Gill, 2007, p. 28)

Here the NCSL is promoting the notion that good uses of technologies equates to research and presentation skills. While these are worthwhile activities in themselves, they are limited. Young people's lives are fundamentally collaborative in nature. One of the characteristics of students using a range of technologies is the amount of communication and social interaction this involves. Students use landline and mobile phones, text messaging, email, instant messaging and social networking sites to communicate with each other (Childnet International, 2008; Moyle & Owen, 2009). The following statement by a Year 9 student illustrates this:

I mainly use the Internet. The things on the Internet that I use include MSN, hotmail and MySpace. The reasons for going on them is to mainly interact with friends. When I'm doing an assignment, at times I get confused and then I just sign on to MSN and just ask a friend.

(Moyle, 2008 data file)

It is interesting, although not surprising, that research conducted with young people in different countries has found that education-related topics are the most commonly discussed topics by students, when accessing these sites, using the array of technologies available to them (Childnet International, 2008; Moyle & Owen, 2009).

Technologies then, are already being used by students outside of schools to assist in their studies and to communicate widely. Asked whether they think their use of technologies outside of school assists them to learn, the following responses were common from Australian students:

Using technologies allows me to:

- *go beyond what the teachers are teaching*
- *talk to others about what we're learning*
- *teach myself stuff*
- *to learn other things at the same time as learning what is intended.*

(Moyle, 2008, data file)

Leveraging these activities to carefully structure considered learning activities may provide teachers with the opportunity to build upon some of the students' existing practices.

Young people create social networks around common interests and aims. Teenagers play games in social settings using games consoles, the Internet and computers. Furthermore, with the Internet ageing and continually developing, the new tools emerging are predicated on users actively participating in online activities. With the advent of blogging and projects such as *Wikipedia*, it is now as possible for young people to gain feedback from teachers and parents as it is to contribute to online communities and to seek feedback from peers, generous experts and interested strangers. This capacity for sharing information and knowledge has led to the blurring of the boundaries between expert and amateur, friend and mentor (Green & Hannon, 2007).

Online and computer game play is thought to offer the possibility for children and young people to learn and practise a range of skills, including reading and writing. As a primary school student recently reported:

... when playing a game you sometimes see subtitles and you read it. Your reading can improve a lot.

(Moyle, 2008, data file)

Online and computer game play may also assist students to collaborate and share interactive experiences, which can potentially parallel many in the real world (Puttnam, 2009). Some have argued that playing online games in groups with others, particularly when working collaboratively toward a common goal, such as with guilds and game groups in MMOGs, can provide the basis for project-based learning and how to work in groups towards shared objectives. These experiences are seen as transferable to other facets of life, including to the workplace and the community (Green & Hannon, 2007; Seely Brown & Thomas, 2006). But how to build students' abilities to transfer skills, knowledge and understandings to new contexts, remains problematic and unresolved, as was discussed in Section 3.

Building innovation for 2020 and beyond

With technologies, young people in the 21st century have the opportunity to display complex learning styles that are shaped by the ubiquity, accessibility and ease of use of digital resources. Children in junior primary school play by creating stories, making things together and painting,

and through these activities develop and refine their abilities to think creatively and work collaboratively (Resnick, 2007). These are exactly the same abilities, identified as being the most valuable for achieving success and satisfaction in the 21st century (Resnick, 2007). Secondary school students are playing multiplayer games in teams. Judging from the *YouTube* videos about how to be an effective guildmaster in *World of Warcraft*, the capabilities required include being able to attract, evaluate and recruit new members, create apprenticeship programs, orchestrate group strategies, and manage disputes. These leadership and management skills too are valued in the modern workplace (Green & Hannon, 2007; Seely Brown & Thomas, 2006). The challenge for educators is how to build young people's interests and innovative capabilities with technologies, in ways that have meaning and interest for them. How can this be done? What strategies enable teachers to build students' innovation and creative capabilities? Here are some suggestions.

Educating for the future

Schools must create learning environments that encourage both teachers and students to experiment with ideas. Teaching students to be able to analyse and question information available to them across the disciplines is a capability that will be of value to students beyond schools (Sahlberg, 2009). Inquiry-based, project-based and problem-based learning are approaches that use information processing to support students' learning about issues of meaning and relevance to them. These approaches fit well with technology-rich learning environments that focus on the learning experiences rather than the technologies. These approaches are appropriate both for personalised learning and for group work (Underwood, Baguley, Banyard, Coyne, Farrington, Selwood & Selwood, 2007). The focus of such learning environments is on the students' excitement about solving problems or investigating an issue that is of interest to them. In these environments the focus is on the learning and the inclusion of technologies in ways that support students to achieve their learning objectives.

Inquiry-based learning and similar approaches can be used to support students to respond to problems in their immediate environs, by encouraging experimentation with the potential solutions and through using technologies to assist in predictions as well as background research. Software applications can be used as tools to support students' inquiries by assisting them to organise ideas (for example, with concept mapping software), to search for current information (for example, through accessing the websites of major libraries and universities around the world, using online books and checking news sources), to prepare background papers (using word processing software) and to present ideas (for example, with presentation software).

A challenge for teachers aiming to build students' innovation and creative capabilities with and through technologies, however, is to move students from being users and consumers of technologies to being creators and producers with technologies. At the *Lifelong Kindergarten* located in MIT Media Lab, the Internet is used to support young people to create their own interactive stories, games and animations, and then to share their creations with others on the Internet (Resnick, 2007). Through the Internet, students are afforded a ready-made audience for their creations, and their audiences provide feedback by commenting on their postings and contributing to group efforts to further develop and improve the software creations posted. Such iterative, creative communities of young people are dependent upon being able to communicate and collaborate online from computers and other mobile devices. As such, a high quality 21st century education depends upon allowing students to discuss their learning with other students, to network and communicate with each other, to share their ideas and solutions to problems they are trying to collectively solve. Networking between students and teachers in different institutions can enrich the curricula and increase the transfer of generic and subject-related knowledge and skills between practitioners.

The patterns of technologies use by Australian children and young people suggests that most are confident users of social networking sites. The use of these sites for teaching and learning purposes offers teachers and students opportunities to develop a range of general capabilities, including literacy skills, and can provide students and teachers with opportunities

to include social and explorative aspects in their learning. There are several potential uses of social networking sites for school education which include creating e-portfolios and using them as online spaces where children and young people can record their achievements, house examples of their work and promote their talents and interests (Childnet International, 2008). Indeed, as interoperable IT infrastructures are put in place, e-portfolios provide a mechanism by which students' learning can become seamless, irrespective of the institution in which they are enrolled.

As the interactions between people over the Internet are mediated through screen interfaces, technologies provide ample opportunities for students to develop their literacy and communication skills. The Internet provides both teachers and students with opportunities to learn about each others' work by sharing examples of it through public showcases and online events, to collaborate on joint projects, and to form online communities of practice around topics of interest (Childnet International, 2008).

Concluding comments

Australian children and teenagers have access to and use technologies for a variety of purposes, and most uses are underpinned by the desire to communicate with others and to collaborate on activities. Despite fears to the contrary, children could well be reading and writing more than their peers 20 years ago, albeit through a variety of media. Indeed, children and young people are engaging with each other using the many communication channels available to them. As children grow older, there appears to be a shift in the way they use the Internet, moving from entertainment and game playing to social interactions.

There is much we do not know or understand about the ways in which children and young people interact and use technologies; for example, it appears from the nature of their mobile phone ownership and use, that their mobiles are closely tied to these students' identities. The reasons for gender differences in mobile phone ownership and use by Australian students are currently unexplained. Likewise, it is unknown why mobile phone ownership is highest among the poorest and richest students in Australian schools. These issues raise questions about how and why young Australians use mobile technologies, and what are the implications from these trends for teaching and learning.

Technologies such as Web 2.0 social networking technologies are providing new opportunities for education. Used well, these technologies can enhance students' learning by facilitating collaboration, innovation and creativity for individuals and among groups of students. The benefits of including Web 2.0 social networking technologies for learning, however, depends upon the teaching and learning approaches used, and this shifts the emphasis to the skills and the role of the teacher and to pre-service teacher education.

Furthermore, the ubiquity of several technologies, and the robustness of young people's abilities to communicate and collaborate, presents challenges for educators and stakeholders about how they conceive of schools. Indeed, it is time to reconsider what is a school and in what ways it can best fulfil its roles. As children and young people are communicating with each other in online settings, the importance of learning in face-to-face settings is highlighted. Attendance at school brings young people physically together into social situations, and it is here they learn how to play games in real time and space, how to get on with others and how to resolve disputes. Through face-to-face learning, and through discussions with their peers, as well as by using the Internet, it is possible for young people to discover information, to clarify meanings and to create new ideas, both in real-time settings and online.

So what makes a school in the 21st century? The characteristics that constitute the identity of such a school are reflected in its physical design and in its culture and organisation. It is to these issues we now turn in Section 5.

Creating 21st century schools

Given past experience, the way schools are structured as learning environments today will shape the ways we think about, experience and conduct education for the next 50 to 100 years (Rudd, Gifford, Morrison & Facer, 2006). In the 21st century, Australian schools are to be places that support learners, both to develop their capabilities for their short-term student lives and to support them to become lifelong learners (Wyn, 2009). Australian educational leaders are expected to understand how technologies can contribute to high quality teaching and learning (Moyle, 2006). This is especially so as secondary school principals in Australia plan for and roll out computers and associated peripherals, funded through the national policy, the *Digital Education Revolution's National Secondary School Computer Fund*.

In policies, technologies are presented as a lever for changes to schools. In Australia and overseas, technologies are promoted as a means of transforming teaching and learning, so pedagogies become more innovative, and by default create innovative schools and students (Australian Labor Party, 2007; Office for Policy, Research and Innovation, Department of Education and Early Childhood Development (Victoria), n.d.; Department of Education and Training, Qld, 2000; Department of Education and Children's Services, South Australia, SA, 2006; Williamson & Payton, 2009). To achieve the transformations advocated in these policies, schools are required to foster technologies-enabled teaching and learning to inspire students to become intellectual risk-takers and creative problem-solvers. The organisation and architecture of the school then, have to be oriented towards supporting technologies-enabled learning (Fisher, 2007).

The use of technologies in 21st century schools is physically dependent upon a robust IT infrastructure. But the inclusion of technologies in teaching and learning requires more than just an IT backbone. It also requires the alignment of the structures or organisational arrangements in schools which support teaching and learning; not only the physical attributes of schools and their respective infrastructures, but also the philosophy, policies, rules and traditions that define what people take to be fundamental to the functioning of a school.

Defining schools

Traditionally, schools have been thought of as places where teaching and learning take place. That is, schools are commonly thought of as physical places. School buildings and the culture of schools are symbolic of the dominant views about what is valued within a particular school. The embodiment of school education, most obvious in the physical design of schools, reflects

the philosophical beliefs informing the construction of those buildings. Hargreaves (2004) has likened 19th and 20th century schools to the asylum, prison and factory. These school designs were suited to the industrial economy (Cornell, 2002). Early schools in Australia resemble churches, hospitals and prisons, consistent with Australia's British traditions. These institutional styles of schools are no longer effective, either economically or structurally in terms of the goals of 21st century school education (Dede, 2009), including in Australia (Wyn, 2009).

Students' attendance at schools has been a consistent feature of Australian school education. The requirement to physically attend school in a school building has defined Australian compulsory education. As early as 1796, Governor Hunter, the second Governor of NSW stated:

... public school for the care and education of the children is much wanted to save them from certain ruin.

(Governor Hunter in ABS, 1909, p. 880)

In 1909, the ABS *Yearbook* reported that each of the colonies had in place requirements for compulsory school attendance. These arrangements were achieved through the respective state Education Acts, as the following extract from the Victorian Education Act of 1872 illustrates:

The parents of children of not less than six years and no more than fifteen years shall cause such children (unless there is some reasonable excuse) to attend school for a period of sixty days in each half year.

(Victorian Education Act of 1872: Sections 13–14, in Turney, 1975, pp. 62–63)

Late 19th century thinking was that 'a little education is good for all children but much education is good for only a few' (Butts, 1964, p. 31). That is, public school education at that time operated much like a safety net; it was a way of providing schooling to all those who could not afford a private school education. As Spaul (1998) explains:

... the constitutional basis of education was founded on a legal guarantee that the states should provide a minimum standard of education for the mass of children.

(Spaul, 1998, p. 5)

Over time, a view developed that children located in the country were entitled to an education equivalent to their city counterparts, and that it was a responsibility of state education departments to provide it. In the 20th century, to provide universal schooling to most Australian children, distance education was introduced; first through the use of travelling teachers, then correspondence lessons, and later through Schools of the Air and distance education schools (Moyle, 2001). The predominant distance education methodology adopted for much of the 20th century was 'correspondence schooling'. Teachers produced written materials that were posted to the students. The learning was mediated over a relatively long period of time through the use of pen and paper, and conveyed using the postal services.

In the 1950s, small rural schools were merged into larger 'area schools' and with this, Schools of the Air emerged. Schools of the Air used HF radios to provide schooling to students who were located too far away to physically attend any schools. The HF radio allowed teachers to conduct lessons in real time with more than one student at a time. That is, teachers were able to construct small classes of students and talk with them over the radio. In this way, radio transmissions (as a mode of delivery) were added to correspondence school methods. This meant the teaching methodologies of the distance education teacher expanded. With the growing ubiquity of the telephone in homes, conference calls became possible and more recently sophisticated telecommunications such as broadband and satellites have enabled computers and the Internet to be used to overcome time and distance, for education purposes.

Throughout the 20th century, special permission from the respective department of education was required before a student could be exempted from physically attending school, and be allowed to undertake school education at a distance. The ability to physically attend a school then, has been a requirement defining compulsory education, and has been a differentiating

characteristic between face-to-face school education conducted in school buildings and that delivered through distance education, provided by the state and conducted in the home. Distance and the sparseness of some of Australia's population, along with the legislative requirements for the provision of compulsory schooling, have provided Australian school education with a history of constructing pedagogies that are pertinent not only to teaching in face-to-face settings, but are also pertinent to overcoming the teaching and learning problems created by distance.

With the increasing availability of technologies for educational purposes, however, no longer do schools have to be conceptualised as only physical places. In physical and virtual ways, using a variety of approaches, schools can support students to learn and to practise different sorts of interpersonal relationships in a range of contexts. Now schools can be considered more as environments that consist of physical, online, or simulated learning spaces, or they can be environments that consist of any combination of these environments. To create 21st century schools that enable learning with technologies in multiple environments though requires a whole school approach.

Whole school approach

Australian school education policies such as the *Melbourne Declaration* and the *National Curriculum* place an emphasis upon building innovative capabilities of students within and across discipline boundaries. A major imperative in 21st century schools is to do so by seamlessly including technologies into classroom practices. Technologies then are a central part of the work of all schools and are integral to students' learning environments.

Students express a range of expectations about how they want their school to technologically support their learning. They expect it to occur at any time and in any location (Moyle & Owen, 2009). Furthermore, they want the infrastructure to be able to track their learning progress on different subjects online at any time, both as a snapshot in time and over time and place, and to access information about their progress online.

Students want to be able to access more learning resources online. They want to be able to access lesson materials online and build on their classroom activities:

If you are absent you need to be able to get access to your assignments as well as lessons that the teacher did in class that day. Also it makes the amount of information deeper than is available to us.

(Moyle, 2007, data file)

Students like the functionality of technologies, which allows them to have some control over the nature and pace of their learning:

It is easier to learn new things and more complicated stuff and gives many people more opportunities ... It is an easier, faster way to learn.

(Moyle, 2008, data file)

Students want to be able to communicate with their teachers outside class time, which email allows them to do. Some are already able to do this:

Teachers now make sure to check their email every day. With Internet, it's instant so you can contact other students or teachers to get information quickly.

(Moyle, 2007, data file)

Students also like to use technologies to verify information provided by their teachers, as the following statement by a Year 9 student illustrates:

If we didn't have technologies we would have to be focusing more on the teacher's point of view, and as much as they are here to teach, it has been proven that they aren't always right.

(Moyle, 2008, data file)

To establish integrated structures in a school that enable a culture of inquiry, one where pedagogy drives decisions, including the deployment of technologies, is a complex task. An emphasis on the integration of technologies into teaching and learning requires technological considerations to be incorporated into the full range of a school's operations. An holistic and coordinated approach has to be taken to the physical, technological, human, organisational and informational infrastructures within schools. These infrastructures should together form an integrated architecture across the whole school and contribute to and support the overall development of the student as a whole person, where their learning includes technologies.

Integrated architecture

Each infrastructure that forms part of an integrated architecture of a student-centred school has its own functions. The concept of an integrated architecture, however, does not view the different types of infrastructure as being completely self-contained. There are overlaps between them and they interact with each other. In schools where there is a seamless integration of technologies into teaching and learning, the functioning of these respective infrastructures is in alignment (Moyle 2008a; 2008b). Each element in the architecture, separately and together, has as its primary focus supporting students to learn.

Physical infrastructure

The physical infrastructure of a school's integrated architecture refers to the nature of the physical design of a school and the way the buildings and spaces are deployed for teaching and learning purposes. Both teachers and students require not only tools for learning, but also learning spaces that enable collaborative planning and information sharing. Now school buildings have to be places in which students are able to meet, discuss their studies, learn and practise different sorts of activities and interpersonal relationships (Moyle, 2005a). Teachers and students also require suitable learning places which, at a minimum, enable them to use functioning computers connected to fast Internet services.

In Australia, there has been a renewed interest in the physical infrastructure of schools with the inclusion in the national economic stimulus package of funds for building and refurbishing schools, through the *Building the Education Revolution* initiative. One of the challenges that has emerged from this initiative, however, is that as the *Building the Education Revolution* is a stimulus package aimed at generating employment rapidly, the timelines within which the building programs in schools have had to be initiated has seen schools and departments of education pulling out old architectural plans, many of which were prepared before technologies were seen to be fundamental to teaching and learning. These classroom plans were not designed to accommodate computers or to meet infrastructure requirements such as appropriate furniture, wiring and electrical demands. They were not plans for 21st century places of learning.

Schools with classroom designs that support teaching and learning in the 21st century have different requirements from schools in the past. The Victorian Department of Education and Early Childhood Development (DEECD), for example, states that the schools they now design and build have to:

- *promote effective learning and teaching*
- *incorporate new technology*
- *be environmentally sustainable*
- *support community involvement.*

(DEECD Victoria, 2009b, p. 1)

These criteria embody the policy suggestions made by the OECD (2009b) which were outlined in Section 1.

There is an emerging emphasis away from factory-based school designs, and a move towards designs that build a sense of wellbeing and creativity. *Partnership for 21st Century Skills* advises

that ‘the school building should inspire intellectual curiosity and promote social interactions’ (*Partnership for 21st Century Skills*, n.d., p. 7). In a similar vein, Cornell (2002) has argued the physical environment of schools should be sufficiently aesthetic so that students who *have* to be at school *want* to be at school.

Classroom designs, irrespective of their intended use and shape are physical forms constructed to be places for learning, and this influences what people do, and therefore the patterns of teaching and learning that occur within them (Radcliffe, Wilson, Powell & Tibbetts, 2008). Fisher (2007) argues that since technologies are now ubiquitous, school designs no longer have to accommodate fixed items of equipment such as computers. Classrooms can be designed to be flexible and changeable, to accommodate different learning styles that include access to wireless connectivity and the use of mobile technologies. Objects such as projectors, computers or printers can now be accommodated relatively easily, which means that classroom designs can focus on the pedagogies and people, rather than on equipment requirements.

Fisher (2006) has created several different architectural designs to accommodate emerging pedagogies, which include teaching and learning with technologies that focus on students developing their innovation and creative capabilities. His designs aim to link pedagogy with space and provide students with a ‘home base’, from which they can access places for quiet work, thinking spaces, group learning spaces, display and presentation spaces, specialised learning spaces, break-out spaces and so on. Australian schools in which these design premises have been employed include the Australian Science and Maths School in South Australia, Copperfield College Junior Campus in Victoria and Canning High School in Western Australia (Fisher, 2006).

The design of the furniture to fit in the new designs for schools also has to reflect the types of teaching and learning educators are seeking to implement, and the ways in which students are expected to learn. One of the barriers to including technologies in teaching and learning can be the lack of appropriate furniture on which to place computers in classrooms, in teachers’ preparation areas and in computer laboratories, and this impedes the uptake of technologies-enabled pedagogies (Moyle, 2005b). Learning environments in the 21st century for students and staff then, must have furniture that is:

... comfortable, adjustable, intuitive, reconfigurable, technology-capable, compressible, and attractive.

(Cornell, 2002, p. 41)

As such, furniture that supports teaching and learning with technologies includes chairs and tables that adjust to accommodate children of different ages and sizes, and can be easily rearranged inside a learning space.

The physical infrastructure of a 21st century school then places students at the heart of school designs, where the primary purpose of the design is to support the teaching and learning by students and teachers. Such an approach to school planning and design not only requires an understanding of and alignment with the priorities and contexts for students’ learning, but also of the human and organisational infrastructure requirements of the school’s staff.

Technological infrastructure

Central to the inclusion of technologies into the daily practices of schools is the IT or technological infrastructure of a school. This infrastructure comprises all the telecommunications, hardware and software applications, databases and networks required to operate the multiple technologies available in schools. High-speed bandwidth and robust networks are necessary if technologies-enabled teaching and learning, with the range of technologies available to school staff members, students and parents, is to be a reality. These facilities are required to underpin teaching and learning with technologies, the innovation processes in schools and the diffusion of technologies within and across schools. The data the technological infrastructure of a school houses can

assist in conducting school-based research and provide evidence to inform decision-making within the school.

As outlined in Section 1, schools' technological infrastructure supports several products and processes for teaching and learning purposes, including:

- computer servers to run operating systems and to host Internet applications
- desktop computers and laptops for staff and students
- the Internet (for email, access to online content, collaborating using Web 2.0 and Web 3.0 interfaces, and using Internet-enabled applications such as learning management systems)
- the information systems of the school (for example, student data and administration databases, finances, course timetabling and library systems software)
- mobile technologies (for example, PDAs, for recording student attendance).

The quality of students' experiences with schools' online environments is influenced by the consistency of the interfaces used within various locations in a school (Moyle, 2008a). Students value online experiences where they add value to their face-to-face classroom experiences (Moyle & Owen, 2009). Characteristics of high quality IT or technological infrastructure that supports teaching and learning in a school include it being:

- affordable and sustainable
- reliable and robust, so that downtime is minimised and there is confidence by students and teachers alike that the technologies will work
- secure, with appropriate access to the content being held as required by the respective members of the school community
- scaleable (that is, the size of the technological infrastructure can be increased and decreased without affecting its functionality)
- flexible, so it can be managed in the context of supporting the other infrastructures of the school
- accessible, so that the staff with the expertise can support and troubleshoot the technologies and provide support
- interoperable with other technologies being used in the school
- versatile, so that the respective components of the technological infrastructure do not create a 'lock-in' to one specific vendor (Moyle 2005a; 2005b).

If these characteristics of a technological infrastructure are met, then the technological infrastructure will be trusted by staff and students, and it will support their teaching and learning requirements. Furthermore, there will be commonly understood systems for sharing information among staff, students and the broader school community. Achieving the level of collaboration between students and teachers that is hoped for within and across schools and school jurisdictions requires the respective technical systems to 'talk' with each other. The way schools' and school jurisdictions' respective technological infrastructures interoperate, has not been substantively addressed in practical terms; neither as an element of the Australian school education sector's national technology infrastructure (Croger, 2007), nor in relation to the school sector's place in Australia's national innovation system (Australian Government, DIISR, 2009). Some small pilot projects are being undertaken in 2010, but the results of these are still being developed (see, for example, Systems Interoperability Framework Australia, 2009). Further research is required to demonstrate the extent to which the technological infrastructure of schools and school systems are embedded in standards, and how interoperable they can be.

The technological infrastructure of a school intersects with the physical, organisational and informational infrastructures to enable access to information and information flows, and to leverage the capacity of students and staff for knowledge creation. Effective use of the technological infrastructure of a school is dependent upon the interactions between the skills and capabilities of the staff and students, exercised within the organisational infrastructure of a school.

Organisational infrastructure

Organisations such as schools are constituted by dynamic sets of processes. The organisational infrastructure of a school refers to the arrangements used across the school, at a whole school level, to organise a school. The concept of an organisational infrastructure applies to the strategy, structures and processes of the school, and includes the culture, customs, traditions and mores of the school. It refers to the connectedness of people and functions within a school, and to the school's connectedness to its community. It also refers to the strategies used to build connections between both staff and students to the philosophy, vision and values within a school, and how these are imbued with technologies.

The organisational infrastructure of a school particularly makes use of its physical and human infrastructures. To assist in the organisation of a school, the use of technologies such as database software systems, email and other communication systems (that is, the technological and informational infrastructures) underpin the organisational infrastructure. The quality of the organisational infrastructure depends upon how the human infrastructure and the work people do is aligned with the organisational and strategic goals of the school. The value of a school's organisational infrastructure can be determined through mapping the processes, procedures and communications used within a school, and aligning these to the human infrastructure and strategic plans of the school for teaching and learning with technologies.

In the 21st century, the organisational infrastructure of a school has to support students to build their innovation and creative capabilities, and this can involve bringing about change. The way a school mobilises and sustains the changes necessary to execute strategic plans can also be considered a part of a school's organisational infrastructure. That is, the organisational infrastructure of a school includes its capacity for development, and refers to the strategies intended to change the beliefs, attitudes, values and/or structure of the school so that it can better adapt to new challenges, such as including technologies into the classroom practices of students and teachers.

Understanding its organisational infrastructure also involves viewing a school as a social system, with the collection of its respective working parts interacting with each other to function as a whole. Linked to the concept of an organisational infrastructure is the concept of 'systems thinking' developed by Peter Senge. Systems thinking involves developing the ability to understand the whole organisation, and to examine the interrelationships and dynamics between its parts (Senge, 2006). It requires stepping back from seeing the individual components, to seeing the organisation as a whole. An appreciation of systems thinking requires a focus on strategies to achieve the school's mission and vision, on the definition of desired, collective outcomes, and on the conduct of rigorous assessment to determine whether the outcomes have been achieved. In this way, systems thinking leads to a recognition of how to improve the organisation of a school and how feedback can be used effectively.

Leadership

School leaders are critical to fostering a school's organisational development and a 'whole school approach' to teaching and learning, and they are also critical to institutional change. Principals are in-school curriculum and pedagogy leaders (Mulford, 2008), and are central figures in leading processes for creating the conditions for technologies-enabled teaching and learning in their schools.

Orienting a school's operations towards students' learning, where technologies are integrated into classroom practices that foster innovation and creativity, represents a major whole school reform. Creating an integrated architecture requires school leaders to facilitate and coordinate substantial organisational changes, as these leaders are a critical 'hinge' or point of convergence between the organisational and human infrastructures of a school. Effective leadership fosters the flows and processes of the school and facilitates their operation, so that the organisational infrastructure of the school is effective and students are engaged in their learning (Lee & Gaffney, 2008).

Approaches to whole school organisational changes require 21st century school leaders to put in place processes that allow for the identification of the factors that will lead to the meaningful inclusion of technologies into classroom practices, by both students and staff. Such an approach requires school leaders and teachers to understand their students' capabilities, and for school leaders to understand their staff's and their own capabilities, including their abilities in teaching and learning with technologies. It also involves reviewing the structures and processes within a school, in relation to how the school can better adapt to the new challenges presented by installing and using its technological infrastructure. As such, school leaders have to ensure the following whole school components explicitly include technologies:

- the school's mission, vision and strategic plan
- classroom practices
- the school and faculty budgets
- the organisational culture and structures of the school
- the leadership and management systems and strategies
- the nature and design of classrooms and teachers' work spaces
- risk-management strategies.

The goal of organisational developments in schools is to focus on the learning outcomes planned for students and to improve the functioning of the school as a whole organisation, to better allow teachers and students to use technologies to achieve their planned outcomes.

Successful 21st century school leaders do not lead in isolation however. Where schools are focused upon including technologies into teaching and learning, the school principal is a driver with a vision, and his or her 'technologies leadership' in the school is respected and valued. The complexity and extent of work involved in establishing conditions that support the integration of technologies into teaching and learning requires different leadership styles at different times, styles appropriate to different contexts (Mulford, 2006). This has led some school leaders to instigate team approaches to school leadership, where they develop models of shared or distributed leadership, fostering teacher-leaders of learning with technologies in schools. Such models assist with the reconsideration of classroom practices and take account of technologies and their role in building innovation capabilities (Gill, 2007; Moyle, 2006).

Transforming schools then requires leaders who can look simultaneously at both the individual parts of the school as an organisation and also view the school as a whole. School leaders themselves however, face a range of issues and dilemmas about how to bring about organisational change. School leaders report their most urgent support required is for specialised assistance to do with practical implementation issues. For example, there are resourcing issues and accountability requirements for schools establishing and maintaining effective technological infrastructures designed to support teaching and learning with technologies. Indeed, how to identify what school-based financial and budget models can best be used to support the widespread diffusion of technologies in their school has been identified by Australian principals as one of the issues with which they require support (Moyle, 2006).

The processes of organisational development to include technologies in teaching and learning in schools then requires an organisational infrastructure that enables staff and school leaders to be able to make wise and continuous use of data, and to share it using the technological and information infrastructures of the school. The organisational infrastructure requires the staff of the school to have the ability to learn from others who are both inside and outside the school, and the insight to be able to link policies to bigger pictures. That is, an organisational infrastructure in a school is dependent on a high quality human infrastructure.

Human infrastructure

The human infrastructure of a school comprises the individual and the aggregated skills, knowledge and capabilities of all the employees, including school leaders and the volunteers in a school's workforce: this is the human infrastructure of a school. The people that form the human infrastructure of a school are fundamental to what makes a 21st century school and are

critical to students' and a school's success. It is the contributions of the workforce of schools that enables their aims and strategic plans to be carried out.

Schools that include technologies in teaching and learning have school leaders and staff with a passion for education, who see the value of technologies in students' learning and who understand the implications for students of using technologies in meaningful and meaning-making ways. The contributions that staff of schools make to the value of technologies in teaching and learning resides in their skills, knowledge and capabilities about technologies, and their roles in teaching and learning. Individual and collective duty statements, when well-aligned with the school's strategic plan, sit at the intersection of the human and the organisational infrastructures of schools. How each member of a school's staff includes technologies into their daily work, the ways in which staff skills and capabilities are utilised, and the nature of individual and collective roles or duty statements, impact on the ways in which technologies are included in students' learning activities.

A key factor in the educational and social progress of students is the teachers and school leaders with whom students learn (Mulford, 2008). Students value high quality teachers who form positive relationships with students and construct relevant and engaging learning contexts, with and without technologies (Moyle & Owen, 2009), as the following excerpts from a student focus group discussion indicate:

I think a good teacher is one that will understand us, explain things to us, makes class interesting, someone that will stay on the subject when you are trying to learn, someone that will not put you down, for example, say that you won't be whatever you want to be when you get older because you may not pass.

A good teacher is relaxed, calm and fun, and a teacher that you can understand.

A good teacher is someone that can give you one on one, and can explain things to you in your language and not the teacher's, so that you can actually understand it.

A good teacher is someone who does not get really angry over a small thing, and understands if you are on a computer they understand the difference between playing games and making one.

(Moyle, 2008, data files)

Characteristics of 21st century schools, where educators actively contribute to a robust human infrastructure that supports teaching and learning with technologies, include the following:

- The staff see the benefits of including technologies in teaching and learning.
- There is a critical mass of motivated staff who are willing to change and learn.
- The teaching and learning conducted with technologies meets the needs of students and is consistent with local, state and national goals.
- There is goodwill among the staff, parents and students (Moyle, 2008b).

Furthermore, recent research suggests that the pedagogical principles students like their teachers to adopt when teaching include the following:

- Explain less, but provide the structures for students, so they can find out about things for themselves (McWilliam, 2008; Moyle & Owen, 2009).
- Make sure that whatever students cite as their sources have veracity (Atkinson & Burden, 2007).
- Ensure students justify the claims they make and reflect upon what they discover (Laurillard, 2002).
- Scaffold the processes of learning so that the risks of failure are minimised and students learn from their mistakes, rather than worry about their failure to achieve (McWilliam, 2008).
- Create learning environments that foster play and encourage students to reflect on what they are learning from playing (Resnick, 2007).

- Promote and value students creatively experimenting in their learning (Matthews, 2008).
- Be a role-model to students and to colleagues (McWilliam, 2008; Mulford, 2008; Moyle & Owen, 2009).

The evidence reviewed here indicates that recruitment, induction, capacity building, and retention of high quality leaders and managers, and the employment of creative and innovative teachers are fundamental to the work of 21st century schools.

Human infrastructure of technologically-enabled schools tends to employ shared or distributed leadership models, focused on incorporating technologies into teaching and learning, including the IT Systems Manager, who contributes unique skills to the leadership team and to the school community. Indeed, the administration of 21st century schools requires the following: officers who are readily available to provide technical support to teachers and students in classrooms; processes in place to ensure that software licence agreements are kept up-to-date; and computers and software updated in a non-disruptive and timely manner.

Staff in 21st century schools understand how technologies can contribute to high quality teaching and learning which builds the innovation capabilities of students. Communication and information-sharing strategies are critical to achieving such an outcome, which further highlights the interfaces that exist between the organisational, human, technological and informational infrastructures of a school.

Informational infrastructure

The informational infrastructure of a school refers to the ways in which information is held in or carried around the school community, mostly over the technological infrastructure or IT systems that form the school's network. Ideally, an effective informational infrastructure in a school enables students individually and collectively, at any time and from any location, to do the following:

- access information about their own learning
- use and create online resources
- share information and create knowledge with others
- develop their capabilities as collaborative learners
- practise reading, writing and technology skills
- learn the social mores of participating in simulations and online groups.

The informational infrastructure interacts with the organisational infrastructure of a school to support information or data flows between the respective functions within a school. These structures support the interactions between the IT, teaching and learning and administration requirements of teachers and students, in order that classroom practices are supported, to meet the curriculum and assessment requirements of students, and to report students' attendance and achievements. As such, the informational infrastructure in a school supports teachers and school leaders to:

- make decisions based on school data
- broaden classroom practices
- achieve the school's strategic plans
- monitor, record and promote students' achievements
- share information and foster communication strategies.

The informational infrastructure of a school is working well when there is alignment between the human, informational, technological and organisational infrastructures and strategies, because such alignments mean that information is not only accessible, but is used by the people for whom it is intended. The value of an informational infrastructure, however, can only be realised if there is both the willingness and the capacity of staff and the school leadership to upload and share information using the technological infrastructure of the school (Moyle, 2008a).

Communication, collaboration and cloud computing

In the future, as mobile technologies continue to develop, it is likely that students and educators will be able to access more on-demand information and services, such as through cloud computing, which involves using the Internet to access third-party applications (Johnson et al., 2009). Cloud computing relies on accessing and sharing resources, rather than maintaining local servers for software and hardware. Cloud computing is valued for its capacity to enable collaboration over the Internet, and for its flexibility in handling the complex computing demands inherent in the IT work of schools. The information infrastructure using cloud computing enables students to collaborate on shared projects, irrespective of where they are located.

The 2009 Australia and New Zealand edition of the Horizon Report highlights some of the features of cloud computing for education purposes as follows:

... a number of cloud-based applications allow workgroups to collaborate in ways that automatically track changes and present the latest versions to users. ... Office 2010 can now be set up and configured to run in private cloud environments, combining the flexibility of cloud-based productivity tools with the security of a privately-controlled cluster.

(Johnson et al., 2009, p. 12)

Furthermore, it is likely that technical developments in both mobile technologies and cloud computing will enable people to access information and download what they require while being mobile (Price, Roussos, Falcao & Sheridan, 2009). Indeed, as learning becomes less restricted to classrooms, connected mobile devices and other augmented environments will provide the capacity for educators and students to bridge gaps between learning contexts, including between home and school, and to contribute to joint constructions of knowledge over time and space (Price et al., 2009). A challenge for schools though, will be to determine which information should sit in the 'cloud' and which information should sit elsewhere, as these decisions will interface with questions about how much time students should attend school, and the nature of the learning they undertake while at school, compared to what they do in other locations.

Data-driven decision-making

The informational infrastructure of schools also refers to the information schools collect which can afford deeper understandings about staff and students, and about their learning. Using information to inform decisions and strategies about how to improve the effectiveness of the school as a whole is sometimes referred to as data-driven decision-making (Consortium for School Networking (CoSN), 2004).

The thoughtful use of school-based data can inform the development of strategies to better achieve a school's educational goals of including technologies in classroom practices. School leaders can use local data to inform the processes required to move from vision to implementation, and for solving challenges positively. School-based information can be used to determine the nature and impact of the technologies being used and of the quality of innovation initiatives being undertaken in the classroom.

The informational infrastructure for schools is a powerful tool in the iterative process of continuous improvement that underpins the organisational developments in schools. Successful 21st century school leaders maintain inclusive and cohesive processes to develop, implement and monitor short-, medium- and long-term systemic and systematic approaches to transforming their schools. They use technological and informational infrastructures to collect and analyse data, interpret results and communicate findings in order to improve organisational practices and the quality of students' learning with technologies (CoSN, 2004; Moyle, 2006).

Foundations for an integrated architecture

To align the respective infrastructures that form the integrated architecture of a 21st century school requires a foundation of knowledge, understanding, confidence, skills and capabilities of staff and school leaders sufficient to accommodate the changes required to build the innovation capabilities of students and to maximise the benefits of technologies in schools. The learning of all students and staff is the foundation of such a school's architecture, and it is dependent upon a supply of appropriately prepared teachers. But addressing the educational, emotional, social, technical, ethical and philosophical aspects that underpin teaching and learning with technologies is demanding and requires funding. Indeed, one of the challenges for schools, universities and governments at local and national levels is to make sufficient investments into the pre-service and professional learning of educators, who, after all, are the human infrastructure of the education sector.

While the Australian Government, through the *Digital Education Revolution* has made \$2.1 billion available to the state and territories for the purchase of computing equipment (Australian Government, DEEWR, 2008b), this amount of funding has not been matched at either state or national levels, for the provision of professional learning opportunities for teachers and university teacher educators to upskill their knowledge, skills and understandings concerning teaching and learning with technologies. Yet pre-service teacher education and professional development are acknowledged as fundamental to the implementation of technologies in classrooms.

Pre-service teacher education

During the next ten years, Australia, together with several countries around the world, is likely to face a teacher shortage (McKenzie, Kos, Walker, Hong & Owen, 2008). Teenagers currently in secondary schools will soon become teachers, and they will be followed by children in primary schools, a decade later. That is, by 2030, the knowledge economy will be driven by the young people who are currently in primary schools. In this context, transitions in both directions between schools and universities are becoming increasingly important (Bradley et al., 2008).

Learning how to seamlessly and meaningfully include technologies into their classroom practices has been identified, by both pre-service and early career teachers, as an important part of their preparation, as they learn to become teachers (Moyle & Owen, 2009). But pre-service teachers have consistently expressed concerns about the ability of both their university lecturers and their supervising teachers to assist them to learn how to include technologies into their classroom activities while on their respective practical placements (Albion, 2003; Markauskaite, Goodwin, Reid & Reimann, 2006; Moyle & Owen, 2009). Additionally, pre-service teacher education students report they feel they have to learn about and build their student behaviour management strategies before they can confidently include technologies in their teaching and learning activities (Pegg, Reading & Williams, 2007; Moyle, 2009). One way in which pre-service teachers can gain this confidence in their capabilities in classrooms is to practise different teaching and learning approaches within risk-free environments. Indeed, the importance of being located in schools where the culture supports and develops a critical mass of enthusiastic and innovative teachers who are capable of teaching others how to include technologies seamlessly into their classroom activities, is emphasised by student teachers (Markauskaite et al., 2006; Pegg, Reading & Williams, 2007).

Building transition programs from schools to higher education, and particularly building sustainable links between schools and teacher education faculties in universities, is critical to the improvement of future staffing of schools. Building these transitions, with a view to supporting teaching and learning with technologies that develop students' innovation and creative capabilities, however, requires more focused work be undertaken within schools and universities over the next decade. This work will demand that a greater emphasis be placed on the professional learning and development provided for all staff in schools.

Professional learning and development

To have teachers incorporate technologies in their classroom practice in innovative and engaging ways requires specific professional learning support. Successful schools that build students' innovation and technological capabilities require staff who are willing and able to participate in ongoing professional learning about how to include technologies into students' learning. These activities should build on each staff members' existing experiences and capabilities. Furthermore, as Becker and Riel (2000) found, the more extensively teachers are involved in professional learning activities, the more likely they are to use computers in exemplary ways.

Most professional learning undertaken by teachers concerning technologies occurs at school (Moyle, 2006). This points to the importance of school leaders being well-versed in current theories and practices about the place of technologies in teaching and learning. Principals of schools that have substantial IT infrastructures not only have to identify strategies for providing professional learning for the teaching staff, but also have to identify strategies for providing professional learning for the technical staff working with technologies. What constitutes appropriate school-based professional learning and the role the school leadership should play in the provision of the professional learning to support teaching and learning with technologies, however, has only started to be explored in the last few years in Australia.

Teachers, technical support officers and school leaders each have to determine what professional learning they require in order to reconceptualise classroom practices so that they meaningfully include technologies. These professional learning strategies have to combine and integrate individual and organisational developments together, by focusing on mutually reinforcing content and strategies (Fullan, 2008) to support the overall goal of building students' innovation capabilities with technologies. Some of the school-based professional learning and development strategies being used include school visits, coaching and mentoring, communities of practice and building partnerships with institutions beyond the school gates.

Visiting other schools

One of the more revealing professional learning activities school leadership teams and staff can undertake to gain a broader understanding of the ways in which teaching and learning can include technologies is to visit other schools locally, nationally and internationally. They can then take the better ideas back to their own schools to implement and adapt them (Gill, 2007). Identifying local and global trends in other schools can be beneficial for influencing and informing professional and organisational strategies in their own schools (Principals Australia, 2006).

Some of the issues educators identify as being beneficial to investigate on such visits include examining how team approaches to leadership and teaching and learning can be established to support learning with technologies. An examination of the specific roles, rules, expectations and accountability mechanisms required for such teams can form the basis for their own school-based professional learning (Moyle, 2006). Since the inclusion of technologies into teaching and learning often involves change management, identifying strategies in other schools that have fostered increased use of technologies in teaching and learning, investigating how to lead and manage people who resist change, and gaining insights into how to personalise school-based professional learning of staff (Moyle, 2006), are also seen as valuable strategies for school improvement.

Coaching and mentoring

One of the ways teachers and school leaders can build confidence about their vision for embedding technologies into teaching and learning is through being involved in coaching and mentoring programs. Such processes provide educators with opportunities to revisit their core values for teaching and learning, and assist them to identify the relationships between their core values and teaching and learning with technologies. Listening to others and being listened to, within and beyond the school, helps people to clarify their ideas and to learn from each other.

As such, the opportunity to be a mentor to another is not only helpful to that person, but also professionally rewarding to the person offering the mentoring (Mulford, 2008; 2006).

Furthermore, a successful teacher or principal peer-mentoring program can also be a positive incentive to other school staff to try mentoring approaches with their peers. Peer-to-peer mentoring can occur between teachers and principals within one school or in a variety of schools, and can be supported by online connections to other people and resources (Mulford, 2008). In this way, it is possible to generate new, innovative practices within a school, and schools are likely to find this a particularly useful professional development methodology, given the variations in technologies skills and abilities evident across school staffs.

Communities of practice

Communities of practice are groups of people who participate voluntarily and together share a similar interest. Through the establishment of common goals, they seek to learn together. A successful community of practice shares information and knowledge within the community. Communities of practice however, are based upon relationships rather than simply on the transfer of information. In this way, membership of a community of practice involves an emotional as well as an intellectual commitment (Molphy, Pocknee & Young, 2007).

In the 21st century, the technological infrastructure available to most schools is robust enough to support online communications among communities of practice, whether they are located in the same school, in the same local region, in another state or overseas. Principals can use communities of practice to support their own work, and can provide the necessary time and infrastructure to enable teachers to also participate in communities of practice. Through such mechanisms, school principals can support staff in using technologies to build their innovation capabilities.

The notion of communities of practice can also be applied to classrooms. Students can use social networking sites to build upon each others' work, to share ideas and determine agreements about classroom practices. While the technologies enable such approaches to learning to be applied in classrooms, the filtering systems of schools can sometimes work against such activities being put into practice. It is issues such as this to which school principals have to be alert, as promises of constructive learning opportunities can rapidly turn to frustration for teachers and students if certain ports are blocked, thereby making such learning opportunities impossible.

The concept of communities of practice can also be broadened to establish links with other schools so that whole school communities, including students, can learn from each other and stimulate, support and add to each other's work. There are now several technologies that allow asynchronous online communications with audio and video functions that can be used, depending on the available bandwidth and filtering systems. The use of video in these programs allows members of communities of practice to see each other in real time and to discuss and record their views and opinions for future use.

Sustaining partnerships

Professional learning and development can also be fostered through building and sustaining partnerships with agencies outside of the school. Involving stakeholders, such as parents, community members, academics, professional associations and industry members in the work of schools enables students and staff to access and use all that expertise available to them. Given the technological infrastructures available in schools, partnerships can now be sustained online as well as in face-to-face settings.

Regular engagement with professional associations and industry members provides schools with networks, from which they can gain insights into current practices and the latest innovations and developments occurring in teaching and learning with technologies. Reciprocal relationships within the school community enable school leaders to demonstrate to their staff and their school communities the intrinsic rewards and benefits gained from such work.

Building partnerships between schools and universities can enable mutually beneficial relationships to be developed, ones that can support improvement in the quality of pre-service

teacher education and the quality of the professional learning and development that occurs in schools (Pegg, Reading & Williams, 2007). Despite the importance in the 21st century of schools and universities building and sustaining partnerships (Bradley et al., 2008), evidence to date suggests that existing university–school relationships are largely wanting (Jones, 2002; Pegg, Reading & Williams, 2007). This is particularly the case in relation to the lack of support pre-service teachers report they receive in developing their abilities in teaching and learning with technologies (Moyle & Owen, 2009).

Sustaining partnerships requires effective communication strategies to keep parents, partners and other stakeholders involved and informed of new developments, and initiatives coordinated. It is at these points within the school's integrated architecture that the quality of the information infrastructure is particularly highlighted.

Concluding comments

Schools in the 21st century have to be oriented towards supporting technologies-enabled learning. It is abundantly apparent though, that the physical design and structures of schools created in the 19th century are no longer appropriate in the 21st century. In addition, as teaching and learning becomes increasingly possible in virtual environments, schools no longer have to be defined only by their physical attributes. There are now new opportunities for schools to create learning activities for students which blend physical attendance at school with online learning. These new opportunities, however, challenge the pedagogies traditionally used by teachers, the way schools are organised, and the attendance requirements legislated by State Education Acts. Schools then are faced with making changes to the ways they conduct their business at multiple levels, and these changes have to be made in tandem. Bringing about changes at multiple levels within a school requires whole school approaches to the planning and implementation of change.

School leadership is critical to bringing about the changes required at the levels of policy and practice in a school, and this requires leaders to conceptualise and strategically plan how to bring about these changes in a coordinated manner across a school. Viewing schools as a whole organisation comprising several different infrastructures that interact with each other to form an integrated architecture can assist school leaders to undertake such an enterprise. Successful 21st century education leaders know, understand and respect their school communities (Principals Australia, 2006), and they use the full suite of expertise available to them within and beyond the school to support them to facilitate change. In this context, team approaches to leadership within schools are increasingly being identified in the research as enabling successful whole school change.

Fundamental to altering the culture and the ways in which schools operate and how educators teach are changes to pre-service teacher education, and the provision of multiple and ongoing opportunities for in-service professional learning and development. These cultural and operational changes have implications for the sorts of learning a whole staff in a school requires in order to meaningfully integrate the technologies into their classroom activities. Revisiting the ways in which student teachers undertake their practicum and how professional learning is conducted in schools then, are emerging as issues requiring more research and more funding. But more than this, there is a growing recognition by researchers and practitioners of the necessity to reconsider the assumptions and paradigms upon which teaching and learning with technologies are based. Section 6 will address these issues.

Challenging paradigms

The dominant policy paradigm in Australia within which education sits has been shown to be an economic one. This review paper has examined the ways in which education policies and practices are being created to address the economic priorities outlined in national and international policies and reports. It is timely to reflect on some of the issues that seem to have fallen between the gaps at the intersections of policies that are oriented towards the economic priority of building students' innovation and creativity with technologies. Where are the silences and what are the policy agendas that are only being whispered?

The choices a school or department of education makes about the technologies it deploys are reflections of the values and philosophies that the school or department endorses. It has been shown earlier that the choices made about technologies and how they are used to build creativity and innovation depend upon an array of educational, social and economic factors. The implications of these choices impact upon the ways in which students learn, with and through technologies at school. For example, the nature of the technological hardware and software chosen influences the pedagogical approaches possible within a learning environment and, as such, influences the sorts of technical and pedagogical skills teachers, school leaders, technical support officers and students have and require. Decisions about every aspect of including technologies in teaching and learning disrupts previous conceptions of school education (Christensen, Horn & Johnson, 2008), ranging from assumptions previously made about the physical set-up of classrooms, through to the range of pedagogies that include technologies.

Alternatives to the 'commonsense' of the market

It was argued in Sections 2 and 3 that school education and commercial technologies markets have become intertwined. The 'commonsense' (Gramsci, 1971) of these markets sees the selling of proprietary technologies products such as computer hardware and software to Australian teachers and students as a normal practice. 'Commonsense' here refers to the way market dominance is created and maintained through the acceptance by those subordinated (for example, teachers and students) of the commonsense or normal reality of purchasing proprietary and off-the-shelf technologies, and by the policy-makers who provide the mechanisms by which the 'commonsense' is operationalised then reinforced. Gramsci (1971) referred to this phenomenon as 'hegemony'.

The dominance of closed, proprietary IT environments, particularly in government schools, indicates that the preferred baseline policy position of government departments of education is to

purchase proprietary software. This policy position is the opposite to adopting open environments as the norm, and to purchasing proprietary software only if there is no other choice. Under the current policy position, vendors are able to maintain market dominance by 'locking-in' clients, such as schools and departments of education, to particular sorts of software. Vendors make financial and technical arrangements for the use of a particular piece of software such that it is difficult for a client to change to an alternative. Ploys such as this lock in the client, thereby maintaining a revenue stream for the vendor.

This review paper posits that open environments would be more economically viable and more pedagogically sound. Yet the practice in Australian schools of opting for proprietary software is rarely questioned in schools or the literature. As discussed in Section 2, the lack of debate and indeed the acceptance of the so-called commonsense of such approaches to the purchases of hardware and software (Moyle, 2003) works against students and teachers having the freedom to experiment, to be creative and innovative with technologies in schools. It is time then for this review paper to examine some of the assumptions made about technologies and to look over the fence to directions in open education and open source software.

Open education

It has been argued in this review paper that choices about what technologies are used in schools, and how they are deployed and utilised, are derived from and have social purposes and consequences. So too, decisions about the technologies used in schools represent deeper philosophical views about the political, social and instrumental implications of those technologies and of the socially reproductive role of schools.

There has been a confluence of issues in the 21st century, which has led to the rise of open education as an alternative to purchasing off-the-shelf proprietary software and also to existing educational publishing models. As technologies have brought the market, vendors and proprietary software into schools, concerns have been raised about the privatisation of what are supposed to be spaces and places that have traditionally contributed to the common good, without the intrusion of markets. There are several reasons for these reactions to markets in schools, including that it goes against the history and tradition of Australian school education being 'free, compulsory and secular' (Moyle, 2003).

Furthermore, as understandings have developed and become more sophisticated about the processes of knowledge-building, about the ways in which children and young people currently use technologies, and about the pedagogies that include technologies that enable students to exhibit their innovative and creative abilities, counter-hegemonic approaches to technology-enabled education, broadly referred to as 'open education', have gained greater prominence. Some educators have posited the view that, rather than locking up knowledge, processes and resources in private markets, they are interested in choosing a different path: one where everyone can access and contribute to the creation of knowledge. There is a genuine interest among some educators about how teachers and learners can together create, shape and build knowledge together, deepening their own knowledge, skills and understandings as they go.

'Open education' is a broad, collective label that refers to open educational resources and it draws upon open technologies, such as open source software, open standards and open licencing regimes, to facilitate collaborative, flexible learning. Where there is an open sharing of teaching practices and a progressive building of knowledge, educators act collaboratively and benefit from the best ideas of their colleagues in Australia and around the world. That is, open education combines the established tradition of sharing good ideas with colleagues, and the collaborative, social and interactive culture of the Internet (Shuttleworth Foundation and Open Society Institute, 2007).

In 2007, a small group of educators and technologies experts met in Cape Town, South Africa to discuss ways in which open education efforts could be broadened and deepened by working together. The aim of the meeting was to accelerate efforts to continue building and promoting open resources, technologies and teaching practices in education. This meeting

resulted in the release of *The Cape Town Open Education Declaration*. The following is an extract from that *Declaration*:

We invite learners, educators, trainers, authors, schools, colleges, universities, publishers, unions, professional societies, policymakers, governments, foundations and others who share our vision to commit to the pursuit and promotion of open education and, in particular, to these three strategies to increase the reach and impact of open educational resources:

- 1 Educators and learners: First, we encourage educators and learners to actively participate in the emerging open education movement. Participating includes: creating, using, adapting and improving open educational resources; embracing educational practices built around collaboration, discovery and the creation of knowledge; and inviting peers and colleagues to get involved. Creating and using open resources should be considered integral to education and should be supported and rewarded accordingly.*
- 2 Open educational resources: Second, we call on educators, authors, publishers and institutions to release their resources openly. These open educational resources should be freely shared through open licences which facilitate use, revision, translation, improvement and sharing by anyone. Resources should be published in formats that facilitate both use and editing, and that accommodate a diversity of technical platforms. Whenever possible, they should also be available in formats that are accessible to people with disabilities and people who do not yet have access to the Internet.*
- 3 Open education policy: Third, governments, school boards, colleges and universities should make open education a high priority. Ideally, taxpayer-funded educational resources should be open educational resources. Accreditation and adoption processes should give preference to open educational resources. Educational resource repositories should actively include and highlight open educational resources within their collections.*

These strategies represent more than just the right thing to do. They constitute a wise investment in teaching and learning for the 21st century. They will make it possible to redirect funds from expensive textbooks towards better learning. They will help teachers excel in their work and provide new opportunities for visibility and global impact. They will accelerate innovation in teaching. They will give more control over learning to the learners themselves. These are strategies that make sense for everyone.

(Shuttleworth Foundation and Open Society Institute, 2007, p.1)

This *Declaration* has now been signed by several thousand people, individually and on behalf of organisations. The intention of the *Declaration* is to promote dialogue about the place of open education, from both practical and philosophical points of view.

Open source software

One expression of open education is the use of open source software in schools. Open source software is software where the source code is open, unrestricted and available by downloading it from the Internet. The ‘open’ in open source software is intended to imply ‘open or free speech’ in the philosophical sense, not ‘free or no cost’ for the product. The programming code of open source software is freely available and viewable by anyone with the skills to do so. The language that makes computers work is the programming language of software, and it is used by programmers to communicate with each other about the functions they wish to make a computer perform. As the programming language of open source software is viewable by anyone with the skills to understand the programming language of software, this characteristic of open source

software makes it particularly attractive to educators teaching programming to students. With open source software, students can learn about programming by actually viewing a functioning software program. This is not the case with proprietary software.

The software itself is developed by identifiable communities who contribute their skills to the development of a particular piece of software, which is known as a 'project'. People in open software communities participate voluntarily, or they may be paid by employers, such as government departments or private companies, to write open source software programs. If students (or for that matter, staff) are sufficiently skilled, they can contribute to ongoing developments of these software projects.

The communities constituting open source projects communicate with each other via the Internet to create their software. Models of open source software development are based on contributing to the public good through online networked activities (Bessen, 2006). The paradigm shift away from personal to networked computers, linked to the Internet, makes the development and use of open source software viable, both technically and philosophically, for the education sector. As a result of those working in open source software communities, there are now alternatives to proprietary software.

As open source software is freely available to the public at large as a public good, rather than for gain or profit, there are no charges made for the licences of open source software. Rather than restricting the right to copy, open licences provide users with varying levels of rights to copy the software. These licences are broadly referred to as 'copyleft' rather than 'copyright' licences; where the right to copy is left in place. Such licences are beneficial to schools, as it enables as many copies of the software to be made by the school as it likes, and it reduces the level of administration required to manage software licences, since there are no renewal or ongoing licensing costs required. It also reduces the risk of inadvertent copyright infringements, sometimes characteristic of activities in schools.

As there are no costs or charges for the licences of open source software, such software offers teachers options not available through proprietary software options, due to their expense. Consider, for example, the way this teacher in Queensland uses open source software.

I teach a KPS class (Knowledge Producing Schools) basically using project-based learning with a community focus. Over the last few years I've had the students building large telescopes with a goal to training them to use them and planning for astronomy nights for local primary schools. We've done this with open source plans for Dobsonian Telescopes, Open source or free astronomy software for making star charts, enhancing images taken with modified web cameras of the moon and planets. In addition to this we've made 3D animations of life cycles of stars etc using an excellent open source program called Blender. We're compiling a kit of resources for teachers of those primary schools we visit including all useful software. In addition to this, I have had students adding Aboriginal constellations and star names into an open source planetarium program called Stellarium. This will then be uploaded to the net for the world to use. The software being used by students in my class are Blender, Celestia, Stellarium, Audacity, Gimp, Cartes Du Ciel, Registax and Newton.

(Lapworth to Moyle, 2009, data file)

Imagine the costs of the software if the software used by this teacher were all proprietary! Additionally he could not teach in this way, about these topics, with proprietary software. Reflect for a moment on how much richer the learning experiences of the students of this teacher in this program are than if they had been restricted to proprietary software. The learning and technologies processes are quite different.

Contributing to open source projects provides students with opportunities to use software more complex than office productivity software, and gives students meaningful and authentic audiences for their work using that software. Students with the interest and capability, and with

a range of skills (that is those who have had the opportunity, and have been well-taught), can not only use open source software, but can also contribute to open source software projects, for example, by developing code or by testing new software for bugs. Participating in active communities of practice on real projects requires young people to work in teams with others in their class and over the Internet. Activities such as these truly build students' innovation and creative capabilities.

Open sharing

One of the challenges for educators, however, whether they are using proprietary or open software or content, is how to collaborate and share experiences of their 'pedagogical know-how' (Dalziel, 2008). Pedagogical know-how includes how to build students' innovation and creativity capabilities with technologies. Questions about how educators may be able to collaborate and share approaches and experiences, however, are not only limited to how people technically use technologies but, in addition, also raise questions about what are the processes by which technology-enabled knowledge-building and sharing can be enabled and promoted.

Dalziel (2008) argues that one of the reasons why, to date, educators have not achieved the level of collaboration across the sector that is technically possible, is because too often learners and teachers have been conceived of as single entities. As such, online content and processes have focused on the individual learner, rather than on the collaborative dimensions to teaching and learning. Indeed, the first commercial computers available were referred to as 'PCs' (personal computers), and were not networked together. Now there are several robust open source platforms, such as *Moodle* and open content repositories such as *MERLOT* (Dalziel, 2008), built specifically for collaboration and re-use of content.

The capacity of open sharing of software and content is no longer restricted by the software, but rather, is now restricted only by the choices people make. Using online learning platforms requires educators to reflect upon the types of learning they value, and the ways in which these approaches to learning can be achieved. Openly sharing and collaboratively contributing to descriptions of successful designs of teaching and learning practices, through open fora, may be one way in which educators can find commonly understood words and mechanisms for sharing descriptions of educational processes and practices. A commonly understood language that conveys the many ways in which technologies in teaching and learning may add value, and/or disrupt, previous conceptions of classroom practices (Christensen et al., 2008). Adopting such practices may assist educators to build ways of using the open platforms available, and collectively to build the knowledge or the pedagogical know-how within and across schools. To be able to adopt these approaches though, means that teachers have to know such approaches exist and they have to be able to develop the knowledge to be able to implement them. Many teachers in Australia do not have either the language or the pedagogical know-how. But this situation can, and should, be changed.

Concluding comments

Australia's policy priorities reflect the macro level, iterative and symbiotic relationships that have emerged between school education and Australia's economic policies, particularly in relation to the nation's productivity and sustainability priorities. This review paper has argued that school education in Australia sits within multiple policy contexts and is linked to Australia's economic policy agenda. There are two intersecting school education policy priorities – how to meaningfully include technologies into teaching and learning, and how to build innovation capabilities in students. These education priorities reflect the current emphases placed on school education, to build and sustain the nation's productivity, nationally and internationally.

Building innovation capabilities in students, and the role technologies play in teaching and learning, have implications for pedagogy and school leadership in Australian schools. These implications are canvassed in Australia's national education and economic policy statements

and were discussed in Section 5. Some of the ramifications of these policies, however, have included the marketisation of school education, and the situating, both in policy and in schools, of market choice as the accepted norm. There is silence or barely any dialogue about alternatives, such as open education initiatives. Yet arguably, these alternative initiatives are cheaper arrangements and they more closely align with Australia's education policy objectives than do the existing provision of technologies in Australian schools. It would be possible, with political will, to redirect the significant, recurrent funds paid for software licences away from commercial vendors to the professional development of educators. It is likely this would create more innovative and creative education environments than the 'off-the-shelf' mentality underpinning the use of computers in schools at the moment. It would put money and resources where it is urgently required – into the development of the human infrastructure of schools.

To adopt such policies about technologies would afford governments and schools the ability to symbolically demonstrate that Australian students are receiving a modern education. They would then model, and be in line with, what educators value as high quality learning, and with what the labour market and other market forces rhetoric argues students are likely to require over the next few decades. As such, it is time to reconceptualise models of education, to move away from those of the 19th and 20th century and, in light of the technological capacity now available to schools, to take into account the demands of the 21st century. As such, it is also time to move beyond the single view of how proprietary technologies can build innovation, to more democratic and open ways of building innovation in Australia's students using technologies, and to identify and practise ways in which formal in-school learning, and informal out-of-school learning by students can be aggregated into meaningful ways of learning.

Building innovation with technologies and placing the learner at the centre of education offers many creative opportunities for students and educators. But challenges abound. There are tensions between the economic purposes of education, driven through national and international forces, and the ways in which teaching and learning can be constructed to build students' general capabilities. In the 21st century the school education sector, as a whole, faces the challenge of determining what constitutes teaching and learning, of deciding what does and will truly build students' innovation and creativity capabilities. Technologies are seen as a way to radically alter traditional learning and teaching patterns. Such approaches to learning place students, not as passive recipients of information, but as an active author, co-creator, evaluator and critical commentator (Redecker, 2008). But currently young people's uses of technologies differ between home and school, with children and young people often 'powering down' for school and 'powering up' at home (Project Tomorrow, 2009). It is time that educators construct learning with technologies in sufficiently complex ways for students to feel they are not only 'powering up' in their personal activities with technologies, but for them to also have a similar sense about learning at school.

A challenge for all Australian schools then, is how to make real the promise of blended learning opportunities, where classrooms make optimal use of both the face-to-face and the virtual environments available to them, so that viable and meaningful learning with technologies is achieved for students and teachers. How can integrated, network-based learning be used to build students' innovation and creativity capabilities? Imagine classrooms where it is possible for a teacher wishing to introduce concepts of life cycles of forests to do so within a simulated environment of a forest, in which the teacher and his or her students all inhabit the forest for a short while. Imagine lessons, where students come prepared to discuss issues of global warming based upon their experiences of online games in which they were involved in trying to save a planet from ecological disaster. Once a school and its staff know how to construct such learning experiences, traditional ways of teaching and learning will no longer be sufficient.

One of the ways to address these challenges is to give the young people in schools a voice about how teaching and learning that includes technologies can occur. To listen to how these young people approach learning and living in their everyday lives will mean that, as educators, we hear the frustrations they experience at school, recognise the challenges they face in learning,

and empathise with their aspirations for how schools can be improved. Then we will have an opportunity to make school education more meaningful for them, and the whole community.

Building innovation with technologies, therefore, presents policy-makers and educators with opportunities and challenges. It requires policy-makers to rethink the resources made available to schools, especially for professional learning and development. It requires rethinking curriculum and assessment approaches and a consideration of these constructs in light of collaborative, rather than simply individualistic points of view. Educators have to reflect upon their roles and capabilities, to revisit their expectations and understandings of learning in light of the educational possibilities now afforded by complex software – such as online games and simulations – and to move on from simply expecting students to use word processing software for the presentation of assignments. Professional development of all teachers in schools, not just those designated as having technologies responsibilities, is required. The challenges are before us.



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Kathryn Moyle is Associate Professor of Education at the University of Canberra. She has published extensively in the fields of technologies and their implications for school reform, curriculum, assessment, teaching and learning, and school leadership. Her most recent research involves listening to the views of students about how they learn with technologies. In recent years she has had a leadership role with the peak body advising government on ICT policy in education.

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