J Sci Teacher Educ (2014) 25:373–393
DOI 10.1007/s10972-014-9387-y

Learning How to Teach Chemistry with Technology: Pre-Service Teachers' Experiences with Integrating Technology into Their Learning and Teaching

Gail Chittleborough

Published online: 30 April 2014

Abstract The Australian Government initiative, Teaching Teachers for the Future (TTF), was a targeted response to improve the preparation of future teachers with integrating technology into their practice. This paper reports on TTF research involving 28 preservice teachers undertaking a chemistry curriculum studies unit that adopted a technological focus. For chemistry teaching the results showed that technological knowledge augmented the fundamental pedagogical knowledge necessary for teaching chemistry content. All the pre-service teachers demonstrated an understanding of the role of technology in teaching and learning and reported an increased skill level in a variety of technologies, many they had not used previously. Some students were sceptical about this learning when schools did not have technological resources available. This paper argues that teacher education courses should include technological skills that match those available in schools, as well as introduce new technologies to support a change in the culture of using technology in schools.

Keywords Chemistry · Technology · Pedagogy · Pre-service teacher · TPACK

Introduction

Experienced teachers have been described as digital immigrants as they respond to the changing technological landscape (Prensky, 2001). Looking forward in an endeavour to improve future teachers expertise in integrating technology in their teaching, the Australian Government initiated a national program called Teaching

G. Chittleborough (✉)
Faculty of Arts and Education, Deakin University, 221 Burwood Hwy, Burwood 3125, Victoria, Australia
e-mail: gail.chittleborough@deakin.edu.au

Teachers for the Future (TTF)[1], from 2010 to 2012. This was aimed at improving the pedagogical and technological skills of pre-service teachers (PST).[2] The intensive national program that invested in changing the practice of teacher educators to reflect the government and curricula policies. This proposition saw that teacher educators could play a significant role in modelling the use of technology and thereby make an impact on the teachers of the future. The TTF program used the Technological, Pedagogical and Content Knowledge TPACK[3] framework proposed by Mishra and Koehler (2006) to provide a foundation for the program. The TPACK framework is "a representation of the knowledge required to use technology in an educational setting in ways that are contextually authentic and pedagogically appropriate" (Abbitt, 2011, p. 281). The use of the TPACK framework gave a clear indication that the TTF program was not just about learning technological skills, but rather it was aimed at demonstrating how technology could be matched to pedagogy and content to meaningfully and purposefully enhance learning opportunities. The intention was to provide PST with knowledge and skills in teaching with technologies in their specific content area of expertise, and make them receptive to using additional technological tools that will inevitably surface along their future career paths.

The TPACK Model

Pedagogical content knowledge is the knowledge and ability to transform specific content knowledge in a way that is communicated to learners (Geddis & Wood, 1997). It is the product of knowledge bases or components, such as subject matter knowledge, subject representations, knowledge of learners, general pedagogical knowledge, curriculum knowledge, knowledge of the context, knowledge of assessment and the beliefs of the teacher (Geddis & Wood, 1997; Magnusson, Krajick & Borko, 1999; Rollnick, Bennett, Rhemtula, Dharsey & Ndlovu, 2008; Shulman, 1986b, 1987; Van Driel, Verloop & de Vos, 1998).

These knowledge categories are not definitive but they are useful to identify the particular characteristic that teachers must have and can learn or develop, and therefore support the claim by that "teaching is essentially a learned profession" (1987, p. 9). By acknowledging the complexity of the teaching profession, Shulman (1986a, 1987) was challenging the perception that anyone can teach. By distinguishing pedagogical content knowledge as a special knowledge, Shulman identified an area of expertise visible in the pedagogical reasoning and actions that teachers performed, but not commonly recognised or acknowledged.

With the ubiquitous use of computers in society there is an increasing need for computer technology to be integrated into teaching. Mishra and Koelher (2006) extended Shulman's model to include technology as shown in Fig. 1 resulting in additional knowledge categories being identified, namely: Technology Knowledge

[1] TTF will be used as an abbreviation for the program Teaching Teachers for the Future.

[2] PST will be used as an abbreviation for Pre-Service Teachers.

[3] TPACK will be used as an abbreviation for the Technological, Pedagogical and Content Knowledge.

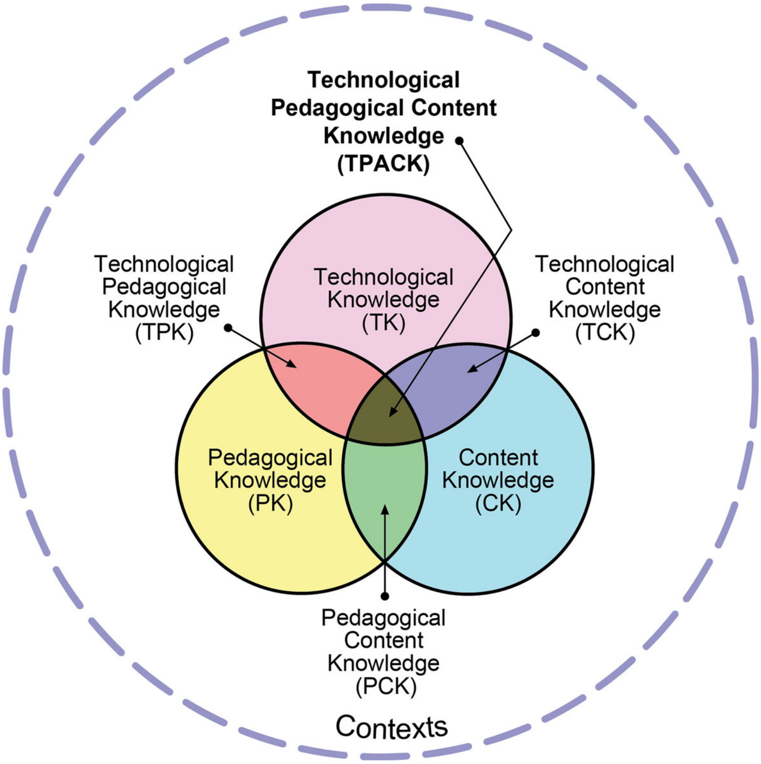

Fig. 1 The TPACK framework and its knowledge components as proposed by Mishra and Koehler (2006, p. 102)

(TK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK) and Technological Pedagogical Content Knowledge (TPCK). The knowledge of content in this research refers to specific chemistry topics such as balancing equations and understanding bonding. The pedagogy encompasses teaching and learning demands in the choice of teaching approaches, that for example cater for the learners' needs and the characteristics of the content. The technology refers to the resources, e.g. digital, text, hardware that are available and appropriate to be used for the teaching and learning. Technology is a distinct knowledge area separate from pedagogical knowledge and content knowledge and warrants the separate domain for technology. It is the rapid expansion of digital technologies in teaching and the growing range of features of digital technologies, many untested in teaching contexts that has created the need for the focus on this domain. The technological knowledge area is rapidly evolving due to changing nature of hardware, software, applications, and the mobility of devices. It is dependent on the features of the available resources. The TPCK knowledge more recently referred to as TPACK, is a knowledge that had previously not been identified. It describes the knowledge and skills needed to select the appropriate available digital technology and use it in a pedagogically sound way to transform particular content knowledge so that it meets the needs of individual learners.

Rollnick et al. (2008) report the consequences of teacher's lack of subject matter knowledge on their PCK, with teachers adopting a more structured teaching approach using rote teaching and algorithmic approaches. Just as subject matter knowledge is a pre-requisite for developing PCK (Van Driel et al., 1998), technological knowledge is a prerequisite for developing TPACK. The inference here is that teachers' lack of technological knowledge will have implications on their TPACK for chemistry teaching.

The TPACK framework has proved to be useful in guiding teachers and pre-service teachers to evaluate the integration of technologies (Hubbard & Price, 2013; Jang & Chen, 2010; Maeng, Mulvey, Smetana, & Bell, 2013). Many teachers and pre-service teachers do not have the technological knowledge (TK) and skills to teach using technology and do not have a developed pedagogical knowledge for using technologies (TPK). They are reticent to use technologies when students have demonstrated greater ICT skills (Mishra and Koehler, 2006). For these reasons the TPACK framework can help focus attention on assessing and situating technology in pedagogical practice.

There are numerous factors that influence a teacher's TPACK knowledge including having sufficient time and motivation, being prepared to take risks and having adequate resources. Teachers and pre-service teachers need to be supported in taking risks to improve/transform the way they do things. Access to resources requires sufficient infrastructure and equipment that is reliable, accessible and is kept current. Just as Shulman described PCK, the TPACK knowledge base grows with experience as teachers draw on it to provide the reasons for the actions and choices they make in their teaching. Shulman explained that this involves "a cycle through the activities of comprehension, transformation, instruction, evaluation and reflection." (Shulman, 1987, p. 14).

Table 1 Examples of information communication technology (ICT) resources used in this unit

Hardware	Software	Online
Laptops	PowerPoint, Word,	E-mails
Tablets	Edit images/video	Blogs
Portable devices	Wiki, Inspiration,	Wikis
Interactive whiteboard	Animation-software	Internet sites
Computer	Slowmation	You-Tube clips
Camera	Software for the	Social book-marking
Internet	Dataloggers	Search Engines
I-phone	E-mail	
Scanner		
Voice recorder		
Data-loggers		
Digital microscope		

Technological Pedagogical Knowledge for Chemistry Teaching (TPK)

A chemistry classroom requires information to be handled in contemporary ways as provided for by a digital medium. Table 1 shows some examples of the online, software and hardware resources that were used in this study.

Technological Chemistry Content Knowledge for Chemistry Teaching (TCK)

The use of digital technologies is most relevant to teaching chemistry because of the nature of the content and the visual impact it can provide to help explain the abstract unseen level, for example, representing the sub-microscopic state of matter, showing real chemicals that are not readily available or accessible for use, providing simulations for experiments that can't be done safely in the laboratory, or for which equipment is not available in the classroom. Digital representations like simulations and animations can save time, present data in multiple formats, provide interactivity, and allow easy manipulation of large amounts of data. (Woodfield, Catlin, Waddoups, Moore, Swan, Allen & Bodily, 2004; Paiva, Gil, & Correia, 2003). Technological knowledge is changing in response to the increased availability and mobility of hardware, software, and applications and the increased digital expertise of many learners.

Technological Pedagogical Chemistry Content Knowledge for Chemistry Teaching (TPACK)

By drawing on the three knowledge bases, namely, content, pedagogical and technological, the PST make informed assessments of the suitability of various technological tools to communicate chemical content and best match to the level of the learner. The successful integration of the technological resources into teaching to promote learning about chemistry can demonstrate Technological Pedagogical Content Knowledge (TPACK) in this discipline area. Van Driel and Berry (2012, p. 27) emphasise that PCK is specific to the "context, situation and person" and is not a repertoire of teaching strategies that can be learnt. The role and impact of available technologies are a significant part of the "context, situation and person".

Research Questions

The aim of this study was to examine the impact of a technologically focused teaching program on the perceptions of 28 PST using ICT.

RQ1 How can we teach PST to evaluate possible ICT resources?
RQ2 What are PST perceptions of using technology at university and in teaching chemistry in schools?

Research Methodology

This research is a case study of the experiences of 28 volunteer PST in the chemistry curriculum unit. Eighteen of the PST taking the unit were in their third year of a

4-year Bachelor of Science/Bachelor of Teaching course and the remaining ten students were undertaking a Masters of Teaching, and were approximately half way through their course. The unit is designed to prepare PST to teach chemistry in senior high school (for ages 16–18 years) and focuses on developing pedagogical content knowledge for teaching chemistry. The PST examined the use of ICT in teaching chemistry; answering questions such as, “Why use it?” “When to use it?”, “How to use it?”, “What does it include?” and “What skills do I need?”

The methodology included collecting a variety of data over the 4-month period to produce a rich description of the case. The educator of this unit was not involved in recruiting participants, interviewing or surveying the students. The PST assignment work was offered for inclusion in the research data after all were assessed and all unit requirements completed. The unit specifically included tasks in which PST had to incorporate technology. The teaching unit focussed on developing PCK, which is a complex and subject specific knowledge domain. Johnstone (1982, 2006) distinguished three levels of chemical representation of matter that form an important foundation to the pre-service teachers developing pedagogical content knowledge. They are:

> The macroscopic level—comprising tangible and visible chemicals, which may or may not be part of students’ everyday experiences.
> The sub-microscopic level—comprising the particulate level, which can be used to describe the movement of electrons, molecules, particles or atoms.
> The symbolic level—comprising a large variety of pictorial representations, algebraic and computational forms.

An understanding of the three levels of representation is critical in teaching and learning chemistry because the subjects is essentially about the abstract concept of the atomic theory of matter. Overtly presenting the three levels can help learners to make links between these levels (Treagust et al. 2003). The design of the teaching unit provided learning opportunities to trial specific strategies, allow collaboration among PST, and encourage reflection, both individually and collectively (Van Driel & Berry, 2012).

The results describe 28 PST experiences using technology with their own learning. All students were given opportunities to improve their technological knowledge and skills by:

- working in an online environment, contributing to a discussion space and working on a wiki to generate a shared response to set tasks
- Manipulating digital data—such as video, images, simulations, data logging;
- Developing an understanding of the TPACK model

For Assignment 1, students were required to post critical reflections on a minimum of 6 readings on the online discussion space and respond to other students’ comments. Assignment 2 required pairs of students to create a multi-media teaching resource on an emerging science topic such as biotechnology, nanotechnology, green chemistry etc. Assignment 3 required each PST to create a teaching resource for use with the interactive whiteboard on a difficult chemical concept. In groups of 5, students viewed each other’s assignments on an online space and

Table 2 The assessment criteria and TPACK knowledge bases[1] for Assignments 1, 2, 3

Assessment criteria	Knowledge base
1. Discussion of the relevance, application and meaningfulness of the article to teaching chemistry	PK, CK, TK
2. The quality of the presentation of how this teaching resource could be used to teach emerging science topic to students in a chemistry class	TPACK
Relevant characteristics of the multimedia object used in this teaching,	TPK
Identification of the essential chemical concepts to be covered and the accuracy and detail of the emerging science	TCK
3. Engagement value, and interactivity and effectiveness of the resource	PK, TPK
Accuracy of the resource with respect to the scientific concept	CK, TCK
Critical feedback informed by constructivist learning theories with consideration to the: appropriateness, targeting common alternative conceptions, responsiveness, reflection and collaboration	TPACK

[1] TPACK knowledge bases

CK content knowledge, *PK* pedagogical knowledge, *TK* technological knowledge, *TPK* technological pedagogical knowledge, *TCK* technological content knowledge, *TPACK* technological pedagogical content knowledge

contributed to an online wiki—commenting on each other's assignments and contributing to a shared response from the group. The assessment criteria for assignments were linked to the TPACK framework so that all knowledge bases were addressed (see Table 2). For many students the technologies were new to them so they had to learn the new technological knowledge (TK). The opportunities for collaboration and sharing are intentional to provide opportunities for the PST to reflect and discuss the pedagogical value, thereby developing PCK and TPCK.

Data Sources

The data included the unit teaching material; the educator's observations as a participant researcher; an anonymous online survey administered at the end of the unit that asked students about their technological and pedagogical knowledge; the assignment tasks which were collected and examined for evidence of student's technological skill level and TPACK; and focus group interviews which were conducted with 8 of the 28 students where they were asked about their perceptions of changes to their skill level and how they have used the new skills in their professional experience in schools. The online survey is adapted from the *Survey of Pre-service Teachers' Knowledge of Teaching and Technology* (Schmidt, Baran, Thompson, Mishra, Koehler, & Shin, 2009); the response rate however was low with only 7 responses. Data coding used a number 1–28 for participants and the letter "I" for Interview, "A" for assignment work, and (S) for Survey. The assignment work was viewed and the feedback sheets scrutinized for common approaches. Data was examined for issues and evidence of pedagogical, content and TK's and interactions of these.

Results

The results from Assignments 2 and 3 provide evidence that PST learnt new technological skills and demonstrated an understanding of the pedagogical role of the technology in teaching (RQ1). Interview data and survey comments are used to provide insight into the PST learning experience (RQ2).

Assignment 2 Multimedia task on Emerging Sciences RQ1

By creating and presenting the multimedia task the PST had to evaluate the ICT resources (RQ1). The most common form of multimedia resource was PowerPoint with multiple ready-made videos, with music, one with a voiceover, another with animation, and all with images and links to relevant websites. Other formats were a wiki, a prezi (http://prezi.com), one with a "Cryptic Image" activity—a type of quiz with cryptic clues, a student- made video and a slow-mation resource. The resource and the presentation provided the PST with an opportunity to demonstrate their understanding of the emerging science and how they would teach it to a class. The task highlighted the important pedagogical knowledge (PK) such as engaging the audience, the need for feedback, the sequencing of information and including responsive aspects (see the rubric Table 5), and good subject matter knowledge (CK) was required to teach the topic. Many assignments included student centred activities to follow the presentation such as the postbox strategy and quizzes. The PST appreciation of the role of technology was evident in the pedagogical justification. Below is an example:

> "Visual: To see the impact that chemical products have, advantages and challenges of green chemistry, green chemistry in everyday applications—experiment glue from milk (renewable resource) something they can do themselves.
>
> Comparison: Traditional chemicals to more innovate chemicals to see the health benefits of green chemistry e.g. dry cleaning
>
> You tube, discussions, team work are used throughout this presentation to engage students in this important topic." (16A)

The excerpt from the rationale of another submission below shows how the design of the teaching resource leads the learner to the desired objective:

> The presentation contains video content and an executable game for students to try out. The resource asks students to perform their own research following what they had learned by completing the content on the powerpoint presentation. Students would have already studied many aspects of the periodic table, however looking at Titanium in the powerpoint presentation, they can observe how the theories they learned either support or contradict the use of titanium in industry.
>
> I also aimed to follow the constructivist learning model, encouraging and building on student output. The content begins as a general knowledge

> content, but eventually focuses on single aspect of nanotechnology, namely Titanium dioxide, in sunscreens. This is then followed by getting students to conduct their own research and generate content to present to the class based on an aspect of nanotechnology that interest them. (18A)

The rationale examples provide insight into the PST justification and links to theories of learning. They included attention to the content, pedagogy and the technology. The PST were mostly able to explain and justify their teaching approach with respect to the technology, pedagogy and chemistry content knowledge.

Assignment 3 Interactive Whiteboard (IWB) Task RQ1

The 28 teaching resources produced by the preservice teachers for assignment 3 were analysed for the teaching strategies used and the IWB features (see Table 3). All the teaching resources presented information, often with step-by-step explanations, using text, analogies, images, diagrams, and multimedia tools such as animations, simulations and you-tube clips.

The resources asked questions requiring students to respond and check their answers. The resources commonly required students to demonstrate understanding through tasks such as matching, labeling diagrams and interpreting a simulation; they often provided immediate feedback, necessitated repetition and included games and quizzes. The IWB features that were used included drag and drop; reveal using the eraser, a click, pull-tab and a blind, the infinite cloner, a correction capability. Eleven of the 28 resources included chemical information at three levels of representation, symbolic, sub-microscopic, and macroscopic representations (see Table 4). The results (Table 4) show that 11 of the 28 IWB Teaching resources included representations of matter at all three levels, 9 resources included representations at 2 levels and 8 resources had representation at only one level. The inclusion of multiple levels could be an indicator of the PSTs awareness of the importance of providing learning opportunities that links across the levels to promote understanding. Ready-made resources such as simulations, animations, flash files, quiz templates and applets were mostly embedded and integrated into the resource (see Fig. 2). Each PST individually evaluated one other students IWB teaching resource on the wiki. For example one PST wrote: "(*Student 1) combats the alternative concepts by providing students with multiple visual representations of the bonding theories, for example Lewis dot structures and the sharing on electrons diagrams*" *(Wiki group 2).* The feedback highlighted the features of the tool and its relevance to the content (Table 5).

The teaching resources provided opportunities for learners to apply chemical ideas, for example, using an atomic palette to build compounds by "drag and drop" and the capability to check their understanding of valencies. The PST demonstrated technological knowledge about IWB technology through the resources they created. The pedagogical power of the interactive whiteboard is its ability to provide instant feedback and easy access to the multimedia resources.

Table 3 IWB-features and teaching strategies in the IWB teaching resources

Topic	Teaching strategy	IWB Feature
Equations	Questions; reveal and check; drag and drop;	Drag and drop, reveal, check, infinite cloner
Hydrocarbons	Questions, click to reveal correct answer	Drag and drop, reveal, infinite cloner
Galvanic cells	Label diagram, questions, click to reveal correct answer, keyword match, erase to reveal	Label, reveal, keyword match, erase, flash files erase,
Atomic structure	Label diagram; content; game; "build an atom" Phet;	Drag and drop, infinite cloner
Reaction rates	Simulations, match words and definitions, check;	Drag and drop, click to reveal, infinite cloner
Iupac naming	Pull-in- tabs with content summaries; drag and label; links to hint pages	Erase, reveal, check, infinite cloner
Functional groups	Questions to identify the molecule	flowchart-yes/no responses
Acids and bases	Pull-in tabs with content, Questions then check by dragging blind or erasing.	Drag and drop, matching check, erase, flash files
Periodic table	Label diagram; building compounds	Infinite cloner, atom pallette, PT applet, challenge;
Equilibrium constant	Information; questions; check your answers	Blind reveal, worked examples, annotations, check
Periodic table	Information pages, examples; label diagrams;	Flash files self-check reveal
Balancing equations	Information questions answers check answers	Reveal, pull tab, drag and drop
Melting points	Information pages, drag, game, matching activity	Flash files, matching keywords, infinite cloner
Acids and bases	Information pages, drag, check	Drag and drop, matching, reveal,
Equations	Information pages, drag; check;	Simulation link, animation,
Endo/exothermic	Matching information, animation, youtube, quiz.	Flash templates-categorisation and quizzes
Equilibrium	information, interpreting diagrams	Simulation
Acids and bases	Information, questions, drag, step by step	Drag and drop, matching, click to reveal,
Metallic bonding	Information, links	Drag and drop, click to reveal answers
Acids andBases	Information, questions, analogy, images interpret step by step; reveal blind tool	Reveal, blind
Acids and bases	Information, questions answers,	Drag and drop, click to reveal answers
Acids and bases	Information pages- diagrams, text, drag, questions	Reveal, blind
Equations	Practicing balancing equation,	Infinite cloner, reveal, check answers
Electrochemistry	Information pages, diagrams text, drag, questions, diagrams,	Reveal/click on box, check answers/pulltab to reveal/label annotate diagram

Table 3 continued

Topic	Teaching strategy	IWB Feature
Stoichiometry	Information, drag, questions, answers, scaffolding, processes	Flash templates-categorisation & quizzes; reveal/click on box/pull tab
Flame tests	Information, fill in the blanks,	Drag and drop, infinite cloner, check
Electrochemistry	Information, interpreting animation	Flash—animation, check. answers, matching.
Gas equation	Information pages, drag, game, matching activity	Flash-matching, reveal/click on box/pull tab.

Table 4 Submicroscopic, symbolic and macroscopic representations used in IWB teaching resources

Symbolic	Sub-microscopic	Macroscopic	Total
Y	Y	Y	11
Y	Y	N	8
Y	N	N	8
Y	N	Y	1

Each resource was assessed for its navigation and sequencing. Some resources provided alternative learning pathways to provide differentiated learning opportunities for students of different abilities. Several students reflected on the value of the interactive whiteboard assignment commenting on the ease of using great images, that ability to keep a record of student contributions and the benefit of using online applications like lab simulations. An example of a section of one group response on the wiki is shown in Table 6. Some PST were critical that the interactive whiteboard is better suited for primary and junior levels of high school, than senior chemistry lessons. This was based on their professional experiences in secondary schools where there were no interactive whiteboards.

PST Perceptions of Using Technology RQ2

Four key issues emerged from the interview and written survey data. They are: learning with technology, the technology available in schools, sharing resources and the TPACK framework. The source of the data is shown by a number 1–28 for participants, the letter “I” for Interview, “A” for assignment work, and (S) for Survey is presented to support these key issues.

Learning with Technology

There are three concerns about learning with technology—the time required to learn new technologies, evaluating and adapting ready-made teaching resources, and changing curriculum studies to include technology with pedagogical content knowledge.

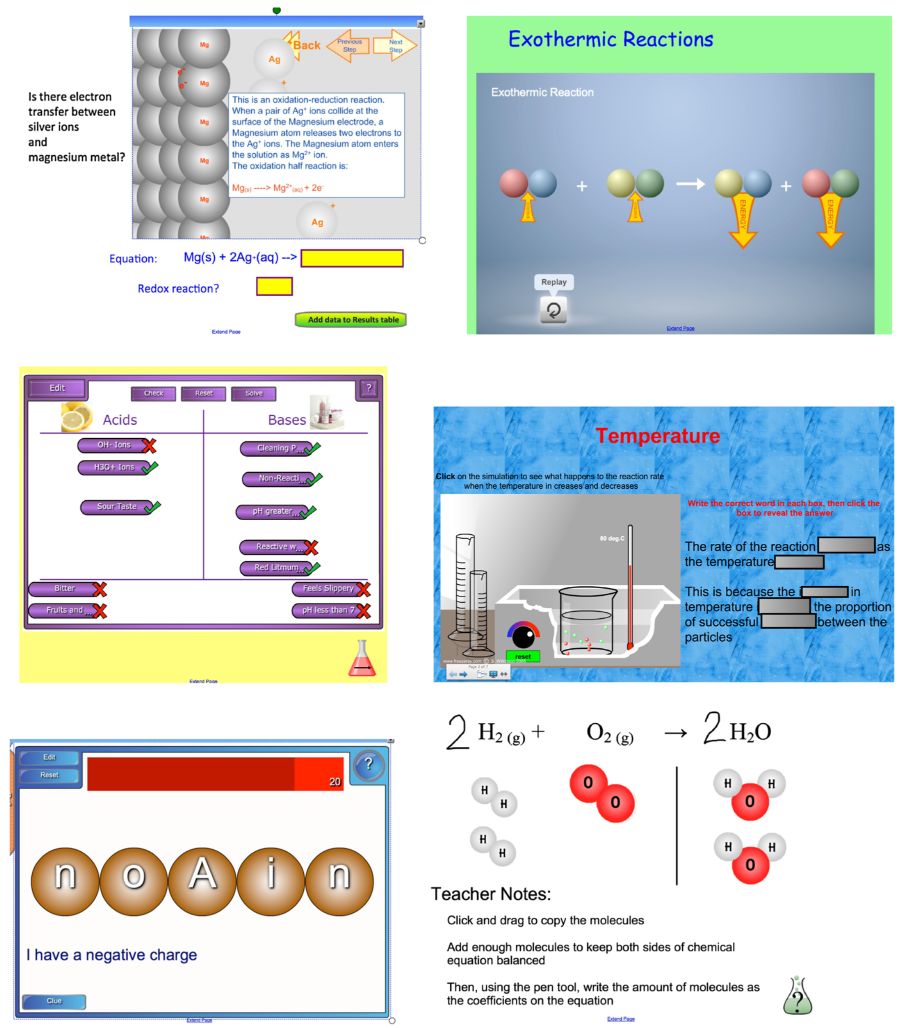

Fig. 2 Sample pages from IWB Teaching Resources—examples of embedded animations and simulations, games, matching templates with correction facility

Many students commented on the time needed to learn new programs. They liked having the set task because it forced them to learn, but they were also frustrated as the learning was not always straightforward. PST described how they searched the Internet for ready-made resources, acknowledging that there were many resources available and it was a matter of being selective and mixing and creating a resource that suited their needs. Another explained how she Googled solutions to problems, for example:

> But now, like I know that I can jump onto the Internet and find another person's smartboard and upload that and use that. So yeah I think now that I know about it it's definitely something I'd use as a teaching tool. (7I)

Table 5 Rubric used in Assignment 2

Criteria	Undeveloped	Developing	Proficient	Exemplary
Clarity of presentation of the teaching idea/resource				
Voice Projection Appropriate Vocabulary Inclusivity of audience Supportive of audience Main points apparent Logical structure Appropriate use of presenting tools	Voice is not projected well Vocabulary is ordinary. No account of prior knowledge No support for audience differences The sequence and structure is not logically presented Method of presentation is not the most appropriate	Voice is decipherable Everyday Vocabulary Little evidence of attempts to include all the audience No obvious structure to presentation Form of presentation satisfactory but not distinctive	Voice is clear Vocabulary includes some appropriate use of science education terminology Attempts to be inclusive of all the audience prior knowledge Logical structure and sequence of presentation Good and appropriate choice of presentation tools/resources	Voice is projected well Vocabulary is professional and appropriate for discussion on science education Inclusive of all the audience differences including prior knowledge Logical structure and sequence of presentation Good and appropriate choice of presentation tools/resources
Quality of presentation of the teaching idea/resource				
Content, purpose Critical evaluation Pedagogical power Quality of presenting tools- e.g. powerpoint, model, demonstration, use of whiteboard etc.	Content—not relevant to teaching science Year 11–12 No critical evaluation of the idea/resource to teaching chemistry Pedagogical power not mentioned Poor quality of presenting tools- e.g. powerpoint, model, demonstration, use of whiteboard etc.	Content—relevant to teaching chemistry Year 11–12 Fair evaluation of the idea/ resource to teaching science Few links to teaching made Satisfactory use of presenting tools Links to Curriculum vague	Content—very relevant to teaching chemistry Year 11–12; Good evaluation of the idea/ resource to chemistry Pedagogical power of the idea/resource to teaching science Quality of presenting tools- good Links to Study Design- accurate and well described	Content –very relevant to teaching chemistry Year 11–12 purpose well described Critical evaluation of the idea/ resource to teaching science Pedagogical power of the idea/resource to teaching science Quality of presenting tools- outstanding Links to Study Design - accurate and detailed

Table 5 continued

Criteria	Undeveloped	Developing	Proficient	Exemplary
Engagement with the class				
Eye contact	Poor eye contact with audience	Fair eye contact with audience	Good eye contact with audience	Good eye contact with audience
Assumptions	Presentation takes no account of the prior knowledge of the audience	Presentation does attempt to takes into account the prior knowledge of the audience	Presentation takes into account the audience's prior knowledge	Good evidence of audience engagement-
Evidence of audience engagement	No challenges for audience	Few challenges presented to audience	Attempts made to challenge audience	Presenters respond well to audience' questions/ comments
Response to audience' questions, feedback	Audience not engaged	Some evidence of audience engagement-questions/comments	Some of audience engagement-questions/ comments	Behaviour of audience—interested, engaged
	No enthusiasm for subject	Presenters try to respond to audience	presenters respond well to audience' questions/ comments	Challenges audience—promotes thinking

Table 6 Excerpt of group 1 shared response about IWB assignment

Adding interactivity into the classroom allows the students to share the experience of learning. It adds another element into the process, and breaks the tedium of simple powerpoint presentation, and text based approaches. Animations, simulations and interactive games allow the teacher to represent ideas and processes which are hard to describe using static images, and by involving the students, allows them to immerse themselves into the content, and make it their own. In my presentation, I designed it with my own students in mind, I knew they were struggling with balancing chemical equations, and they needed another way to visualise the process. I came up with the diagrammatic representation to show how to do this in a visual way. When I tried it out in class, the class became enthusiastic, and there was almost 100 % participation, and the students began to show evidence they were understanding what to do. I'm sure this could be replicated in many different areas of chemistry, and other subjects

> ICT is a necessary tool for modern classroom. If I want to teach effectively, I have to embrace it, and be comfortable using it. If i have trouble, then I can google it for suggested solutions. (S)

While PST did access online resources, they were also mindful of assessing the resource and adapting it to their needs. The comments below by PST provide evidence that they were developing TPACK that included evaluating the appropriateness and suitability of technological resources for the teaching and learning purpose:

> Yeah I reckon the knowledge of using the, like making your own like notebook or whatever it is, is really beneficial because sometimes getting some

off the internet isn't quite what you want in your lesson. And so the ability to make your own is really more creative and … more, fits more into your specific lesson I guess. (7I)

I think there is plenty of content out there but it's probably more the point of there's a lot of content that's probably too specific on a particular subject where they're going into way too much detail and it's sort of one that's been made and then you've got so much you have to alter. (4I)

The future chemistry teachers are approaching lesson planning from a pedagogical position that includes technology, this compares to the more traditional approach where technology is added. A PST explains his position:

I have to teach balancing equation and normally you would think I would be on the board balancing equations, then they just do lot's and lot's of examples. But since the information we've got about technology we'd be looking for videos or for games or for different things that they could use online to do the activity, or you'd create something more interactive using notebook. Or, I think it just causes you to think more outside the box and go out of just writing something on the board, or you giving that example.

All the students interviewed agreed that technology was relevant because it provided greater flexibility, offered a range of teaching resources that could appeal to a diverse range of learning styles, and was aligned with the experiences of the digital native learners. There were some specific references to technology being well suited to explain abstract chemical concepts, for example;

I have critically learned the important of ICT on teaching macro, micro and symbolic representations, of molecules with diagrams and pictures, (S)

Overall learning new technologies was seen as an appropriate and valued part of the curriculum unit, as evidenced by this comment:

The unit has broadened my skills as a teacher and given me the opportunity to learn new skills and open my thinking to new methods of teaching, which I wouldn't have tried before. Now I see the benefit in using IT and have been using it frequently (S)

Technology Available in Schools

The interviewed PST voiced frustration at spending a lot of time learning new hardware and software programs that from their experience were not available in many secondary schools. Individual schools choose technology according to available budgets, teacher requests and the schools preferences, and it could be smartboards, laptops, tablets or i-pads, or none of these and it could be just one or two devices or class sets for the whole school. The other issue is the reliability of technology in schools and the need to plan backup lesson in case the technology fails. The comment below resonates these issues:

> It's just like so obviously you learn the new ways of using technology and so when you're actually on rounds you try to play around with it. They've all got notebooks at the school now and technology, if it doesn't work, it's a massive problem because there's your whole lesson plan gone and you have to go to plan b. And generally at the beginning you just rely on the technology to work, so your plan B's definitely very rushed and it's not really effective because what you're actually, you really are basing it on computer. So I find technology great when it works but there are so many times in the classroom where it doesn't work. (15I)

This comment by a PST demonstrates the different messages being received from university studies and their professional school experiences:

> Yeah and so it also makes it hard talking to a senior to your supervisor that doesn't use PowerPoint, that doesn't use smartboard, that doesn't use any of that technology, and you go to talk to them about integrating some of that technology into your lesson and you basically get told "Oh we don't do that at this school". So I think maybe they're teaching us too much in this unit because that's not in the schools yet, like so where's that line, how do we differentiate between that? So we're getting taught all this fantastic stuff- (14I)

The eight PST in the interview reported that they did try to incorporate technology into their teaching while on professional experience in schools. They used video, PowerPoint, animations, songs, smartboards and clickers (student-response–technology), which shows a diverse suite of technology being available in schools and being used. One PST reported how he provided technical instruction to his supervising teacher:

> I put some video in classes and that worked extremely well and then the teacher I was with, I showed him how to get his u-tube videos and download them separately so he could take them into the class without needing the internet there. And he took that on board and the next few weeks after that he was actually just showing them video after video and thought that was excellent, fantastic. So I think it can work really well when it's in your favour. (7I)

> This comment is significant because it shows that PST can introduce new ideas about technology into schools, but the results are mixed depending on factors such as the existing school cultures, PST skill/confidence level and attitudes and relationships between PST and their supervisors.

Sharing Resources

Using the wikispace as a collaborative and shared online space in Assignment 3 was new to many PST. The PST interviewed acknowledged the value of the wiki because it allowed for the sharing of resources. This appealed to PST as they think about their future teaching and the need to build their repertoire of resources, especially after they left the collaborative university environment, as shown in this comment:

> …Lesson plans that we've all had to do, I know they're assignments, but I think we all take pride in what we write for most of our work and so someone's got to, you know at the end of next year we're out there in the workforce and you're suddenly teaching and you've got to do this concept that you've never taught but Jim's (Pseudonym for PST 4) taught and, or did an assignment on, he chose it as one of his topics and he's got at least a couple of lessons. You could access that sort of stuff and we do that around here, like Jim showed me how to download You-tube videos, I didn't know that. So while we're at uni we're able to share resources, but if we're taught how you use technology to stay in contact and share and continue to keep that community sort of feel. (14I)

All the PST interviewed were keen on this idea of an ongoing network to share resources with comments such as: "*Yeah definitely because what's the point of being one chemistry teacher with one resource, there's so many different ways you can teach, why not share*." *(15I)*. This would need to match the national based curriculum rather than resources on the web. One pre-service teacher explained that the web resources "*wouldn't be relevant to your class*" (11I). The concept of sharing is very consistent with their day-to-day social media experience where sharing is commonplace.

TPACK Framework

When asked about TPACK in the interview in the last week of the teaching period, none of the eight PST interviewed were able to tell the interviewer what the acronym stood for, despite having had a 20-min introduction to it and being available on the university online platform. Despite this, the PST were able to describe the links between pedagogy, technology and content that they used in their teaching and all the PST agreed that technology was equally as important to lesson planning as the content and pedagogy. On the survey, one student described her TPACK knowledge:

> There are many opportunities to incorporate ICT into teaching. However, it is better to start with the subject-matter and then try to maximise learning through the use of ICT, rather than starting from the technology a priori (S)

Being confident to take on new technologies is reflected in this response to the request to "comment on what you have learnt about the use of ICT in your teaching" on the survey:

> It has highlighted that learning to teach is an ongoing, career-life long process. (S)

Discussion

The results show PST using technology effectively and meaningfully in their own learning that would be suitable for their teaching. The design of the tasks required the PST to learn new technologies and apply them to teaching chemistry. The assessment tasks required the PST to evaluate ICT resources (RQ1). Learning new software programs can be tedious and frustrating, but the process of learning one relevant program is worthwhile because it is mastery in itself and it may imprint skills that are transferable when learning other programs. Recognising the inevitability of life-long learning applies particularly to technology due to its dynamic nature. The curriculum studies unit is an appropriate time to broaden the PST technological skill and knowledge base by having assessment tasks that require creating teaching resources as well as interrogating the value and suitability of the technology in a teaching context. It is also appropriate in the curriculum studies unit to learn about TPACK alongside pedagogical content knowledge in the context of teaching chemistry.

For teaching how to teach chemistry the technological tools with attributes such as visualisation, interactivity and simulations particularly suit explaining the abstract nature of chemistry content. The justification provided by PST in presentations of the multimedia tasks and on the wiki in the interactive whiteboard task showed their developing TPACK and PCK since they were mostly able to explain and justify their teaching approach—both in written and verbal forms with respect to the chemistry content, pedagogy and TK.

Shulman (1987) explained that the significant skill in teaching is the application and use of the knowledge base that teachers draw on to provide the reasons for the actions and choices they make in their teaching; Shulman referred to this as pedagogical reasoning and consequent actions. The assessment tasks and professional experiences provide opportunities for the PST to draw on their knowledge bases to justify their professional decision-making. This provided evidence of pedagogical reasoning. So it wasn't important that the PST had not remembered the meaning of the acronym TPACK; rather that they were able to demonstrate the TPACK knowledge base through their resources, actions and comments. The extent to which PST actually used the TPACK framework as a learning tool or an evaluation tool is not clear, but they demonstrated an understanding of the concept of TPACK.

It is contentious whether technological knowledge is a separate domain, equal to "pedagogy" and "content" or a component knowledge—contributing to the PCK, thereby expunging the notion of TPACK. The technological knowledge is presented as a separate domain here because it is distinguishable from content and pedagogical knowledge. The frameworks are invented structures or organisational frames that provide hierarchy and meaning. The PCK and the TPACK frameworks helped to unpack the components of professional practice and also provide a vocabulary for discussion that PST used in their assignments. The educator used the frameworks as checkpoints in planning the assessment tasks to ensure that all knowledge bases were addressed. The role of technology in representing content and influencing the way we teach and the way students learn, means that technology has become a knowledge base in its own right.

The teacher education program described here has intentionally included opportunities for PST to learn new technologies and practice integrating them into teaching resources. The unit design included instruction in chemical contexts that included content, pedagogy and technology perspectives. The assessment tasks provided opportunities for students to demonstrate their creativity and application of these educational ideas. The unit helped the PST to develop skills in critical thinking, reflection, and evaluation alongside the content, pedagogy and technology skills. This approach is based on "constructivist and situated theories" as described by Van Driel & Berry, 2012, p. 27). This opportunity to develop PCK and TPACK knowledge through collaboration, reflection and sharing is similar to results reported by Jang and Chen (2010). These are skills common in many teacher education programs.

Using new technologies in teaching brings with it the risk of mis-using technology or not using technology in a pedagogically effective way—e.g. only using technology as a repository, or using technology because it entertains. So the PST need skills to evaluate the technology for its purpose and, have opportunities to practice this in a learning environment. The two assignment tasks reported here were challenging, but they provided an opportunity for PST to practice developing and evaluating resources. Most PST were able to demonstrate an ability to evaluate technology and demonstrate some competencies of TPACK in both assignment tasks. It is therefore necessary to teach PST to use ICT whether it is available in all schools, because students need experience in learning new technological knowledge and applying it.

In addressing RQ2: *What are PST perceptions of using technology at university and in teaching chemistry in schools?* While the PST interviewed appreciated the technology, some could not see the opportunity of using it in schools in the near future and by the time it is available and reliable, they thought they would need to relearn how to use it. Many teachers are reluctant to depend on technology due to some poor previous outcomes (Hall & Hord, 2001). Schools block some useful online web materials.

In schools, the PST had to work with the technology available, this may differ at different schools, and also differ from that available in university. Some PST voiced frustration at having to learn new technological skills that they considered futile, as they could not see opportunities in schools to use the skills in the near future. This opinion was based on their professional experiences at schools, where some had seen technology ignored by teachers and some had experienced unreliable technology. This undermined the value of the technology focus at university and highlights the need for curriculum studies at university to reflect the way chemistry is taught in the classroom as well as present future technologies. Despite this, *many* PST reported that they had successfully used the available technology in their teaching.

The PST in this study expressed enthusiasm and interest in integrating technology in their teaching and in using technologies such as wikis to share teaching resources. The interview data indicated that they considered it worthwhile, and more than a course requirement. The results demonstrate that the PST had a high level of confidence in using technology in teaching and an ability to evaluate the technology. The experiences provided in the curriculum studies unit is significant in developing the PST attitudes about using technology in teaching in the future. Williams, Foulger, & Wetzel, (2009) report similar gains in confidence after targeted instruction. The particular technologies that are developed should be relevant but more importantly they are designed to develop PST abilities to select appropriate technology and use it effectively in their teaching. As resourcing in schools improves, teachers with confidence and experience are more likely to utilise technologies in their teaching. Teachers confident in using technologies are more likely to help in changing the culture of using technology in schools.

Conclusion

The TPACK framework has been a useful tool for examining the data. Technology is particularly well suited to chemistry because it can provide a range of visual representations that explain abstract chemical ideas. Technologies provide significant tools such as providing explanations, visualisations and feedback. It is important to recognize that the contents of teachers' professional knowledge bases are changing in response to the changing methods of teaching and learning, including changes as a result of new technologies being available. The research showed how PST included technology as part of the lesson preparation and did not add technology on as a later addition. They were receptive to adopt new technology and integrate it in their teaching methodology. These experiences help to build confidence in using technologies and demonstrate that technology skills and knowledge are now an important component of a teachers' professional knowledge base. PST experiences with integrating technology in lesson planning have provided opportunities to develop and use technological skills in a teaching context.

The results present examples of the PST teaching with technologies impacting on existing teacher's practice in schools. This is an important observation and illustrates new ways teaching approaches filter into the current practice. This modelling of practice has the potential to impact on existing teachers' attitudes and culture towards the use of technology.

The research results show that there are still major challenges of how best to prepare future teachers for the diverse technological facilities available in schools. This emanates from the difficulties the PST experienced in schools where the access and use of technological resources varied greatly. It is suggested that curriculum studies at university should focus on technological skills that match those available in schools, so PST are better prepared for their professional experience with regards to the technology. Better communication between schools and universities regarding schools facilities and expectations of technology being used would help to improve the PST experiences with integrating technology into their learning and teaching. In addition, there is a need for universities to introduce PST to new technologies to ensure they are well prepared for future technological opportunities in teaching.

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