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Increasing Learner Engagement of Learning Technologies and Science TPACK Through Representational Challenges

Peter Hubber, Esther Loong,

Abstract

There have been calls to embed Information and Communication Technology (ICT) into pre-service teacher courses in preference to technology only courses as a means to provide graduate pre-service teachers with the necessary skills to integrate ICT into their teaching practice. This chapter describes a case study of a pre-service science education curriculum course that was designed to embed ICT into its curriculum, assessment and delivery. The tutor modelled best teaching practice in the use of learning technologies. The theoretical framework is Technological Pedagogical and Content Knowledge (TPACK) viewed through a representation construction approach. This approach involved the students undertaking a series of representational challenges where they constructed and critiqued representations. The study found increased student engagement with learning technologies and an enhanced TPACK over the period of the course. Several factors that may have led to these findings are discussed.

Introduction

The integration of technology into schools and colleges has been seen as an essential step towards the improvement in teaching and learning in many countries. For this reason many governments have invested heavily in the building and maintenance of Information and Communication Technology (ICT) structures in schools (Pelgrum, 2001). For example, the Australian government has recently invested $2.5 billion into an initiative called the Digital Education Revolution (http://www.deewr.gov.au/Schooling/DigitalEducationRevolution/Pages/default.asp) with programs that aim at increasing ICT proficiencies in pre-service and practicing teachers and equipping Year 9--12 students with a laptop each. Investment by governments into school ICT structures has meant that many new educational technology tools are available to teachers.

ICT as a learning technology, facilitating mobility and connectivity, has now moved out of the computer room into the everyday practice of teaching and learning. However, whilst ‘most teachers and students now benefit in some way from access to computers and digital resources, only a minority are reaping the full benefits of the information technology revolution’ (COAG Productivity Working Group, 2008, p. 1). Integrating technology into instruction is still challenging for most teachers (Guzey & Roehrig, 2009). The level of ICT integration in classrooms remains low as teachers are using ICT to support, enhance and complement existing classroom practice rather than re-shaping subject content, goals and pedagogies (Prestridge, 2007). Well-integrated and effective classroom use of ICT is currently rare (Osborne & Hennessy, 2003).

Providing graduate teachers with the necessary skills to teach in classrooms of the 21st century has been the responsibility of pre-service teaching programs which involve the delivery of tertiary institution-based courses and practicum experiences in school settings. In terms of the development of pre-service teachers’ competencies in ICT integration, there are still multiple gaps in curriculum design and delivery of teacher education courses (Lawless & Pellegrino, 2007; Tondeur, van Braak, & Valcke, 2007). Whilst single technology courses are often provided in teacher education programs (Hsu & Sharma, 2006) such courses do not prepare teachers with the necessary skills involved in integrating ICT (Lawless & Pellegrino, 2007; Sanber, 2007). A recent study of pre-service teachers’
perceptions of their ICT experiences in teacher preparation programs (DEEWR, 2009) found they expressed concerns at the lack of modelling by lecturers in embedding ICT into courses and insufficient assistance in how to embed ICT in classroom practices. The students also expressed concerns with the quality of support offered to them by practicum supervising teachers about teaching and learning with digital technologies.

Teachers need to understand the precise role of technology in teaching and learning (Mishra & Koehler, 2006) which provides a strong argument to embed ICT into teacher preparation courses and practicum experiences. Lawless and Pellegrino (2007) suggested that ‘decisions about when to use technology, what technology to use, and for what purposes cannot be made in isolation of theories and research on learning, instruction, and assessment’ (p. 581). There should be a focus on methods of teaching via technology within teacher preparation programs (Mishra & Koehler, 2006). Further, many of the activities of such programs should be set in a context of teaching and learning relevant to the participants. One method for accomplishing this with pre-service teachers is to have them use a variety of technological resources to explore problems and topics relevant to the levels at which they will teach (Hardy, 2010). Pre-service teachers are more likely to use technology when the technology is perceived to be useful, improves their performance and makes them more efficient (Teo, 2011). This view is consistent with the assertion made by Goodhue and Thompson (1995) that for a technology to have impact on individual performance it must be utilized and has a good task-technology fit. In other words, there is a match between the capabilities of the technology to the demands of the task.

In resolving the issue of lack of integration of ICT into classrooms, part of the Australian government's Digital Education Revolution has been funding for the Teaching Teachers for the Future (TTF) project. This project aims to ‘drive change in Information and Communication Technology in Education (ICTE) proficiency of graduate teachers across Australia and enable pre-service teachers to achieve and demonstrate (upon graduation) competence in the effective and innovative use of ICTE to improve student learning’ (ACDE, 2011, p.11). Key components of this project entailed the construction of a set of ‘National Professional Standards for Graduate Teachers with ICT Elaborations’ (AITSL, 2011) and the implementation of pre-service teaching courses designed to address these standards.

This chapter reports on a case study of a semester length course titled ‘Resources in the Contemporary Science Curriculum’ delivered to a mixed cohort of pre-service secondary science education teachers that was part of the TTF project. The course embedded learning technologies into its design not only to deliver the course curriculum but also to give the pre-service teachers insight into the manner in which they could embed learning technologies into their own teaching practice. The research questions that framed this case study were, ‘Through participation in the course (a) what are the levels of pre-service teachers’ engagement with ICT, and (b) what are the changes in pre-service students’ understandings of the ways in which ICT can be embedded into the teaching and learning of science?’

Theoretical framework

In this case study, the theoretical framework is based on Mishra and Koehler’s (2006) Technological Pedagogical Content Knowledge (TPACK) viewed through a representational construction teaching approach (Tytler & Hubber, 2011). TPACK is a framework for understanding the specialized, multi-faceted forms of knowledge required by teachers to integrate technology in their teaching. These forms of knowledge are content, pedagogy and technology knowledge (TK). For example, a teacher has the intention of introducing the particle model to explain various properties of matter to her Year 7 class. She will need to
have the necessary content knowledge of the particle model and possess pedagogical knowledge of the ways in which Year 7 students effectively learn abstract concepts, for example, how to conduct a role-play to represent particle motion in a solid piece of matter. She may wish to elicit her students’ prior views on the nature of matter using an online survey and so will require the technological knowledge to construct and administer the survey. Having an understanding of each of these knowledge domains is not sufficient for quality teaching. The teacher also requires a nuanced understanding of the complex interplays between these three key sources of knowledge (Mishra & Koehler, 2006). TPACK refers to the understanding that emerges from the interaction of content, pedagogy and TK. In the example given above, the teacher's TPACK informs her that the affordances of the instant feedback gained from the online survey will allow her to gain insights into the Year 7 students’ prior understandings of the nature of matter. This information will be used in a formative way to plan a teaching sequence for a topic she knows will be difficult for the Year 7 students to learn because of its abstract content.

The representational perspective is based on a growing consensus that quality learning must involve richer and more sustained reasoning and engagement with the mediating tools of the discipline in ways that entail the acquisition of a subject-specific set of purpose-designed literacies (Lemke, 2004; Moje, 2007). Students use the multi-modal representational tools of science to generate, coordinate and critique evidence (Ford & Forman, 2006), involving models and model-based reasoning (Lehrer & Schauble, 2006). A recent Australian Research Council (ARC) funded project, Representations in Learning Science (RILS), successfully developed a theoretically sophisticated but practical, representation construction approach to teaching and learning that links student learning and engagement with the epistemic (knowledge production) practices of science (Prain, Tytler, Waldrip, & Hubber, 2010; Tytler & Hubber, 2011). This approach involves challenging students to generate and negotiate the representations (text, graphs, models, diagrams) that constitute the discursive practices of science, rather than focusing on the text-based, definitional versions of concepts. The representation construction approach is based on sequences of representational challenges which involve students constructing representations to actively explore and make claims about phenomena. It thus represents a more active view of knowledge than traditional structural approaches and encourages visual as well as the traditional text-based literacies. RILS has successfully demonstrated enhanced outcomes for students, in terms of sustained engagement with ideas, and quality learning, and for teachers’ enhanced pedagogical knowledge and understanding of how knowledge in science is developed and communicated (Hubber, 2010a; Hubber, Tytler, & Haslam, 2010). This representation construction approach shows promise of resolving the tension between enquiry approaches to learning science and the need to introduce students to the conceptual canons of science (Klein & Kirkpatrick, 2010). It also shows promise in providing a wider pedagogical approach to embedding ICT into a teacher’s classroom practice.

In successfully adopting a representation construction approach to the implementation of ICT, a teacher requires sophisticated levels of TPACK. In the words of Mishra and Koehler (2006) TPACK, ‘requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies;...and how technology can help redress some of the problems that students face’ (p. 1029). Pre-service teachers need to know that technologies have constrained and afforded a range of representations,
analogies, examples, explanations and demonstrations that can help make subject matter more accessible to the learner and this understanding becomes part of a teacher’s TPACK (Mishra & Koehler, 2006). Sutherland et al. (2004) cautioned that within a particular knowledge domain, such as science, it may be important for young people to be able to work with both digital and non-digital tools. Students should also be engaging in discussions about the relative merits of different tools, so that they can become resourceful learners. The students need to be made aware of the relative affordances of the ICT tools when using and communicating with such tools. This is part of a representation construction approach where students take into consideration the affordances and constraints of the representations they construct and critique.

There have been several attempts at enhancing the TPACK of pre-service teachers (Hardy, 2010; Haydn & Barton, 2007; Sanber, 2007; Shin et al., 2009). Hardy (2010) found practically oriented methods that meet a variety of teachers’ technology needs which enhance pre-service teachers’ TPACK. Similarly, Shin et al. (2009) found pre-service teachers gained a deeper and more complex understanding of TPACK in courses where they worked on a range of assignments that required them to learn and use technology in multiple pedagogical contexts. Sanber (2007) found an important factor in increasing pre-service teachers’ TPACK was the level of ICT skills in the trainers, whilst Haydn and Barton (2007) indicated that it was the extent to which ICT was effectively modelled by the trainers. These researchers also indicated other factors such as the need for ICT activities to have a direct relationship with the pre-service teachers’ subject areas. There was also a need for the provision of sufficient time for the teachers and their trainers to use and critique the multitude of ICT resources and devices for their efficacy in using them in the classroom. This is an important factor as computer self-efficacy, which is the users’ beliefs about their ability to use a technology, has a direct effect on its utilization (Strong, Dishaw, & Bandy, 2006).

The representation construction approach provides an useful pedagogy with which to embed ICT into science classrooms and pre-service teacher training courses. In using ICT tools and devices, teachers require a certain level of technological knowledge. In addition, they require an understanding of the science content and appropriate pedagogy, informed by a representation construction approach, which underpins the TPACK framework.

Methods

A mixed methods methodology was employed to answer the research questions. The data collection instruments included a pre- and post-course survey, field notes, focus group interview and students’ artefacts, such as their digital portfolio of resources and their rationales for use in the science classroom.

The pre- and post-course survey was one developed by Schmidt et al. (2009) to ascertain pre-service teachers’ knowledge of teaching and technology. It consisted of a series of statements related to each of the knowledge domains of the TPACK framework. The following are examples of statements found in the survey:

(a) I know how to solve my own technical problems (TK).

(b) I have sufficient knowledge about science (Content Knowledge).
(c) I know how to assess student performance in a classroom (Pedagogical Knowledge).

(d) I can select effective teaching approaches to guide student thinking and learning in science (Pedagogical Content Knowledge).

(e) I know about technologies that I can use for understanding and doing science (Technological Content Knowledge [TCK]).

(f) I can select technologies to use in my classroom that enhance what I teach, how I teach and what students learn (TPACK).

Respondents were to rate each statement on a 5-point Likert scale from strongly disagree, disagree, neither agree or disagree, agree to strongly agree. The respondents were also asked to describe a specific episode where each of their tutor, practicum supervisor and themselves demonstrated the use of ICT in their teaching practice.

The semester length course titled ‘Resources in the Contemporary Science Curriculum’ was delivered to a mixed cohort of pre-service secondary science teachers. The cohort of students consisted of 15 final year undergraduate double degree (bachelors of science and teaching) and 13 postgraduate master of teaching students. The course was delivered to 19 students in on-campus mode with a workshop format and delivered to 9 students in off-campus mode through a web-based online learning management system called Blackboard (http://www.blackboard.com/). The structure of each mode of the course is given below.

**On-Campus Course Structure**

The on-campus course was delivered as nine 3-hour workshop tutorials over the period of 12 weeks. During this period, the students undertook a 3-week practicum in a neighbouring secondary school. This practicum experience was not embedded into the course as tasks undertaken by the student at the school were solely determined by the student’s supervising teacher. The supervising teacher also provided the entire assessment of the student’s teaching performance at the school.

Each workshop involved exploring key elements of a particular theme (see Table 1). This was done using a variety of pedagogical approaches that were often enquiry and/or activity based. One of the prominent pedagogies was the representation construction approach. As the title of the course implies, the workshops involved exploring a range of resources that might contribute to a contemporary science curriculum. Among the resources were ICT tools that included Web 2.0 tools such as online surveys, Prezi (web-based presentation http://prezi.com/), web quests, blogs and website building. The resources were critiqued for their affordances for student learning of science and many were presented to the students in a way that modelled their use in practice. Importance was placed on the tutor as modelling the types of pedagogical practices of an effective science teacher. For example, in the first workshop the social bookmarking website, Delicious (www.delicious.com), was presented to the students and the affordances of this resource for student learning of science was discussed. The tutor created a Delicious website for the course with full editing rights to all students with the purpose of creating a shared repository of annotated online resources. Throughout the semester both the tutor and students contributed to this site.
Apart from the many ICT resources in the form of tools and devices that were embedded into the course, another resource was the use of experts external to the university. Some of the workshops were run, in part, by visiting experts, one of whom was a specialist in the Victorian Education Departments’ online system, called the Ultranet (http://www.education.vic.gov.au/about/directions/ultranet/default.htm), which is used by teachers, parents and children in Victorian government schools. Other visiting experts included early career practicing science teachers chosen for their expertise in embedding ICT in their current practice. One of the workshops was an excursion to the Melbourne Museum which had a pre-service teacher program led by museum staff. The workshop program promoted current learning theory and its application to museum experience, the deconstruction of exhibitions and practical activities for use in the classroom.

A feature of each workshop was the modelling of a representation construction approach that began with the administration of a task in the form of a representational challenge (refer to Table 1). The students were required to complete the task within the time period of the workshop. These challenges were modelled on similar tasks that might be administered to secondary school science students. This placed the students in the role of the secondary science learner. Students often completed the challenges in groups of two to four students. Several of the challenges had an ICT component that required a certain level of technological knowledge. Therefore, apart from modelling representation construction pedagogy, these challenges were designed to enhance the

<table>
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<td>Enquiry in the science classroom</td>
<td>Multimedia CD Rom: Inquiry-Based Teaching (Science by Doing, 2010)</td>
<td>Representing properties of matter</td>
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<tr>
<td>3</td>
<td>• The role of practical work</td>
<td>Website: Performance Assessment Links in Science (PALS)</td>
<td>Creating an animation: Ice-cream challenge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Website: Science Education Assessment Resources (SEAR) (<a href="http://crn.vce.curriculum.edu.au/sear">http://crn.vce.curriculum.edu.au/sear</a>)</td>
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<td></td>
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<td>• White coffee problem</td>
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<td></td>
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<td>• Adaptation challenge</td>
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<td></td>
<td></td>
<td></td>
<td>• Light reflection challenge</td>
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<td></td>
<td></td>
<td></td>
<td>• Hand motion challenge</td>
</tr>
</tbody>
</table>

Creating my webpage: wix.com (http://www.wix.com)
students’ technological knowledge. A significant component of the representation construction approach, which was modelled in the workshops, was the critique of the students’ constructed representations. Following the completion of the challenge, each group presented their constructed representations to the class who then critiqued the representations as to whether they fitted the purposes of the challenge.

Following the critique of the students’ constructed representations, there was usually a class discussion from a teachers’ perspective as to the efficacy of the challenge for use in a secondary science classroom in terms of enhancing school students’ conceptual understanding and/or skill development. The discussion included ways in which the challenge might be modified to support student learning of science at different year levels and science disciplines. The workshop activities where the students undertook the challenges and discussed their efficacy for implementation into science classrooms were seen as a means to enhance their TPACK and, in doing so, get greater insight into ways in which ICT can be embedded into a teacher’s practice.

By undertaking the challenges and then discussing their efficacy for learning science in the classroom, the students switched roles from learner to teacher. Several of the students also took on the role as teacher providing advice and support to those students who lacked sufficient ICT skills in completing the challenges. A description of some of the ICT-based representational challenges is given in the following sections.

Creating My Webpage (Workshop 1)

This challenge required the construction and publication of a website which later would contain the electronic portfolio (see course assessment section below). A freeware webpage construction website (www.wix.com) was provided as a possible tool to complete this task.

Ice-Cream Challenge (Workshop 2)

This challenge was modified from a classroom activity from the Science Upda8 website (http://www.upd8.org.uk/activity/308/Instant-ice-cream.html). It required the students to create an animation using Microsoft PowerPoint that provided a particle model explanation of the two physical change processes of mixing and freezing in making ice cream. The use of animation allowed for model-based reasoning of dynamic processes which are involved when applying the particle model to explain macroscopic behaviour of matter.

Construction of Online Survey (Workshop 4)

This task challenged students to construct an online survey using the freeware option of the website resource SurveyMonkey (http://www.surveymonkey.com). The purpose of the survey was to construct a diagnostic instrument designed to elicit children’s prior learning on a particular science topic. Apart from considering the mechanics of constructing the survey the students needed to also consider the nature of the questions to be asked of children given the research literature, which suggested that they may hold misconceptions in the topic to be taught.

600 Million Years in 60 Seconds (Gaff, 2011) (Workshop 5)

This challenge was given as a group task whilst students were on an excursion (Table 1, workshop 5) at the Melbourne Museum. Each team member had a specific role – presenter, camera person or director. The challenge for the team was to create a 60-second video using flip camera technology, laptop, stopwatch and museum object (such as a fossil) to answer a mission question. The mission
question was unique to each group, examples of which were, ‘birds evolved from dinosaurs, how do we know?’ and ‘mega fauna roamed Australia, how do we know?’ To answer the mission question, the group used the information presented in the *600 Million Years: Victoria Evolves* exhibition which brought the story of Victoria's evolution to life through animation, animatronics, models and multimedia interactives. This challenge was a new initiative by the museum to engage visiting school groups to the exhibitions (Gaff, 2011).

**ICT Challenges (Workshop 9)**

Students had the choice of undertaking one of four challenges: white coffee problem, adaptation challenge, light reflection challenge or hand motion challenge. After the completion of the challenge, students were to present their findings to the rest of the class. In the white coffee problem, students were challenged to use digital thermometers and other equipment to answer the question, ‘if one has just poured a fresh brew of coffee and one can’t drink for a few minutes should one add milk now or after two minutes?’ For the adaptation challenge, students were challenged to collect evidence of adaptation in two animals and present their findings in a *Prezi* (http://prezi.com/) presentation. For the light reflection challenge, the students were to use digital light probes to determine which type of coloured paper other than white reflects the most amount of light. For the hand motion challenge, the students were provided with a short video of a person walking and challenged to use motion analysis software to determine if a person's hand actually moves backwards when the person is moving in a forwards direction.

**Off-Campus Course Structure**

The same curriculum content was delivered to both off-campus and on-campus cohorts of students. For the off-campus students, the curriculum was delivered in each of the 12 weeks through a web-based online learning management system called *Blackboard*. The same ICT representational challenges were given to the off-campus students (except for the digital probe tasks). Students were often sent to a particular online resource to read, explore, investigate and then respond to a particular discussion thread. Assessment was the same as for on-campus students except for a hurdle assessment requiring a set number of quality submissions to the discussions associated with the weekly tasks. It is the author’s university’s policy that the same curriculum and assessment be applied to each course that is offered in on-campus and off-campus modes of delivery.

**Course Assessment**

The assessment for the course consisted of three tasks, details of which are given below. As stated previously, the same assessment was applied to both on-campus and off-campus delivery modes which was in line with university policy. The assessment tasks, with percentage weightings, were as follows:

(a) Teacher demonstration (25%): Students were to research and develop a teacher demonstration that could be used in the science classroom. Apart from a written report the on-campus students were required to provide an oral presentation that included the demonstration to the rest of the students. The off-campus students were required to provide a written report and an online presentation to fellow off-campus students.

(b) Electronic portfolio (40%): The students were to prepare an electronic portfolio of six teaching and learning resources that would be of benefit to them in their future professional practice as a secondary science teacher. There was a requirement that among the six resources two had to
be specifically ICT based. The first one was a digital teaching resource that would be used in the classroom. Two examples given were a web quest and online survey. A standard PowerPoint presentation was not allowed. The second one was a digital student work sample in response to a representational challenge given by the teacher. Apart from providing details about the challenge, the students were also required to complete the task as if they were the secondary science learner. Examples given were an animation and podcast. For each resource, a rationale (including citations and references) was to be written outlining its features for its effective use in a science classroom in terms of improved learning outcomes for students. The overall challenge given to the students was for them to construct a website to be then used as a repository for their portfolio.

(c) Research report (30%): The students were to write a report that included a literature review on the theme ‘learning science in settings other than the classroom’ and construct a planning document that detailed an excursion that could be undertaken by students in a neighbouring school. The planning document was to include a rationale for conducting the excursion, details of the learning experiences to be handled by the students during the excursion as well as prior to and following the excursion and the protocols to follow at a school level to allow an excursion to be undertaken.

Findings

The main findings in the data were increased engagement of ICT tools and devices and increased TPACK of the pre-service science teachers over the duration of the course. Table 2 provides pre- and post-course survey data related to students’ ratings of statements within each of the TPACK framework knowledge domains. This data represents the pre-service teachers’ perceptions of their own levels of teaching and TK. The data indicates increased levels in each of the knowledge domains, including TPACK, over the duration of the course. The data also indicates that at the beginning of the course the students’ perceived levels of content and pedagogical knowledge were significantly higher than their TK and over the duration of the course most gains were found in those knowledge domains related to technology, namely, TK, TCK and TPACK.

Supportive evidence for the Table 2 data was found in data collected from the other instruments in this study. This data also provided evidence of increased engagement of ICT tools and devices and greater insights into the increased levels of technology and teaching knowledge perceived by the students. This is presented and discussed in the following sections.

<table>
<thead>
<tr>
<th>Knowledge Domain</th>
<th>Pre-Test (%)</th>
<th>Post-Test (%)</th>
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<tbody>
<tr>
<td>Technology Knowledge (TK)</td>
<td>59.7</td>
<td>77.8</td>
</tr>
<tr>
<td>Content Knowledge (CK)</td>
<td>86.1</td>
<td>100</td>
</tr>
<tr>
<td>Pedagogical Knowledge (PK)</td>
<td>80.7</td>
<td>89.0</td>
</tr>
<tr>
<td>Pedagogical Content Knowledge (PCK)</td>
<td>83.3</td>
<td>91.7</td>
</tr>
<tr>
<td>Technological Content Knowledge (TCK)</td>
<td>58.3</td>
<td>83.3</td>
</tr>
<tr>
<td>Technological Content and Pedagogical Knowledge (TPACK)</td>
<td>63.3</td>
<td>79.2</td>
</tr>
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\( n=12 \)
There was general agreement among the students in the focus group interview that through their participation in the course they had increased their engagement of ICT tools and devices. An outcome of this engagement was an increase in their TK.

One reason offered by the students was that the course gave them the opportunity to create something with the new technologies arising from the representational challenges given in the tutorials and the digital portfolio assessment task. When asked ‘do you think your technology core skills have improved through participation in this unit (course)?’ one student responded, ‘Definitely. This unit actually is giving us a chance to create some things...and actually we improve our knowledge as well’.

Another reason was suggested by a student who responded that improvement in TK for her was as a result of, ‘being forced to use the software for assessment...because we’re actually forced to do it electronically or forced to do it that way for the assessment, then we do it’. There was a view that the assessment tasks placed the students out of their comfort zone in terms of adopting new technologies; this was not seen as a bad thing and is illustrated by the following comment, but I think...it puts people out of their comfort zone. So we sort of tend to go back to the things that we find comfortable like Word and PowerPoint and Publisher instead of sort of venturing out into these other ones...The assessment just forces you over that resistance to use it...It gets you over that barrier.

It was evident in the on-campus workshops that students readily engaged in undertaking the representational challenges and, for many, their attempts at the challenges meant learning new technological knowledge. These challenges were often completed in small groups and support was provided not only by the tutor but also other students. When presenting their constructed representations in response to the challenges it was often observed that the students were pleased with their efforts, particularly if it involved gaining new technological knowledge.

For the off-campus course, evidence of increased engagement with ICT tools and TK was seen in the discussion threads within the Blackboard learning management system that were constructed so that the students could upload and discuss their responses to the ICT representational challenges. The following discussion thread to the ice-cream animation challenge indicated one student’s posting and responses from another student. This was a good challenge, I have not used PowerPoint like this before. This was very fiddly, but kinda fun and addictive. [This student attached his PowerPoint animation] [Student 1]That was great. How did you move all the particles- did you move each particle using the custom drawing? That is the kind of thing I wanted to get my particles to do but was unsure how to do it. Great Job! [Student 2]

Within the on-campus workshops, there was evidence of collaborative support from the tutor and students to support those students in gaining the necessary technological knowledge to complete the challenges. It was also evident that the collective skill base of the whole group exceeded that of the tutor. Course support for off-campus students was undertaken on a needs basis where students would post a message outlining their problem. This was often resolved by either the tutor or another student. Outside of the workshop and online course environment, students resorted to publicly produced video tutorial support or their peers. In the focus group interview when asked, ‘what information technology support the students had outside of the university environment?’, one student responded, using the little web videos that they often provide for different things. Like
particularly with software they’ll have videos of tutorials for explaining this is how you do this. Whereas with the tools they think it was more a pick it up and play with it until we figure it out.

The following quotes were from students who used specific ICT resources or tools for the first time in the course. They indicate high levels of engagement and a sense of achievement in gaining a useful skill. As you probably know my ICT knowledge is very limited. I was really impressed to see what a web quest is and I think it has huge benefits particularly for people like me who are just starting to get into web based learning... I also think this is something that I could set up without too much trouble. [off-campus student] It was the first time [in this course] I used a digital microscope that you plugged into your laptop. That's cool. [on-campus student] Below is a link to an online quiz I designed on the topic of 'Mixtures' in Chemistry. While using SurveyMonkey, I particularly liked it, because it is easy to design a quiz/survey. [off-campus student] I've made a Prezi today and actually found it pretty interesting and will probably make more for this assignment and in the future as well. [on-campus student] We spent a whole afternoon in the library playing with Prezi and working it out. [on-campus student]

The major assessment task for the course, a digital portfolio, required the students to use their technological knowledge to construct a digital teaching resource and a student digital artefact in response to a representational challenge designed by the student. Whilst most of the students had not constructed a webpage before they all completed this challenge successfully producing well-designed web pages making it easier for the reader to access the embedded resources.

Apart from creating a website to contain their digital portfolios, the variation in the digital resources used by the students to construct the teaching resource can be found in Fig. 1 and for construction of the student artefact can be found in Fig. 2. Both Figs. 1 and 2 show evidence of students’ abilities to construct digital resources using a variety of digital tools and devices.
The technological knowledge required for some tasks were seen as challenging and for other tasks easy to acquire. For example, in completing the digital portfolio one off-campus student remarked in an email, ‘Have to say this was a monumental task for me so for you to be able to see anything will be a bonus!!’. Whilst the digital devices -- data loggers and digital microscopes -- were new to many of the students, they felt such devices were easy to use as evidenced by the following comment by a student in the focus group. No, I haven’t used them [digital devices] before, no USB video cameras and also motion detectors….He [tutor] showed them to us and then I used it. They’re all easy – just pop into your computer via USB. They’re easy to use and they come with the software.

**Content Knowledge (CK) and Pedagogical Knowledge (PK)**

As indicated by Table 2, the students’ perceived levels of CK and PK were high at the beginning of the course. However, where the context of the workshop activities was outside the specific expertise of the students they reported gains in CK. For example, when asked ‘was this unit instrumental in improving your understanding of science?’ One student responded, ‘All the physics stuff. Because I don’t have much of a basis in physics it did help sort of cement some of those concepts’.

Modelling best teaching practice informed by current findings from research by the tutor was seen by the students as beneficial in enhancing their PK. The way Peter [tutor] presented with some of his research done in a classroom… I found that really useful to sort of help to both cement my understanding and help me to visualise what I should be teaching my students and how I should present stuff to them and that kind of thing.

**Technological Pedagogical and Content Knowledge (TPACK)**

The data showed evidence of gains in the students’ TPACK where the students achieved a greater understanding of ways to embed ICT into the teaching and learning of science. Throughout the course, the tutor presented a view that technology should not be seen as an end in itself. Instead, it should be considered as the most appropriate representational tool for learning once the teacher has considered the specific learning outcomes for his/her students and an appropriate pedagogical approach to apply. This view was expressed by a student in the focus group interview, it wasn’t so much a case of okay we need to teach them how to use this tool or we’re going to use this for this reason. It was a case of ‘this is the lesson that I’m teaching, what are the kids learning?’ then matching an appropriate technology and pedagogy.

The emphasis on learning technologies was not seen as a panacea for effective teaching but the role played by the teacher. One student commented, it’s something I’ve really found about the unit. I think that’s what makes an effective teacher you can have all the tools in the world and still not be able to teach…I don’t think that it’s just technology at the forefront. It’s the teachers. It’s what we’re trying to aim to do in terms of students learning science.

In articulating the contribution ICT has for the science classroom one student made the point, ‘It wasn’t just technology for the sake of technology. It was how you could put this technology into your classroom, whether it’s getting the students to utilize it or you’re utilising it yourself and I think Peter (tutor) made that pretty clear’.

The role of the teacher in supporting ICT was mentioned by an off-campus student who made the following comment in relation to evaluating two flash animations that were given in one of the weekly tasks. After completing the flash animations on evolution I have found that there is learning to be accomplished through the use of animations but they need to be well guided and easy to
follow...Though ICT can encourage learning, activities that aren’t clear can be ignored and rendered ineffective.

The students gained insights into the manner in which ICT could be embedded into the science classroom through modelling of best practice undertaken by the tutor. One student commented, ‘Peter (tutor) was putting stuff in all the time. There was good modelling of the technology use’. In response to the survey question, ‘describe a specific episode where a tutor/lecturer effectively demonstrated or modelled content, technologies and teaching approaches in a classroom lesson’ several students made reference to the course in responding, ‘Peter Hubber’s class (all of them)’. Other comments included, many examples from this tute class with the various resources which can be used for different fields of science. Everything we have done in this class from learning about new technologies to them being demonstrated in class, to modelling classroom science activities around the technologies.

The digital portfolio assessment task required the pre-service students to apply, and show, their TPACK as not only were they required to collect and construct digital resources but were also required to provide details as to how the resource might be specifically used in their own classroom as well as provide a rationale for its use. Fig. 3 shows the distribution of resource types among the students’ digital portfolio each of which consisted of 6 resources. This figure shows that the majority of the resources were ICT based despite there being the requirement that only two of the resources be in this form. There was also a wide variety of resources. These findings reflect a high level of engagement with digital technologies several of which employed web 2.0 tools such as online surveys, Prezi (web-based presentation http://prezi.com/), web quests, blogs and website building.

The variety of resource type reflects the open-ended nature of the task in terms of allowing the students flexibility in the type of resource they could choose. This was seen as an important aspect of the assessment task as the decision to use a particular digital technology should not precede subject content and pedagogical decisions.

The students often showed evidence of TPACK in the rationales that accompanied each resource. An example is shown in Fig. 4 where the student created an online survey using the SurveyMonkey tool and provided a rationale for its use.
In the rationale reference was made to a connection with content knowledge expected of Year 12 biology students when she stated that ‘Survey Monkey has been used to develop a series of questions for a year 12 Biology classroom, in preparation for their end of year exam’. She also stated that, ‘Survey Monkey can also be used as a form of assessment tool...[which] can be accessed from both a home or school computer’ and can be used, ‘as a form of pre-testing to identify students prior knowledge and misconceptions of science concepts; knowledge which teachers can use to help plan their lessons on the unit, or the unit itself’. Reference was also made to pedagogical knowledge in terms of initially eliciting students’ understanding of biology concepts and then using this information in class discussions, driven by students, to resolve issues of misunderstandings. The whole process was seen as a revision activity for students to prepare for their final examination, which the pre-service teacher undertook as part of her practicum experience. She wrote, the class of 25 was broken into smaller groups and each team completed the quiz. The groups then swapped answers, and the questions were discussed in class, which promoted discussion and allowed students to raise question about the questions and the corresponding answers, as well as the biology content of the task.

Finally, reference was made to technological knowledge with the production of the online survey. The student highlighted the affordances of an online survey in terms of its accessibility in school or home and the formative assessment features in terms of providing the teacher about students’ prior knowledge of a topic that could inform future teaching practices. The rationale illustrates the student’s TPACK through the explicit links made to each of the three knowledge domains of content, pedagogy and technology.

Many of the students applied their TPACK gained in the course whilst on their practicum rounds. This was evident in the comments made in their digital portfolios, as in the case above, as well as in off-campus discussion and focus group discussion. Indicative comments are given below : I created my online survey on genetics which is what my current class of Year 10 students are completing. [off-campus student] I now use the Delicious website quite frequently. I’d never heard of it before I started the unit and I’ve used it several times in class situations...My supervising teacher thought it was a good idea to use it. [on-campus student]

Apart from the representational challenges the students showed evidence of their TPACK in other areas of the course. The students critiqued a range of online resources in terms of their efficacy of
use in a science classroom. Several students used digital resources for their teacher demonstration, which was part of their formal assessment for the course. For example, a pair of students videotaped a dangerous experiment they had conducted and embedded the video into a multimedia PowerPoint presentation. One of the postgraduate students who had previous employment in the IT industry did not feel as if the course enhanced his technology core skills but gave him an ‘awareness of other tools that are available that are quite straight forward to use’ and better skills in determining the efficacy of an ICT resource’s use in the classroom as ‘there’s an infinite amount of stuff on the Internet and you just don’t know what’s good and what’s not for teaching’.

**Issues Raised by Pre-Service Teachers**

Issues raised by the students in undertaking this course related to time commitment necessary to learn a new technology, access to digital resources and a lack of good models of ICT practice in other courses and practicum schools. Each of these issues is discussed below.

**Time Commitment**

Whilst sufficient time was set aside in the workshop program for students to complete the representational challenges new technologies were often discussed or demonstrated without the students gaining class time to develop an expertise in their use. Students were then required to gain the technological knowledge outside of the class-time. In some cases the time taken to do this was an issue as illustrated by the following comment made by one of the students in the focus group interview. My first Prezi I did took me 6 hours and I only stuck with it because it was a requirement but after the first hour I got annoyed with it. I just wanted to give up. But as part of my assessment criteria was to do a prezi so I was just like “I’ve got to do it.” But if it [the new technology] took me more than an hour to understand or to do something so simple, I just gave up on it because I don’t have time and I know that it’s going to be the same when I get out into a school. If it’s going to take me too long – teachers don’t have the time to do it.

This student’s reference to teachers in schools being ‘time poor’ in learning new technologies is a valid one and supported by the literature (Bingimlas, 2009).

**Access to Digital Resources**

A significant issue for the students was accessibility to web-based resources. Whilst importance was placed by the course tutor to employ freeware software this was not always the case. Some of the restrictions on the freeware were limitations in capabilities (e.g. www.surveymonkey.com) or resources that only provided a limited ‘free’ trial period (e.g. www.inspiration.com). Comments made by students in relation to this issue are given below. The second quote refers to the *Ultranet* which is an online learning management system developed for the Victorian Department of Education and Early Childhood Development (DEECD) to provide extensive services to children, parents and teachers in government schools. The *Ultranet* gives teachers easy access to learning tools and resources; however, access is only possible to registered government teachers. The [Survey Monkey] resource provides an easy tool for teachers to create quizzes without much time needed for formatting. I found the website really useful except you can only create 10 questions for the basic package we sign up for, which as you can see by the structure of the quiz [I constructed] was unanticipated. [off-campus student] I found it quite irritating sometimes, a lot of the things that we’re being introduced to, particularly the Ultranet that we don’t have access to. So we’re being taught about things that we can’t actually use now or programs that we can have a 30 day trial to for free but if we have another assignment later on using the same program we can’t go back and get it. [on-campus student]
The students did get some insight into the *Ultranet* through a presentation by a Victorian Education Department *Ultranet* expert during the week 6 workshop. Despite not getting personal access it was felt by one student that...it was good to know that it’s there. It’s frustrating that you can’t use it and fiddle with it and work out how you’d use it but at least you know it’s there.

**Insufficient Modelling of ICT Practice in Non-Science Courses and Practicum Schools**

In the post-surveys the students were to indicate the percentage of science and non-science teacher educators and practicum supervising teachers who provided effective models of ICT practice. Fig. 5 indicates that whilst science teacher educators were seen as models of effective ICT practice this was not the case for non-science teacher educators. In terms of effective models seen by the students on the practicum experiences there were mixed results. Some students saw the majority of their teachers who were effective models whilst for other students such teachers were in the minority.

**Conclusion**

The course that formed the basis of the case study herein presented was a general science curriculum course as part of two pre-service secondary science teacher programs. This course was purposefully designed to embed learning technologies into its curriculum, assessment and delivery. A representational construction pedagogy that affords the integration of ICT into classroom practice was modelled by the tutor. A high level of engagement with Web 2.0 tools was evidenced by the number of students who chose to create web quests, prezis and other online tools as representations to teach science. There were also increased levels of TPACK achieved by the pre-service secondary science teachers. This was evident in the manner in which the students participated and succeeded in completing the representational challenges which were embedded in the weekly tasks as well as the major assessment task, the digital portfolio. Evidence was also provided by the student reflections of practicum experiences during which they incorporated learning technologies in their teaching. The increased levels of TPACK resulted from significant levels of student engagement with ICT in the course.

There are several possible drivers for the pre-service teachers’ engagement with learning technologies and increased TPACK. One of these drivers is the nature of the representational challenges and the expectation that they be completed as part of the general course work as well as an assessment requirement. The challenges were authentic tasks which highlighted how learning technologies might be used in practice, that is, the school environment. The focus was not on the learning technology but on the outcomes of using the learning technology. An example of an outcome is the understanding of an abstract scientific theory, like the particle model. Another...
example is to fulfil a pedagogical aim to elicit students’ views on a particular phenomenon or scientific issue. The challenges represented activities that were set in the context of teaching and learning of science relevant to the students which concur with the views expressed by Hardy (2010) and Mishra and Koehler (2006). Whilst the acquisition of technological knowledge was seen as challenging and time-consuming for some students it was considered as useful in terms of their improved future teaching practice. Teo (2011) saw these as reason why students might use the technology. This concurs with Goodhue and Thompson’s (1995) idea of good task-technology fit.

Another possible driver for engagement with learning technologies and enhanced TPACK was the competence of a skilled educator modelling best practice in the ways in which ICT can be used in the science classroom. Fig. 5 shows that the students saw a lack of models in their non-science teacher training course and variation in different teachers’ practices observed on practicum. By taking on the multiple roles of learner, pre-service teacher and teacher during the course the students directly experienced a representation construction approach (Tytler & Hubber, 2011), which involves the student construction and critique of representational forms. The representational forms do not necessarily imply the products of a learning technology and so the students saw the use of technologies within a broader pedagogy. In other words, a learning technology needs to be seen as a tool for learning rather than the technology as an end in itself. There was evidence that several students were successfully using learning technologies in their practicum which they negotiated with their supervising teachers and so the student could appreciate what Teo (2011) described as the ‘demands and stresses involved in integrating technology in a real school setting’ (p. 95).

There were several issues that arose in the course that may point to areas for improvement. One issue for the students was the non-access to ICT system structures such as the Victorian government Schools’ Ultranet. Teacher educators and pre-service teachers should be given access to the technologies they are likely to encounter in schools (Teo, 2011). Another issue for the course was the university requirement to provide the same curriculum and assessment to on-campus and off-campus students. Whilst the representational challenges were the same the manner in which they were undertaken was quite different in the two delivery modes. The issues faced by the off-campus students in online learning have not been discussed in this chapter but represent a fruitful research direction. Ma and Yuen (2011) point out that effectiveness of online learning is not guaranteed with learning technologies but may be enhanced through the facilitation of collaborative or group learning in a peer-support and exchange environment.

A final issue relates to embedding learning technologies into whole teacher training programs. This course was a core for the double degree program but not for the master of teaching program for the pre-service secondary science teacher programs and was not offered at all in any of the other secondary teaching programs. Therefore, the ICT experiences of pre-service teachers at this university can vary depending on the courses they undertake. Given that graduate standards for teaching involve ICT skills (AITSL, 2011), it becomes important for program leaders to ensure that all graduates have the necessary ICT knowledge base and confidence to integrate ICT into the curriculum and their teaching when they enter the teaching profession (Jamieson-Proctor, Finger, & Albion, 2010). Consistent with findings from Haydn and Barton (2007) a program approach to embedding ICT may resolve a time issue raised by students in this course in relation to gaining technological knowledge of new technologies. Pre-service teachers can develop their technological knowledge over many courses rather than a select few.

This study shows that where teacher training courses are designed in a manner that embeds learning technologies in the curriculum, assessment and delivery, increased engagement with learning technologies and enhanced TPACK among the pre-service teachers is possible.
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