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Evaluating learning in the 21st century: a digital age learning matrix

Louise Starkey*

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If the purpose of secondary schooling is to educate the upcoming generation to become active participants in society, evaluation of teaching and learning in the information-rich digital age should be underpinned by relevant theories and models. This article describes an evaluation tool developed using emerging ideas about knowledge creation and learning in a connected society. The digital age learning matrix was successfully trialled and applied in a study of six digitally able beginning teachers during their first year of teaching to identify aspects of learning occurring as digital technologies were integrated into their teaching practice. An implication of this study is that teachers, even the digitally able, will be limited in their ability to teach the upcoming generation to be active participants in a digitally enhanced society without understanding how to apply theories of learning that are relevant to a digital age into their practice.

Keywords: beginning teachers; digital; learning; matrix

Introduction

Ideas about knowledge and learning are changing. At the start of the digital age, learning in a secondary school context appears to be slowly evolving from a focus on what has already been discovered and prescribed as ‘knowledge’ towards a focus on critical thinking skills, knowledge creation and learning through connections. This is evident through literature and research (such as Bereiter, 2002 and Gilbert, 2005) and through examination of policy such as a comparison of New Zealand national curriculum documents from pre-1980s and the 2007 New Zealand Curriculum (Ministry of Education, 2007). This article considers how researchers and practitioners can evaluate teaching activities in a way that might be relevant to notions of learning in the digital age.

Teachers are being studied by researchers as they strive to use digital technologies in educationally meaningful ways. Evaluating learning using digital technologies has been attempted in a number of ways. Cassady (2002) summarises ways of evaluating learning in the cognitive domain that are measured by improved student achievement over a project. This type of evaluation differs from one which seeks to evaluate the potential and actual learning in the design of an activity. In a study of effectiveness of digital technology use in Tennessee (Lowther, Strahl, Inan, & Ross, 2008), programme effectiveness was measured by direct classroom observations, surveys,
student performance assessments, focus groups, and student achievement analysis. Observers used a rubric of *meaningfulness* of computer activities and examined how computers were being used, noting cooperative learning, project-based learning, higher level questions, experiential hands-on activities, independent inquiry, student discussion or when students were producers of knowledge. By counting the times that these activities were present, the researchers concluded that there was less transmission teaching observed as a result of the extra support that was included as part of the initiative. It did not examine the *learning* within the teaching activities.

The link between digital technologies and student performance is complex. In a synthesis of literature, Cox et al. (2004) concluded that effective learning with ICT occurs when a teacher *challenges students to think*, which could be how learning occurs without the use of digital technologies. The research by Lowther et al. (2008) gathered student achievement data over two levels of standardised tests. Analysis found that the students taking part in the programme which had digital technologies and support performed as well or better than the control students in most, but not all, of the tests. Although this suggested that the introduction of digital technologies and associated support did not make a significant difference to student achievement, conclusions concerning effectiveness depend on whether what was being measured was compatible with the aims of integrating digital technologies into the teaching and learning process (Heppell, 1999). The students observed spent more time learning through student-centred studies and cooperative learning activities, which may have benefits in other areas not measured directly in the standardised tests. What was being measured was based on a concept of learning or knowledge developed prior to the digital age. Heppell (1999) argued that the ways in which we assess teaching and learning using digital technologies is problematic as the measures have been constructed using pedagogical beliefs which predate the digital age.

Researching how digital technologies are being used in the teaching and learning process could be a valid way of examining effectiveness if the link between the use and the learning is explicit. Research to date rarely makes this link explicit and evaluations appear to be based on researcher beliefs about learning which are either not expressed or vague. Furthermore, traditional achievement measures may not be valid as they are unlikely to have been designed to take account of the way that students learn in a connected world or apply the use of digital technologies to construct knowledge (Loveless, 2002). For example, when Larry Cuban (2001) examined the use of computers in Silicon Valley, he reported ‘no clear and substantial evidence of students increasing their academic achievement as a result of using information technologies’ (Cuban, 2001, p. 133). In Cuban’s study the student learning or achievement was measured using traditional measurements, but Sutherland et al. (2004) point out that not only should the content of assessment reflect the digital age, but modes of assessment should also reflect what is important for the world beyond school.

An effective evaluation tool would recognise the range of ways technologies can be used for learning and the importance of critical thinking, creativity (knowledge creation) and making connections in an information-rich Web 2.0 world. Teaching a flexible curriculum in an information-rich Web 2.0 environment would require a pedagogical approach which includes collaboration or interaction beyond the classroom and opportunities for students to create and critique knowledge.

The first aspect of learning in a digitally enhanced Web 2.0 society is the ability to connect and collaborate with others beyond a constrained physical environment. This has been noted by researchers. Jonassen, Peck, and Wilson (2000) wrote about
the use of computers as a learning tool, stressing that digital technologies promote meaningful learning only when learners are engaged in knowledge construction, conversation, articulation, collaboration, authentication and reflection. To engage in this meaningful learning the learners would have to have connections to other learners or people with whom they can interact, collaborate, critique and gain authentication. These people could be within the schooling community or they could be beyond the school environment.

A review carried out in England identified some issues and challenges in the use of digital technologies in education (Becta, 2007). This included using technologies to support learners working together. A model to evaluate effectiveness of digital technologies should consider the collaborative nature of knowledge creation and learning.

The second aspect is the creation of knowledge through connections. Ideas about ‘knowledge’ appear to be changing from something that is found in the heads of individuals or in books to something that is not fixed, is debatable, accessible through a range of media and created through networks, connections and collaboration (Bereiter, 2002; Gilbert, 2005; Siemens, 2004). Building on this evolving concept of knowledge, Siemens (2004) developed ‘connectivism’ as a learning theory for the digital age. The theory considers how people, organisations and/or technology can collaboratively construct knowledge. Siemens describes connectivism as:

> the integration of principles explored by chaos, network, and complexity and self-organization theories. Learning is a process that occurs within nebulous environments of shifting core elements – not entirely under the control of the individual. Learning … can reside outside of ourselves (within an organization or a database), is focused on connecting specialized information sets, and the connections that enable us to learn more are more important than our current state of knowing. (Siemens, 2004)

The connections that a student makes could thus be identified as important aspects of learning in the digital age and it is through those connections that knowledge is created and critiqued.

The notion of creativity applied to knowledge is a way of exploring how knowledge may be created within the context of digital age secondary schooling. Creativity has been described in various ways. Plato described creativity when he compared two types of artist; true artists as those who bring into birth some new reality as opposed to artists who deal only with appearances and not with reality itself (Plato, 360 BCE, as cited in H. Anderson, 1959, p. 57). He was making a distinction between artists who were skilled at manipulating tools and artists who were able to show something new as a result of manipulating the tools. This distinction is important. Taking this definition, being able to reproduce an existing reality or knowledge is skilful rather than a demonstration of creativity in the sense of creating new knowledge.

A second definition of creativity comes from an educational setting. The National Advisory Committee on Creative and Cultural Education in England gives a schooling-based definition of creativity as: ‘Imaginative activity fashioned so as to produce outcomes that are both original and of value’ (NACCCE, 1999, p. 29). This aligns with Plato’s definition.

Downes (2007) defined creativity as ‘the manipulation of one’s experiences using the tools at one’s disposal’. In this definition, Downes implies that original ideas are the result of experiences. This definition like the previous one requires a product, but differs in that it specifies that tools are an important aspect of creativity.
Not all definitions of creativity include having a tangible product. In a presentation titled ‘Do Schools Kill Creativity?’, Robinson (2006) defines creativity as ‘having original ideas that have value’. Combining the ideas of Plato, NACCCE, Downes and Robinson a model of creativity was developed (Figure 1).

In the digital age the notion of connections and collaboration becomes explicit, with the model underpinned by critical thinking. Knowledge is rarely developed in isolation, and between the students’ ideas and the creative product, there would usually be critique and evaluation from other people. The phenomenon of the long tail (C. Anderson, 2006) means that through the World Wide Web, learners and knowledge creators are able to connect with others in the world with similar interests who are able to critique and give feedback, something that was not easy prior to Web 2.0 becoming accessible. Collaboration and connections through digital technologies allow sharing and critique of knowledge as it develops. This feedback can be used to ascertain whether the created knowledge has value. Sharing and critique of evolving knowledge could be an important aspect of learning in the digital age included in an evaluation tool. The creativity model for the digital age (Figure 2) could be renamed ‘Knowledge creation in the digital age’.

A third aspect is critique. While ideas about knowledge evolve through research, debate and technological advances, the process of teaching and learning in schools is also changing. Digital technologies have become increasingly complex and ubiquitous. A range of computer software, internet access, cell phone communication, cameras, video, and learner management systems are available at school. The introduction of a networked world where information can be found in seconds (with the right key words), mashed, further developed and shared using Web 2.0 applications, is contributing to less importance being placed on remembering facts and figures and increasing importance on the understanding of concepts, critique of information and sources, creativity, and the connections learners make (Tapscott & Williams, 2006).
The use of critical thinking has been identified as particularly important in the digital age. Relatively quick access to a wide range of information means that the user needs the ability to critically evaluate the validity and relative value of information accessed. A change in the approach to learning has been caused by the extensive access to a range of information. In the past the library, a book or an expert (e.g. a teacher) were consulted, and the value or validity was less likely to be questioned (Rowlands et al., 2008). This is one way in which critical thinking is an important aspect of learning when using digital technologies and this should be underpinned by the belief that knowledge is debatable.

Critical thinking was defined by Chaffee (1988) as:

Our active, purposeful, and organized efforts to make sense of our world by carefully examining our thinking, and the thinking of others, in order to clarify and improve our understanding. (p. 29)

The use of critical thinking becomes important in the digital age as relatively quick access to a wide range of information means that the user needs the ability to critically evaluate the validity and value of information accessed. Being taught to think critically and evaluate processes and emerging ideas are important if students are to actively participate in a digitally enhanced world rather than being limited to being consumers of knowledge.

In the digital age students who can think critically, learn through connections, create knowledge and understand concepts should be able to actively participate in a digitally enhanced society. Digital technology has been found to help students understand core concepts in subjects like science, maths and English (Roschelle, Pea, Hoadley, Gordin, & Means, 2000). While understanding concepts remains an important fourth aspect of learning, it is the critiquing, evaluating, developing, and sharing
thinking or knowledge which emerges from conceptual understanding that becomes an important focus in the digital age. This is a new focus which has not been explored extensively yet by researchers.

The way school-based teaching activities which use digital technologies are assessed has been problematic as measures used were constructed prior to digital technology being available (Heppell, 2007). Evaluating teaching tasks by applying traditional measures is unlikely to take account of the way that students learn in a connected world or apply the use of digital technologies to develop knowledge, therefore it is an invalid measure (Loveless, 2002). An evaluation tool for the digital age would combine ideas of knowledge, teaching and learning in a connected world with the use of digital technologies.

A study of digitally able beginning teachers
Cox et al. (2004) reviewed the literature and surmised that, as with most teaching, lessons with ICT that are poorly planned or executed lead to unfocused students and limited learning. It appears that it is the teacher rather than the technology that influences the effectiveness of digital technology use in schools. It is unlikely that there is exemplary practice across an entire secondary school due to the diverse nature of schools and the complexity of the management and organisational structures needed to support such diversity effectively (Auld et al., 2008). A multiple case study approach to research allows the close examination of teaching and learning in the context of the digital age.

For the purpose of a doctoral study, six digitally confident teachers volunteered to be examined through interviews and observation during their first year of secondary school teaching to identify how they used digital technologies in their teaching practice and the learning that occurred. The methodological approach taken in this research was a multiple case study (Stake, 2006; Yin, 2003) underpinned by a conceptual framework based on complexity theory and derived from the work of Davis and Sumara (2006) and Morrison (2002). This allowed examination of the complex situations in which the beginning teachers carried out pedagogical reasoning and action. A digital age learning matrix was developed as a research tool based on connectivist learning theory to measure the types of learning activities used by the teachers. Student think-alouds, as described by Ericsson (2006), were used to ascertain the learning that was occurring in the classrooms. This article focuses on the digital age learning matrix as an evaluation tool in this study. The matrix was developed at the beginning of the research and evolved during the course of the investigation.

An evaluation tool for the use of digital technologies or learning
Teachers reflect on their practice and are being studied by researchers as they strive to use digital technologies in educationally meaningful ways. Therefore a method of evaluating such teaching activities is needed which is relevant to the aims of education in the digital age. Learning using digital technologies has been evaluated by researchers (Cassady, 2002; Lowther et al., 2008). An effective evaluation tool would recognise the range of ways technologies can be used for learning and the importance of critical thinking, creativity (knowledge creation), conceptual understanding and making connections in an information-rich Web 2.0 world.

The digital age learning matrix was developed to be used as a research tool to examine the types of teaching activities that incorporate the use of digital technologies
in the classroom. It was used as the basis for discussion during interviews as teachers explain what they are planning or how they have used digital technologies with their students. The matrix was piloted with preservice teachers as they reflected on the use and potential use of digital technologies in their teaching prior to being used with students in the first year of teaching.

Existing taxonomies, while useful and relevant, did not suit the needs of the evaluation tool (Table 1). The SOLO taxonomy (Biggs & Collis, 1982) includes a useful progression, but it fundamentally focuses on the knowledge within the learner, not including the learning or knowledge creation that can occur between learners in a connected world as described by Siemens (2006). It implies that students are learning what is already known and fails to acknowledge the importance of connections with others in the process of learning. Bloom’s taxonomy puts knowledge at the lowest level of cognitive processing which is now thought to be inappropriate. However, the modified Bloom’s taxonomy (Anderson & Krathwohl, 2000) could be useful alongside the matrix even though it is based on cognitive processes and is too linear and restrictive for the holistic approach needed.

Bloom’s modified taxonomy has ‘create’ at the highest level in the cognitive domain, SOLO has extended abstract at the highest level – noting the link between the learning and other contexts. In a digital world, ‘creativity’, especially in terms of ‘creating knowledge’, could be considered as the penultimate learning experience for developing conceptual or procedural understanding. The ultimate goal would be sharing the knowledge that is being created. Through this sharing of knowledge critique may occur and the value of the knowledge can be explored. This can be done through connections in a Web 2.0 learning environment.

Six different aspects of learning using digital technologies were identified in the research tool. The first aspect is when students do something within one context. This could include: looking on the internet for some information, uploading pictures to a wiki, taking a quiz to rote-learn facts or posting a comment on a blog. The second aspect of learning is when students make connections. It may include a compare and share activity, how to do something in different contexts or connecting to a person to share ideas. The third aspect requires students to demonstrate conceptual understanding of ‘big ideas’ (conceptual knowledge). The fourth aspect includes critique and evaluation, exploring the limitations and potential of information, sources or a process (procedural knowledge). The fifth aspect is the creation of knowledge. This includes students developing an original product that provides a new reality, using ideas or processes that they have critiqued and evaluated. The final aspect of learning brings together the idea of connectedness, critique and creativity. It occurs when students share their emerging knowledge through authentic contexts and gain feedback. It could be that through sharing emerging knowledge that value is ascertained (or not).

The aspects are not necessarily sequential, and a teaching activity in secondary schooling would rarely aim to include all aspects. The purpose of the matrix was as an evaluation tool, one that a teacher and a researcher, colleague or teacher educator might use as a basis for discussion about the aims and outcomes of a learning activity that uses digital technologies. The creation and sharing of knowledge will occur less often than other aspects and probably only after a thorough understanding of concept(s) or process(es) are gained, depending on the aims of the teaching and learning needs of the students. In the matrix in Table 2 the five categories of digital technology use are matched with aspects of learning.
<table>
<thead>
<tr>
<th>Digital age learning matrix</th>
<th>Modified Bloom’s taxonomy – cognitive process domain</th>
<th>Structure of Observed Learning Outcomes taxonomy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Doing</strong>&lt;br&gt;Isolated information. Focus on completing a measurable task.</td>
<td>1. Remember recognising recalling</td>
<td><strong>Prestructural</strong>: students are simply acquiring bits of unconnected information, which have no organisation and make no sense.</td>
</tr>
<tr>
<td><strong>Thinking about connections</strong>&lt;br&gt;Connecting thinking.&lt;br&gt;Simple connections made within the context of intended learning. Compare and share.</td>
<td>2. Understand interpreting, exemplifying, classifying, summarising, inferring, comparing, explaining&lt;br&gt;3. Apply executing, implementing</td>
<td><strong>Unistructural</strong>: simple and obvious connections are made, but their significance is not grasped.</td>
</tr>
<tr>
<td><strong>Thinking about concepts</strong>&lt;br&gt;Develop conceptual understanding of ‘big ideas’.</td>
<td>4. Analyse, differentiating, organising, attributing</td>
<td><strong>Multistructural</strong>: a number of connections may be made, but the meta-connections between them are missed, as is their significance for the whole.</td>
</tr>
<tr>
<td><strong>Critiquing and evaluating</strong>&lt;br&gt;Evaluating and critiquing to explore the limitations and potential of information, sources or a process.</td>
<td>5. Evaluate checking, critiquing</td>
<td><strong>Relational level</strong>: the student is now able to appreciate the significance of the parts in relation to the whole.</td>
</tr>
<tr>
<td><strong>Creating knowledge</strong>&lt;br&gt;Creativity – applying ideas, processes and/or experiences to develop a new reality.</td>
<td>6. Create generating, planning, producing</td>
<td><strong>Extended abstract</strong>: the student is making connections not only within the given subject area, but also beyond it, able to generalise and transfer the principles and ideas underlying the specific instance.</td>
</tr>
<tr>
<td><strong>Sharing knowledge</strong>&lt;br&gt;Sharing the new knowledge through authentic contexts and gaining feedback to measure value.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 2. Digital age learning matrix.

<table>
<thead>
<tr>
<th>Aspect of learning:</th>
<th>Doing</th>
<th>Thinking about connections</th>
<th>Thinking about concepts</th>
<th>Critiquing and evaluating</th>
<th>Creating knowledge</th>
<th>Sharing knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Explanation of aspects of learning:</strong></td>
<td>Isolated information.</td>
<td>Connecting thinking.</td>
<td>Develop conceptual understanding of ‘big ideas’.</td>
<td>Evaluating and critiquing to explore the limitations and potential of information, sources or process.</td>
<td>Creativity – applying ideas, processes and/or experiences to develop a new reality.</td>
<td>Sharing the new knowledge through authentic contexts and gaining feedback to measure value.</td>
</tr>
<tr>
<td><strong>Digital technology use:</strong></td>
<td>Focus on completing a measurable task.</td>
<td>Simple connections made within a context. Compare and share.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Accessing information</strong></td>
<td>Accessing:</td>
<td>Information from more than one source is connected or compared in analysis.</td>
<td>Information explicitly develops conceptual understanding.</td>
<td>Information and sources are critiqued and evaluated.</td>
<td>New conceptual understanding is developed. Building on or linking accessed information.</td>
<td>The value of the product is determined by the quality and quantity of feedback from beyond the classroom environment. Learning occurs when the feedback is considered and analysed.</td>
</tr>
<tr>
<td></td>
<td>Pictures</td>
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<td></td>
<td>Graphs</td>
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<td>Movies</td>
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<td>Data</td>
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<tr>
<td></td>
<td>Information</td>
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</tr>
<tr>
<td><strong>Presenting</strong></td>
<td>Present information using:</td>
<td>Presented information has clear connections across formats or ideas.</td>
<td>Presentation (or explanation of presentation) has explicit conceptual underpinning.</td>
<td>The presentation, methods and results are critiqued and evaluated.</td>
<td>Critiqued and developed ideas or new knowledge is presented.</td>
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<td>Sound</td>
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<tr>
<td></td>
<td>Pictures</td>
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<td></td>
<td>Words</td>
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<tr>
<td></td>
<td>Video</td>
<td></td>
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<tr>
<td><strong>Processing information</strong></td>
<td>Information is processed or data/images are manipulated in isolation.</td>
<td>Connections are made between or within processed information/data or images and relevant concepts.</td>
<td>Processed data or information has clear conceptual underpinning.</td>
<td>Process and product are critiqued and evaluated.</td>
<td>Ideas and new knowledge are developed.</td>
<td></td>
</tr>
<tr>
<td>Aspect of learning:</td>
<td>Doing</td>
<td>Thinking about connections</td>
<td>Thinking about concepts</td>
<td>Critiquing and evaluating</td>
<td>Creating knowledge</td>
<td>Sharing knowledge</td>
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<tr>
<td>Explanation of aspects of learning:</td>
<td></td>
<td>Isolated information. Focus on completing a measurable task.</td>
<td>Connecting thinking. Simple connections made within a context. Compare and share.</td>
<td>Develop conceptual understanding of ‘big ideas’.</td>
<td>Evaluating and critiquing to explore the limitations and potential of information, sources or process.</td>
<td>Creativity – applying ideas, processes and/or experiences to develop a new reality.</td>
</tr>
<tr>
<td>Digital technology use:</td>
<td>Gaming or interactive programmes</td>
<td>Play a game. Take a quiz. Enter a virtual world.</td>
<td>Links made between the game/ quiz/ virtual world and other knowledge.</td>
<td>The relevant concepts within the game, quiz or virtual world are identified and explained.</td>
<td>The game, quiz or virtual world is critiqued and evaluated within a conceptual context.</td>
<td>Original ideas are used to create a knowledge product in any medium.</td>
</tr>
</tbody>
</table>
Digital technologies are used in learning for a range of purposes. To explore the aspects of learning, a range of uses of digital technologies in teaching practice are included in the matrix, identified through synthesis of observations and research. Teaching activities could include students accessing information, presenting information, processing information, using gaming or interactive programs, or communicating with others beyond the classroom environment. Through the use of the digital learning matrix teaching activities were examined for the inclusion of critique, connections, collaboration or creation of knowledge.

**Applying the digital age learning matrix**

The digital age learning matrix was developed to evaluate teaching activities in a study of six digitally able beginning teachers as part of a doctoral study using case study methodology. Each of the six case study teachers had students learning through the use of digital technologies during their first year of teaching. The teaching activities were each designed for different purposes and evaluated by comparing the teaching activities and reported student learning with the digital age learning matrix. Different aspects of learning were found in the activities, from completing a measurable task to creating knowledge. The teachers in the study detailed a range of learning activities in which they used digital technologies. Each was aligned with the digital age learning matrix and a summary is shown in Table 3. They were aligned through matching the descriptions and intentions of the teaching with the descriptors on the matrix. Three examples from this study are outlined to illustrate how the matrix was used to evaluate teaching activities.

A teacher of health (case study E) who was teaching a class of year 10 (14-year-old) girls, was using an activity in which the students used Photoshop to develop an understanding of the concept of media manipulation of images. During the lesson the students were asked what they were learning using think-aloud methodology (Ericsson, 2006).

Students typically responded in terms of what they were doing:

I have made my face skinnier, put in a bit of muscle and faded out the marks with skin tone, so I have what I look like now and after. I am learning how to use different types of tools on the computers. (Student, case study E)

This student is developing her skill of using the computer program, rather than understanding concepts or developing knowledge in this particular lesson.

One student’s response aligned with the doing and thinking about concepts categories of the digital age learning matrix:

I have learnt how to use the spot thing, and how people use Photoshop to manipulate images and that it is bad to aspire to be like someone in a magazine because they have been Photoshopped, so it is impossible to look like that unless you do the same. (Student, case study E)

The intention of the teacher was that the students gain an understanding of the concept that the images you see in the media may have been altered. Most of the students were focused on using the program and were not making an explicit connection to the media manipulation of images when asked. Through analysis of the data which included teacher interview, documents (lesson plan) and the student think-
Table 3. Summary of learning activities using digital technologies.

<table>
<thead>
<tr>
<th>Level of learning</th>
<th>Doing</th>
<th>Thinking about connections</th>
<th>Thinking about concepts</th>
<th>Critiquing and evaluating</th>
<th>Creating knowledge</th>
<th>Sharing knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explanation</td>
<td>Isolated information. Focus on completing a measurable task.</td>
<td>Connecting thinking.</td>
<td>Develop conceptual</td>
<td>Evaluating and critiquing</td>
<td>Creativity –</td>
<td>Sharing the new</td>
</tr>
<tr>
<td>of level of</td>
<td></td>
<td>Simple connections made</td>
<td>understanding of ‘big ideas’.</td>
<td>to explore the limitations</td>
<td>applying ideas,</td>
<td>knowledge through</td>
</tr>
<tr>
<td>learning:</td>
<td></td>
<td>within a context.</td>
<td></td>
<td>and potential of</td>
<td>processes and/or</td>
<td>authentic contexts</td>
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<td></td>
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<td>information, sources</td>
<td>experiences to</td>
<td>and gaining</td>
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<td></td>
<td>or process.</td>
<td>develop a new</td>
<td>feedback to</td>
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<td></td>
<td>reality.</td>
<td>measure value.</td>
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<td>A</td>
<td>Downloading pictures</td>
<td>Icebreaker website</td>
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<td>Playing games Internet</td>
<td>Moulin Rouge activity</td>
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<td>pricing of ingredients</td>
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<td>B</td>
<td>Maths website</td>
<td>Anatomy and physiology</td>
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<td>Using cell phones as</td>
<td>Rugby league mathematics</td>
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<td>Rotational symmetry</td>
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<td>D</td>
<td>Online patterns</td>
<td>Creating a business card</td>
<td>Poster design</td>
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<td>Matisse bags</td>
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<td>E</td>
<td>Urban planning decision making</td>
<td>Sports injury research / web quests</td>
<td>Body image and the media</td>
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<td>F</td>
<td>Fast food nutritional value</td>
<td>Developing symbols to communicate an idea</td>
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alouds, it was concluded that this learning activity focused students on altering an image – this was a *doing* type lesson, with students thinking about connections between the image and the alteration. At the conclusion the teacher reflected on the need to include further teaching of the concept in consequent lessons to make it explicit and to ensure the students were connecting the activity with the concept (Table 4). The digital age learning matrix was useful in clarifying how the aspects of learning differed from the intention of the teacher.

A physical education teacher (case study B) in the study used an interactive website with the specific intention that his students would learn to identify and name the major muscle groups in the body. From student think-alouds, observation and teacher reflection it was found that the students focused on *learning about* more than *identifying* the muscles.

The students spent time examining the BBC anatomy site (http://www.bbc.co.uk/science/humanbody). The majority of the students were focused on muscles, bones, organs or nervous system, learning about the function and location of these through the information and activities on the linked sites. When asked what they had learnt, student responses varied, for example four students said:

- We get to learn about body anatomy, bones, types of joints in the body and what they are used for.
- I have learnt where your muscles are, and where the voice box is. It is pretty interesting.
- I have learnt where the muscles go ... I am [now] trying to learn about muscles.
- I found out that not everything goes to the brain, like the knee joint is connected to the base of the spine, that is where the nerves go so that was really interesting. (Students, case study B)

While the teacher had stated a learning intention, the actual learning outcomes were broader and within the context of the wider unit of learning. The students were accessing information about muscles, engaging in the interactive website, connecting their prior learning in class to the interactive website and thinking about concepts of muscle and nerve function. The alignment with the digital age learning matrix is illustrated in Table 5.

The digital age learning matrix was useful in clarifying aspects of learning through discussions with the research participants and from observations. A third beginning teacher (case study D) taught an activity that explicitly included taking, analysing and evaluating digital video of the students’ volleyball technique, an activity which was initiated by the students. This included the critiquing and evaluation aspect of learning. Two other teachers wanted their students creating knowledge through the use of digital technologies. One of these teachers was clear about the purpose of this activity and the idea of creating knowledge:

If they can get the conceptual and holistic view of what art can be – like artists models, how to use artist model – like I am going to use this person’s techniques, how they apply the paint and I am going to use this person’s composition. If they can understand how they can combine that and that they are pretty much sorted because they use that and that and it becomes their own work, even though they have copied other people’s work, they have only taken a small part. That would be knowledge to me, understanding those concepts. (Case study D)
Table 4. Digital age learning matrix example 1: Body image and the media.

<table>
<thead>
<tr>
<th>Aspect of learning:</th>
<th>Doing</th>
<th>Thinking about connections</th>
<th>Thinking about concepts</th>
<th>Critiquing and evaluating</th>
<th>Creating knowledge</th>
<th>Sharing knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explanation of level of learning:</td>
<td>Isolated information. Focus on completing a measurable task.</td>
<td>Connecting thinking. Simple connections made within a context. Compare and share.</td>
<td>Develop conceptual understanding of ‘big ideas’.</td>
<td>Evaluating and critiquing to explore the limitations and potential of information, sources or process.</td>
<td>Creativity – applying ideas, processes and/or experiences to develop a new reality.</td>
<td>Sharing the new knowledge through authentic contexts and gaining feedback to measure value.</td>
</tr>
<tr>
<td>Example 1: Body image and the media. Processing information</td>
<td>Student responses indicate this is where most were operating.</td>
<td>Students were making connections between the image being altered and the process of altering.</td>
<td>While the activity had clear conceptual underpinning, this was not understood by the students.</td>
<td>Not included</td>
<td>Not included</td>
<td>Not included</td>
</tr>
</tbody>
</table>
This belief underpinned a learning activity which involved year 12 art students developing business cards. This activity began with students researching business cards and manually developed background art works for use in a business card. The students took photos of the manually rendered images, uploaded these into Photoshop, digitally manipulated them (such as adding typography, changing colour, shape and/or size or combining images), printed them, further manually manipulated them, photographed them again to eventually produce a business card. Critique of the process and the evolving product occurred at each stage. The alignment with the digital age learning matrix is illustrated in Table 6.

The idea of creating knowledge is not limited to learning through the use of digital technologies. The same teacher used the internet as a source of information for a similar activity but with the younger year 9 students. The students were booked into a computer room for a week to carry out research. The teacher developed an A5 handout which included specific questions that they had to answer, and websites that were possible starting points before Googling the answers. They had to find so many images for each of their questions through Google images. As students found different things, they would share their findings with the class by putting useful websites on the board. The students had to research Matisse using pre-identified websites. They found environmental reasons for why they should make a sustainable product and researched the use of appliqué. They later applied the concepts they had learnt as they made a Matisse-style bag. In this example the aspects of learning in the digital age learning matrix emerged from traditional activities as well as the use of digital technologies. The creation of knowledge was a practical activity where students applied their learning from research through the internet to develop their own interpretations. This activity did not include a sharing knowledge aspect, although such an activity could have been through online critique of the created Matisse bags through a wiki.

Discussion

The digital age learning matrix enabled the alignment of teaching activities to aspects of learning within a context which recognised digital age learning theory as outlined by Siemens (2004) and emerging ideas about knowledge (Bereiter, 2002; Gilbert, 2005). Using the digital age learning matrix as an analysis tool it was identified that the teachers in the study most frequently focused on their students’ engaging in an activity (doing), making connections and developing conceptual knowledge.

Table 3 summarises the reported learning activities which included the use of digital technologies across the year of study. The lines and arrows reflect the aspects included within the learning intention of the teacher. Few examples of critiquing or evaluating were evident in the study (all of which are important skills in an information-rich society). Fewer examples required students to create knowledge through applying concepts or processes. Where knowledge creation was noted, it was not shared (or given value) beyond the classroom, therefore students were not participating in a digitally enhanced society. For sharing of knowledge to occur, a change in the teachers’ epistemological perspective is needed, a finding which aligns with researchers who have examined educational change since the introduction of digital technologies (Cuban, 2001; Ertmer, 2005).

The focus on teaching students to gain conceptual understanding could be attributed to an outcomes-based pedagogical process where the focus is on students learning
Table 5. Digital age learning matrix example 2: Anatomy and physiology.

<table>
<thead>
<tr>
<th>Aspect of learning:</th>
<th>Doing</th>
<th>Thinking about connections</th>
<th>Thinking about concepts</th>
<th>Critiquing and evaluating</th>
<th>Creating knowledge</th>
<th>Sharing knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explanation of level of learning:</td>
<td>Isolated information. Focus on completing a measurable task.</td>
<td>Connecting thinking. Simple connections made within a context. Compare and share.</td>
<td>Develop conceptual understanding of ‘big ideas’.</td>
<td>Evaluating and critiquing to explore the limitations and potential of information, sources or process.</td>
<td>Creativity-Applying ideas, processes and/or experiences to develop a new reality.</td>
<td>Sharing the new knowledge through authentic contexts and gaining feedback to measure value.</td>
</tr>
</tbody>
</table>

**Example 2:** Anatomy and Physiology

- **Accessing information and interactive programmes**
  - Accessing information about muscles and using interactive programmes.
  - Connections made between in class learning about bones and interactive activities.
  - Concepts about muscle movement and bone structure were developed.
  - Not included
  - Not included
  - Not included
Table 6. Digital age learning matrix example 3: Business cards.

<table>
<thead>
<tr>
<th>Aspect of learning:</th>
<th>Doing</th>
<th>Thinking about connections</th>
<th>Thinking about concepts</th>
<th>Critiquing and evaluating</th>
<th>Creating knowledge</th>
<th>Sharing knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processing information</td>
<td>Manipulated digital images of drawn and painted art pieces using Photoshop.</td>
<td>Connections between drawn and digitally altered images made.</td>
<td>Concepts developed in the art works included effective business card design and artistic techniques.</td>
<td>Self, peer and teacher evaluation during the process of developing the business cards.</td>
<td>Final product – the business cards represent a new interpretation based on researched artists.</td>
<td>Not included</td>
</tr>
<tr>
<td>Example 3: Developing business cards</td>
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</table>

Explanation of level of learning:
- **Isolated information.** Focus on completing a measurable task.
- **Connecting thinking.** Simple connections made within a context. Compare and share.
- **Develop conceptual understanding of 'big ideas'.**
- **Evaluating and critiquing to explore the limitations and potential of information, sources or process.**
- **Creativity – applying ideas, processes and/or experiences to develop a new reality.**
- **Sharing the new knowledge through authentic contexts and gaining feedback to measure value.**
or developing their understanding of *prescribed* knowledge. Such an approach underpinned the preservice teacher education where constructivist learning theory was a central tenet. The beginning teachers graduated with an understanding of ideas by theorists such as Bruner, who suggested that learning occurs when students use their existing mental models or schema to develop their knowledge of new concepts or skills (Bruner, 1996). They had studied teaching strategies such as mastery learning and how to apply Bloom’s modified taxonomy (Anderson & Krathwohl, 2000) to the teaching process. Therefore it is understandable that the aspect of learning that was the dominant focus of the teaching using digital technologies was to gain conceptual understanding and the creating, sharing, and critique of emerging knowledge was absent.

If the digitally able are to incorporate knowledge creation, critique and sharing into their teaching practice they will need to understand theories of teaching and learning in the digital age to an extent that it influences their beliefs. A teacher’s beliefs influence their approach to teaching. In studies of teacher use of digital technologies, it has been found that the introduction of digital technologies to teaching practice does not change beliefs about learning processes (Cuban, 2001; Ertmer, 2005). Therefore if teachers are to empower students to graduate from school knowing how to create, critique and share knowledge, then they need to believe that this is an important aim of their teaching. This alone may not be enough. In a study of teachers who were taught about constructivism and who believed that this was how learners learn, it was found that their teaching practice did not align with their beliefs. They were not able to integrate these beliefs into their practice (Chen, 2008). Teachers need to know how to put their beliefs into practice.

The digital age learning matrix evolved as a result of peer feedback and through its use as a research tool. Initially the aspects were called levels of learning, suggesting a sequential or increase in cognitive complexity which was not found to exist. Aspect was a more appropriate description. The matrix was included as a framework for discussion with the case study participants following observations of teaching activities and was a useful tool to clarify the intent of the learning activities and the success of these. Through this process the aspects of learning were clarified. Initially the matrix included four categories including accessing information, presenting, processing information and communicating. Gaming and the use of interactive programs were included within the processing information category. It became apparent that in a Web 2.0 environment this type of use could be more than processing so a fifth category was developed.

The digital age learning matrix was a useful tool to clarify the aspects of learning on which teaching was focusing. It could be extended and applied to all types of teaching activities, not just those which use digital technologies as the aspects are not specific to digital technology use. Accessing information can be through books, people or drawn from experience and presenting information can be through dramatic, written, or pictorial representation which does not include digital technologies. This was evident in example 3 where students were using both traditional and digital media.

The teaching activities over the course of a semester or year could include a range of aspects of learning. It would not be wise or possible to have students creating and sharing knowledge every lesson. There needs to be time for students to think about concepts, make the connections between and within ideas and to learn skills or how to do things. At each of these stages critiquing and evaluating could be present. For example, as a result of developing Matisse bags and sharing critique with a wider
audience, the students in case study D may have found there is an improvement that could be made if they were able to blend colours. This would require a doing type activity followed by further critique.

Heppell (1999) and Loveless (2002) argued that the ways in which we assess learning using digital technologies are problematic as the measures are constructed prior to the digital age. The digital age learning matrix does provide an evaluation tool that recognises knowledge creation, teaching and learning in the digital age, which may provide a step forward in evaluating learning using digital technologies.

Summary
If we are to accept Dewey’s idea that a core purpose of secondary schooling is to educate students to be active participants in the society in which they live (Dewey, 1920), then school leavers in the digital age should be confident in their ability to make connections, understand concepts, critique, create and share knowledge. To explore the extent that a small sample of digitally able beginning teachers were teaching these aspects, a digital age learning matrix was developed as a research tool.

The digital age learning matrix combines categories of observed use of digital technologies with aspects of learning. The aspects were identified through examining the work of researchers in the field of knowledge and the digital age. Learning through connections and sharing of ideas and emerging knowledge are important aspects of how knowledge is developed in an information-rich Web 2.0 society.

The digital age learning matrix was applied to six case studies and it was found that the digitally able first-year teachers were focusing on students gaining conceptual understanding of key ideas within subjects. Few examples of students actively creating or applying this knowledge were noted and students’ emerging knowledge was not applied or shared and critiqued beyond the classroom environment. The focus on teaching to ensure students understand concepts reflects the dominant constructivist perspective of learning found in preservice teacher education that the case study teachers had recently completed. This finding reinforces the idea that effective use of digital technologies aligns with effective teaching practices and teaching practice is based on a teacher’s beliefs about the nature of learning, teaching and knowledge. Being digitally able did not appear to influence the beginning teachers’ ability to teach students to be active participants in the digitally enhanced society in which they live by sharing and critiquing knowledge beyond the classroom environment. This is unlikely to change until teachers understand and can apply theories of learning that are relevant to a digital age.

Ideas about teaching and learning in a digitally enhanced society are evolving. It is time for research which focuses on effective use of digital technologies in schooling to incorporate emerging teaching and learning theory relevant to the digital age. The digital age learning matrix is designed as a reflection or planning tool for teachers incorporating digital technologies into teaching plans and for researchers considering the learning that is occurring in classroom activities which encourage participation in the information-rich Web 2.0 world.

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**Note on contributor**

Dr Louise Starkey is the Associate Dean of Primary and Secondary Teacher Education at Victoria University of Wellington, New Zealand. One of her research interests which began when she was teaching is the future of secondary schooling within a digital cultural context. This is a topic that she has considered from the perspective of a teacher, senior manager and an academic. She is interested in sharing ideas on the topic with anyone with a similar interest.

**References**


