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Teachers' Transition into a 1:1 Laptop Environment: A Longitudinal Case Study of Four Science Teachers over 5 Years

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Abstract

This paper is the final in a multi-phase study exploring the impact of 1:1 laptops in Australian high schools since the Digital Education Revolution of 2008. The overall study tracked the deployment and use of the laptops in the sciences in 16 high schools, collecting various data over five years. The research data is drawn together to report on additional in-depth qualitative follow-up interviews with four teachers, specialising in chemistry, physics, biology and senior school science, who participated in every element of the overall study. Thus, a rich description is provided in the form of longitudinal case studies for these four teachers. Transformational shifts in teachers' confidence are evident; and there are substantial differences and changes over time in the ways laptops are used (e.g. spreadsheets, word processing, internet research and simulations). Many of the reported activities involve lower-order skills and thinking and thus present as lost opportunities for higher-order learning. However, the teachers' use is consistent with syllabus requirements which provide few, or in some cases no direction, toward higher-order activities. A recurrent theme from teachers is that students are more confident than their teachers, often making suggestions for activity resources and trouble-shooting. Thus, implementation of the laptops involved renegotiation of the power dynamics of the classroom, and re-invention of the teacher as a facilitator of thinking and independent learning. Further research is needed to examine these shifts, which are not acknowledged in technology education theory; but which undoubtedly have far reaching ramifications for the future of education.

Introduction

This paper is the culmination of an extensive study into the ways 1:1 laptop computers are used by high school teachers and students in the sciences. The previous articles in this study have examined the similarities and differences between how science teachers and students perceived how they used their laptops (Crook, Sharma, Wilson, & Muller, 2013); the types of uses in terms of lower- and higher-order activities (Crook & Sharma, 2013); quantitative analyses to evaluate the impact of 1:1 laptops on student attainment in the sciences (Crook, Sharma, & Wilson, 2015a); and a curriculum analysis of science syllabuses and their technology requirements that help explain the quantitative findings (Crook, Sharma, & Wilson, 2015b). Having previously used a mixed methods approach to analyse responses from science teachers and students, this study now completes the narrative with a longitudinal case study approach examining four teachers who have participated in all elements of this study which saw the introduction of 1:1 laptops to grade 9 students and followed them through to grade 12. Peta was teaching senior high school physics, Cora chemistry, Ben biology and Sue was teaching senior school science for the period of the study, all using the newly acquired laptops. Within this paper detailed case studies of these four science teachers are provided, with analysis of in-depth interviews and questionnaire responses of the teachers and their students over a period of five years. With the saying 'necessity is the mother of invention' in mind, the study seeks to explore the intended and unintended benefits and challenges of unexpected speedy and often unwelcome change–such as that instigated through the Australia's Digital Education Revolution (DER) which drove the introduction of the laptops. The Australian Labor Government rolled out the $2.4 billion DER in 2008, and the program provided a range of ICT initiatives over seven years (including high speed broadband to all schools, new quality digital education tools, and support to increase ICT proficiency among both teachers and students). However the centrepiece of the DER policy was the goal that each Year 9-12 student throughout Australia would have access to his/her own computer, necessitating the purchase and distribution of more than 800,000 laptops nationally. The analysis in this paper focuses on the journey of the teachers through a period of rapid change with the introduction and invigoration of information and communication technology (ICT) in schools as part of the DER and with reports on: (1) teachers' feelings; (2) teachers' comments on changing practices; and (3) teachers' comments on the impact on students. The teachers' creativity, resilience and reactions are captured as they face challenges common throughout much of today's school education sector.

Literature

Teacher and student use of laptops

According to Abbott, Townsend, Johnston-Wilder and Reynolds (2009, p. 31), the potential of laptops is not obvious to every teacher (and consequently, not obvious to every student). In a study of Australian science teachers, Ainley, Eveleigh, Freeman and O'Malley (2010) found teachers have relatively high levels of confidence in their capacity to use ICT compared to those of other countries. Ainley and colleagues also found that higher levels of ICT use are associated with higher self-efficacy, participation in professional development and a lack of perceived obstacles to ICT use within schools (Ainley, et al., 2010). Using a multi-faceted approach to measure teachers' use of technology, Bebell, Russell and O'Dwyer (2004) demonstrated how complicated and varied technology use actually is in schools. Other studies have highlighted several factors, including the amount of professional development time spent out-of-school hours, and openness to change, which have the biggest impact on teachers' success in integrating technology into the classroom (Gerard, Varma, Corliss, & Linn, 2011; Higgins & Spitulnik, 2008; Klieger, Ben-Hur, & Bar-Yossef, 2010; Vannatta & Fordham, 2004). To enhance teacher use of laptops, school leadership must provide access to facilities, professional development, technical support, and organisational and administrative systems (Cowie, Jones, & Harlow, 2011).

Whilst laptops can add value to the teaching and learning process they can also create classroom management problems (Dunleavy, Dexter, & Heinecke, 2007) and can pose a big distraction to students and their peers (Fried, 2008). Research focusing on students' laptop use has found 'non-school related laptop utilization' can pull the attention of the student away from school related goals and result in lower academic satisfaction, semester grade point average, and performance relative to classmate; whereas, 'school related laptop utilization', when the attention of the student is centred on school-related goals, is positively associated with academic satisfaction (Gaudreau, Miranda, & Gareau, 2014). Some research has highlighted the concept of 'hard fun': with access to laptops, teachers have the capacity to offer their students activities that are both challenging and engaging (Berry & Wintle, 2009). Technologies which do not meet student-identified requirements may prove counterproductive or may simply be ignored (Edmunds, Thorpe, & Conole, 2012).

It has been demonstrated by numerous studies that teachers' own beliefs and attitudes about the relevance of technology to students' learning have the biggest impact on their success in integrating technology into the classroom (Ertmer, Ottenbreit-Leftwich, & York, 2006; Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012; Inan & Lowther, 2010; Ottenbreit-Leftwich, Glazewski, Newby, & Ertmer, 2010). It has been suggested that teachers need to change their mindsets to accept the idea that "teaching is not effective without the appropriate use of information and communication technologies (ICT) resources to facilitate student learning" (Ertmer & Ottenbreit-Leftwich, 2010, p. 255). By using more realistic definitions of technology integration to more accurately represent practicing teachers' values and beliefs, professional development can be more targeted thereby increasing the chances of transfer to the classroom (Ottenbreit-Leftwich et al., 2010). Similarly more attention needs to be given to beliefs, attitudes and confidence related to technology use during pre-service teacher education, as these are perceived as being critical to later success in the classroom (Ertmer et al., 2006; Inan & Lowther, 2010).

Within Australia, the findings of the influential study by Ainley and colleagues (2010) confirmed that the use of ICT is greater when teachers have a higher level of confidence in ICT, when teachers have participated in ICT-related professional development, and when there are fewer contextual obstacles (e.g. infrastructure, digital learning resources, access). This study will examine these issues through longitudinal case studies.

Longitudinal case studies

A small handful of studies have explored technology implementation using detailed longitudinal case studies such as those employed here. Over two years, Windschitl and Sahl (2002) used an ethnographic perspective to study how three middle school teachers learned to use technology in the context of a 1:1 laptop computer program. They found that 1:1 laptops were a catalyst that enabled a dissatisfied teacher using teacher-centred practices, to transform her pedagogy to become more student-centred through collaborative student work and project-based learning.

In a later longitudinal case study over three semesters, Khan (2010) examined how an experienced science teacher taught chemistry with computer simulations and the impact of this on his teaching and students. Using classroom observations, teacher interviews and student surveys, Khan "revealed a pedagogy of teaching science with computer simulations" (Khan, 2010, p. 228). Khan found that by generating, evaluating, and modifying student ideas with the full integration of computer simulation technology, teachers were able to help students to "critically analyse a problem, make unobservable processes more explicit, and contribute to their science learning in ways that go beyond textbooks" (Khan, 2010, p. 228).

More recently, Zheng, Warschauer, Hwang and Collins (2014) performed a year-long, quasi-experimental study investigating the impact of the use of notebook computers and interactive science software in fifth-grade. Conducting classroom observations, teacher and student interviews and analysing examination scores, Zheng and colleagues found that "technology-facilitated science instruction is beneficial for improving at-risk students' science achievement, scaffolding students' scientific understanding, and strengthening students' motivation to pursue STEM-related careers" (Zheng et al., 2014, p. 591).

These studies illustrate the potential of in-depth qualitative data to contribute insights into the dynamics of technology implementation that may not have been anticipated, nor captured, by more structured quantitative data collection. The longitudinal aspect of the research, for example, is particularly useful in developing the rapport necessary to evoke full and frank accounts from the participating teachers and students. Thus as part of a larger project examining laptop use, the qualitative and quantitative data is now drawn together to make a further contribution to our understanding of technology implementation in schools.

Method

In this five-year-long study, teachers and students participated in online surveys and gave permission for examination data to be used in investigating facets of the introduction of 1:1 laptops. These results were presented elsewhere (Crook et al., 2013; Crook & Sharma, 2013; Crook et al., 2015a, 2015b). The missing link was the trials and tribulations of the teachers which this paper now presents. A broad initial research question was posited:

RQ1. What are science teacher's experiences of the implementation of the 1:1 laptops in schools?

In exploring this question in the case studies, two more focused research questions to examine change and impact were considered:

RQ2. How do teachers report on their change in laptop use and associated pedagogy, over the five-year period?

RQ3. What are teachers' perspectives of the impact of 1:1 laptops on overall student study habits and performance in the sciences?

For this study, a mixed methods case study approach was selected (Yin, 2012). Participants were drawn from teachers who had participated in all elements of the study and who were also teaching grade 9 to grade 12 science subjects during the period of this study. In Australia, most science teachers teach grades 7 to 10 science, which is compulsory for students, and specialise in one or more optional grade 11/12 subjects. Teachers for this study were selected on the basis of two criteria: that they had participated in and provided complete data on all of the research phases of the overarching study; and that they represented teachers in each of the four major science subjects taught in grade 12 (Physics, Chemistry, Biology and Senior Science [multidisciplinary]). Four teachers who met the criteria were identified and each was teaching a different science subject: Peta was teaching senior high school physics; Cora chemistry; Ben biology; and Sue was teaching Senior Science. These four teachers presented the basis for the four case studies which provide a rich and insightful description of the use of 1:1 laptops in high school science.

Two data sources were used: first, questionnaires regarding the 1:1 laptop use in science, were completed by teachers and their students at different time intervals; and second, interviews with the teachers were conducted.

Questionnaires

In August and September 2010, 18 months after the students involved in this study had been issued with laptops (see Figure 1), the teachers were asked to complete online questionnaires. The online questionnaires were administered via *Google Doc Forms* for ease, efficiency, security (then 128-bit encryption), and minimising any errors due to transcription. Similarly, in August and September 2012, prior to the students sitting their state-wide external *Higher School Certificate* (HSC) examinations, the teachers were asked to again complete an identical online questionnaire to allow for longitudinal study. An analysis of items on the questionnaire comparing student and teacher perceptions of practices using the 1:1 laptops can be found in the first paper of this study (Crook, Sharma, Wilson, & Muller, 2013).

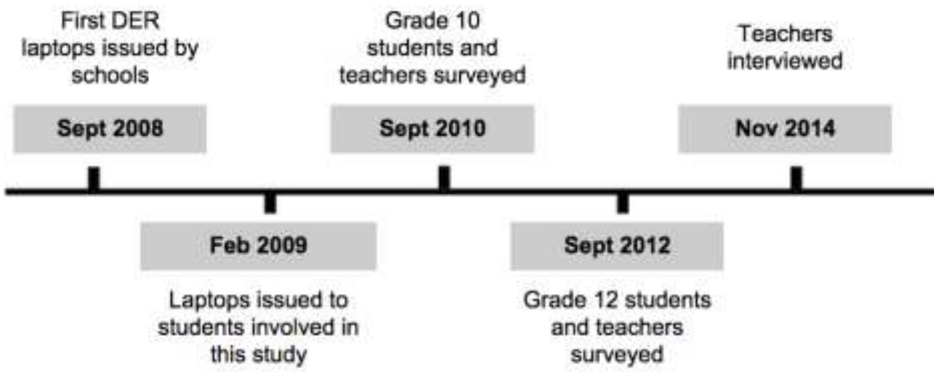

Figure 1: Timeline for this study

The questionnaire items used in this study were identical for the purpose of comparing teachers and students and focused around the nature and level of technology use in the classroom. The following list of activities/applications, that teachers may choose to employ in their classrooms, was provided for them to select using a tick-box list: word processing (e.g. Word, Pages); spreadsheets (e.g. Excel, Numbers); presentations (e.g. PowerPoint, Keynote); simulations; science software; textbook resources (e.g. CD, online). wikis/Nings/Google site; blogs; internet research; learning management system (MyClasses); video-editing (e.g. Windows Movie Maker, iMovie); podcasting (e.g. Audacity, Garageband); databases; email; data logging.

Interviews

Each of the four teachers was invited to a semi-structured interview to elaborate on their experiences of teaching science with 1:1 laptops and how that had evolved for them over time. The interview questions were:

(1) Thinking back to 2008, how did you feel *when you heard* that every grade 9 student was going to be issued with his or her own laptop?

(2) How did you feel *when you were issued* with your own laptop? Can you remember how confident or not you felt about using a laptop yourself, and in your classroom, back then?

(3) How confident do you feel *now* in using a laptop yourself, and in your classroom?

(4) How has your teaching of grade 10 and grade 12 with laptops *changed over time*? How would you compare your teaching of grade 10 with grade 12 regarding the use of laptops?

(5) Could you expand on your answers regarding *specific technologies* such as word processing, spreadsheets, presentations, simulations, science software, internet research, electronic textbooks, wikis, blogs, email, databases, data logging, video editing, podcasting and the LMS (learning management system)?

(6) Why do you think there is a *difference in your approach* to integrating laptops in grade 10 and grade 12? How familiar are you with the syllabus requirements for the use of technology in grades 10 and 12 sciences?

(7) Finally, how do you feel one-to-one laptops have *impacted on students'* study and overall performance in the sciences?

Analysis

In response to *Teacher Q6* it was possible to identify for each teacher the ICT activities/applications the teacher had used in 2010 and in 2012 with a binary coding of Y representing yes, they did use it, and N if they did not use it. From responses to *Student (Q6)* the percentage of students from that teachers' class in that year who had indicated that they used the ICT activities/applications was calculated. Thus, we extracted whether or not the teacher had indicated that they used each ICT activity/application and the percentage of students from that class who reported using it in their class. These data are presented in Tables 2 to 6.

Interviews were subject to narrative analysis with the transcript data deconstructed and rearranged in temporal order, so that for each case verbatim data was organised with responses relating to a 'pre-laptop period'; to a 'during laptop use'; and 'post-implementation reflections'. In this way the data was organised to reflect each case's journey over the implementation of the laptops. Data was also sorted into the category 'laptop issues' which included any comments on challenges. These categories were further sorted and coded according to a series of inductive codes, which emerged directly out of the transcripts. The emerging codes were: (1) teachers' feelings; (2) comments on changing practice; and (3) comments on the impact of laptops on students.

Comment on the syllabuses and professional development

Before continuing it is important to note the context in which the teachers were operating, in particular, the state-wide syllabus documents which teachers adhere to and the professional development opportunities available. Furthermore, an analysis of the curriculum documents has the potential to shed some light on the approaches and practices reported by the teachers in the case studies. Table 1 captures broadly the instances in the syllabuses (Board of Studies NSW, 2009) when ICT and its use is referred to.

While the senior syllabuses had identical guidelines on the integration of technology in the *course structure*, *skills-conducting investigations*, *key competencies* and *domain: skills* (see Table1), only physics and chemistry had specific mentions in *domain: knowledge and understanding* (the mandated content and suggested activities) regarding the use of technology, particularly physics. The physics and chemistry requirements line up with higher-order thinking as outlined in the second paper of this study (Crook & Sharma, 2013).

The implementation of laptops was rapid and there were few subject-related professional development opportunities. The schools participating in this study had generic opportunities presented to them and onsite help was available to schools. However, there was minimal professional development to help with integrating the laptops with consideration of any technological pedagogical content knowledge (TPACK) and certainly no explicit unpacking of TPACK (Crook, Sharma, & Wilson, 2015b).

Table 1: References to technology in Board of Studies NSW HSC Science Syllabuses

Section	Nature of reference to ICT
Course structure	Practical experiences should emphasise hands-on activities, including, … appropriate computer-based technologies, … internet and digital technologies, … computer simulations, … animation …
Skills–conducting investigations	… using a variety of technologies …
Key competencies	… using technology
Domain skills	... appropriate technology or strategy for data collection, … identifying technology, … employing appropriate technologies; including data loggers and sensors, … digital technologies and the Internet, computer assisted analysis
Domain knowledge & understanding	In Physics: Eight specific mentions of the use of technology: two mandating the use of simulations (along with data loggers and computer analysis in one instance); two suggesting the use of simulations; three suggesting a generic use of technology e.g. *alternate computer technology* (usually best achieved with simulations e.g. replicating a cathode ray oscilloscope); and one recommending data logging. In Chemistry: Four specific mentions of the use of technology: one mandating the use of computer-based technologies to perform a first-hand investigation; and three suggesting the use of simulations/digital technologies as possible secondary sources. In Biology: No reference In Senior Science: No reference

Results

The data relating to each teacher was compiled and is presented: firstly, with a summary table and discussion around the teachers' reported laptop use for lower-order thinking ICT activities/applications such as word processing and email (drawing on questionnaire data); and secondly, with a detailed description of each case study teacher. Each detailed description contains a brief glimpse of the teacher, their school and their networking. This is followed by a summary table and discussion around the teachers' reported laptop use of higher-order ICT activities/applications such as simulations and spreadsheets (drawing on questionnaire data), integrated with the teachers' reflections on the use of laptops over five years (drawing primarily on interview data).

Laptop use for lower-order thinking activities/applications

Table 2 displays six ICT activities/applications by teacher/class for activities which are generally linked with *lower-order thinking* (Crook & Sharma, 2013). The Y and N denote whether or not the teacher engaged in the activity with that class. The percentages are of the proportion of students within that teachers' class who reported engaging in those activities in their classes. These are *standard* ICT applications one would expect to be used, and indeed they are largely being used but to different extents. Amongst these four teachers, LMS is least popular while word processing is most popular.

Table 2: Six *lower-order thinking* activities/applications used by teacher and percentage of students in class reporting the use of this activity/application.

Activity	Word processing	Electronic textbook	Internet research	Presentations	LMS	Email
Cora 2010	Y-100%	Y-42%	Y-83%	Y-17%	N-0%	Y-75%
Cora 2012	Y-95%	Y-74%	Y-74%	Y-21%	N-5%	Y-74%
Peta 2010	Y-100%	Y-79%	Y-96%	Y-83%	Y-42%	Y-42%
Peta 2012	Y-78%	Y-78%	Y-89%	Y-89%	N-0%	Y-78%
Sue 2010	Y-89%	N-44%	Y-78%	Y-67%	Y-56%	N-56%
Sue 2012	Y-100%	Y-58%	Y-84%	Y-58%	N-42%	Y-63%
Ben 2010	Y-85%	Y-85%	Y-100%	Y-23%	Y-62%	Y-15%
Ben 2012	Y-100%	Y-85%	Y-85%	Y-54%	N-46%	N-69%

(Y=yes used/N=not used)

Comparing across the four teachers and their classes, notable observations include that word processing, internet research and electronic textbooks are consistently reported highly amongst the four teachers' classes, both during grade 10 general science and later when they were more settled into using laptops during grade 12 HSC sciences. Also, apart from Cora, an increase in the use of email is noted. The use of LMS and presentations are more ad hoc with no clear patterns. These findings are consistent with a study of pre-service science teachers in Western Australia, where Dawson (2007) found that the most frequent uses of ICT were word processing, Internet research, email, and both teacher and student presentations. The use of laptops for higher-order thinking is discussed in the detailed description for each teacher. Noted below is what stands out for each teacher; summarising lower-order use for each teacher:

- Cora historically communicates via email and has not taken up LMS. She does not use ICT for her presentations very often. Her use of electronic textbook has increased.
- Peta historically has high use of ICT for her presentations to students, in fact the highest. She was using LMS and has changed to communicating via emails.
- Sue is lowest with using an electronic textbook. Over time, Sue uses LMS less and email more but both changes are to small degrees.
- Ben has increased his use of ICT for presentations. He says he does not use LMS and emails, but his students report that he does so.

In short, each teacher has their particular preferences although they do change their approaches and practices. We note there are instances of teachers saying they are not using activities/ applications although a proportion of their students indicate they are. However, there are no cases of the reverse happening. The changes in these teachers' approaches and practices were different, possibly nuanced to their contexts, and further explored in the case studies below.

Case descriptions

Analysis of all the teachers' responses to the interview questions focuses on the categories that emerged: (1) teachers' feelings; (2) comments on changing practice; and (3) comments on the impact on students. These provided a framework for reporting the individual experiences of the case study teachers.

Chemistry: Cora

Cora is a Singaporean-Australian female grade 10 science and grade 12 chemistry teacher in her fifties, with 24 years' teaching experience. She teaches at a large grade 7-12 girls' school in a low-socioeconomic area of southwestern Sydney. In 2010, Cora taught a mixed-ability grade 10 science class while in 2012, she taught a mixed-ability grade 12 chemistry class. Cora has strong connections with her peers and actively works with other coordinators across disciplines in the local regional area. Cora considers herself a leader, taking ownership of her own professional learning and that of her colleagues.

Already a very experienced science teacher, Cora arrived at her school in 2010 as science coordinator (in the first year of data collection). Having just moved from a high socioeconomic school to a low socioeconomic school she noticed a big difference between the schools in terms of technology. Cora said that her previous school had "*really integrated technology*" whereas her new school was "*quite behind*", and even though the teachers were each issued with a laptop "*they never brought it to school*". There was still a lot of angst that the school had moved from PC to Mac, and she "*worried about the professional development of [herself] as a leader, and of the teachers*". However, Cora emphasised that by 2014 this situation had very much changed.

Cora described herself as an early adopter having previously purchased her own laptop, prior to teachers receiving them at her last school, to familiarise herself and her colleagues ahead of time. As such, she felt "*pretty confident*" about using a laptop in 2010 although she had to relearn how to use a Mac. However, she was not so confident about teaching students with their own laptops, largely due to the unreliability of the internet at the time: "*interactivity was very minimal because I always had to second guess when the internet was working*". Internet connectivity was important for Cora. Tables 3a and b below show the students' reported use of the activities/applications in Cora's classes. We note that Cora's students' reported use of wikis went from 0 in 2010 to 84% in 2012, the highest rate of use amongst the teachers.

Table 3: Nine *higher-order thinking* activities/applications used by Cora and percentage of students in class reporting this use.

Table 3a: The more science specific higher-order thinking activities/applications.

Activity	Spread sheets	Simulations	Science software	Databases	Data logging
Cora 2010	Y-17%	Y-8%	N-8%	N-0%	N-0%
Cora 2012	Y-32%	Y-5%	Y-11%	Y-0%	N-0%

(Y=yes used /N=not used)

Table 3b: Higher-order thinking activities/applications involving knowledge creation.

Activity	Wiki	Blogs	Video editing	Podcasting
Cora 2010	N-0%	N-8%	N-0%	N-8%
Cora 2012	Y-84%	N-11%	Y-5%	N-0%

(Y=yes used/N=not used)

In terms of teaching grade 10 science with 1:1 laptops, Cora described how in 2010 she mainly used her laptop for PowerPoint and preparing worksheets. However, in 2014, she hosted all of the work online on Google Sites "*where students can move ahead*" i.e. allowing for self-paced differentiation. Her workload has increased substantially because the students "*know that I access it, so communication both ways has increased so much that we are putting stuff up and constantly having to look at it*". Cora reported a shift in communication, commenting that with:

> *…greater interactivity, collaboration ... you know, kids used to wait until they talked to me, and now it's constant, we're talking things through, and they are talking with each other as well*.

Cora considers herself more "*as a facilitator; it's not always teacher-centred ... the talking time to the class has reduced, the working time has increased*". She put this change down to a combination of better wireless infrastructure over time, plus a constant push by school leadership to integrate the laptops in teaching and learning.

Cora reported mixed feelings prior to the 1:1 implementation. Although she had high levels of confidence, she was worried about her own and other teachers' level of professional development support and was also concerned about technical issues like the shift to Mac. During implementation she reported a high level of excitement and commented that "*our whole philosophy has changed*". She felt that students were highly engaged with the technology and spurred her on. She maintains her enthusiasm, but reports that her workload has increased, with for example, setting up her own YouTube channel with supplementary materials and the increased level of communication with students.

Initially Cora noted that there were barriers to accessing technology for the students, but these were resolved by the end of the study. She was less certain of the impact of the laptops on her grade 10 class than she was of her grade 11/12 chemistry classes. She reported that the technology made the grade 12 class "*more accountable*" (she was accessing students' personal work folders online to review their work) and enabled students to be more independent learners.

Physics: Peta

Peta is a Middle Eastern-Australian grade 10 science and grade 12 physics teacher in her forties. She works in a large girls' grade 7-12 school in a low-socioeconomic area of southwestern Sydney. In 2010, Peta taught the high-ability streams in grade 10 science and her students performed, on average, more than one standard deviation ahead of the others in the school. Peta has a well-established disciplinary network of colleagues in the science departments of other schools.

Peta had moved to the school just prior to the DER. Immediately she noticed a stronger focus on technology than her previous school and she expressed some trepidation: "*oh my god; I cannot teach with technology*". She said she was happy to hear about the student 1:1 laptop initiative because it would give her a chance to orientate to the technology alongside the students, enabling her to "*socialise with them through this particular technology, not only in the classroom but at home as well*". However, Peta initially lacked confidence in employing the laptops pedagogically, and she requested support for lessons using simulations. Her direct approach in asking for support helped her develop confidence and she rated herself as highly confident in the final phase of the research.

Table 4: Nine *higher-order thinking* activities/applications used by Peta and percentage of students in class reporting this use.

Table 4a: The more science specific higher-order thinking activities/applications.

Activity	**Spread sheets**	**Simulations**	**Science software**	**Databases**	**Data logging**
Peta 2010	Y-42%	Y-25%	Y-29%	N-8%	Y-8%
Peta 2012	Y-0%	Y-56%	Y-22%	Y-0%	N-0%

(Y=yes used/ N=not used)

Table 4b: Higher-order thinking activities/applications involving knowledge creation.

Activity	**Wiki**	**Blogs**	**Video editing**	**Podcasting**
Peta 2010	Y-25%	N-4%	N-8%	Y-29%
Peta 2012	Y-78%	Y-11%	N-0%	Y-22%

(Y=yes used /N=not used)

Over two years, Peta's students reported a decrease in the use of word processing (100%→78%) and the LMS (42%→0%) (as shown in Table 2), a dramatic reduction in the use of spreadsheets (42%→0%), but large increases in the use of simulations (25%→56%), wikis (25%→78%) and email (42%→78%). Peta explained: "*I asked them to …go to Wikispaces and start using the extra resources or additional secondary resources [the] app provided them*". It is also interesting to note the increased use of email with older students. Interestingly, Peta is the only teacher from the four who uses podcasting.

Peta teaches physics and there were eight specific references to the use of technology in the syllabus for grade 12 taught in 2012, as stated in Table 1. The syllabus has two instances mandating the use of simulations which Peta has adhered to, and her students also reported the use of simulations. However, Peta does not use data loggers even though there were instances requiring the use of data loggers or similar technologies. As with Cora, Peta reported that the laptops had enabled better communication with students outside of the classroom. In the interview Peta also described how her use of technology had diversified (using Mac, iPad; and Edmodo and Skype when she had to travel, but still teach). She had a clear trajectory of growth in skills and confidence, such that she "*asked to be in charge of a group to help other teachers and students*".

Peta did not think there was any direct impact of the technology upon her students' performance. She noted their high levels of skill with technology, but did not attribute this to school experiences. Rather she reports a shift in the power dynamics of the classroom (and beyond); where initially she wanted to maintain control she later came to understand that the technology enabled student independence and that she has to concede some control to them and their superior skills in accessing and navigating the technology.

Senior science: Sue

Sue is an Anglo-Celtic-Australian female teacher in her fifties. She had been teaching for 14 years at the time of the interviews and is a very proactive participant in the science teacher professional body. She was active in teacher networks state-wide and nationally. Sue teaches in a large coeducational grade 7-12 school in a low-socioeconomic area of southwestern Sydney. In 2010, Sue taught a low-ability grade 10 science class and in 2012 she taught a mixed-ability grade 12 HSC Senior Science class.

Table 5: Nine *higher-order thinking* activities/applications used by Sue and percentage of students in class reporting this use.

Table 5a: The more science specific higher-order thinking activities/applications

Activity	**Spread sheets**	**Simulations**	**Science software**	**Databases**	**Data logging**
Sue 2010	Y-78%	N-22%	N-44%	Y-78%	N-11%
Sue 2012	N-42%	Y-16%	N-26%	N-0%	N-5%

(Y=yes used /N=not used)

Table 5b: Higher-order thinking activities/applications involving knowledge creation.

Activity	**Wiki**	**Blogs**	**Video editing**	**Podcasting**
Sue 2010	Y-78%	N-22%	N-22%	N-11%
Sue 2012	N-26%	N-16%	N-5%	N-0%

(Y=yes used /N=not used)

Over two years, Sue's students reported a decreased use of spreadsheets (78%→42%), science software (42%→26%), LMS (56%→42%) and video editing (22%→5%); a dramatic decrease in wikis (78%→26%) and databases (78%→0%); and an increase in the use of electronic textbooks (44%→58%). The highest reported laptop use for Sue is the 78% of students in 2010 that reported using databases. Even though databases were a mandatory part of the grade 10 science curriculum, very few teachers or students reported engaging with them as reported in previous research of the same district of schools (Crook & Sharma, 2013). However, perhaps due to her role in the science teachers' professional body, she bucks this trend dramatically. Either way, databases did not feature at all in 2012. Sue reported an increased use of simulations by 2012, but the opposite was reported by her students.

Prior to the introduction of the laptops, Sue felt *"a little bit apprehensive, but I did think that it could be valuable"*. She expressed mixed feelings in relation to monitoring and regulating laptop use in the classroom, but enthusiasm and excitement at the resources available through the laptops. Sue considers herself computer savvy and had *"no issue"* with confidence when using technology. Reflecting on the change in her practice over the period, she commented that:

> *…teaching still needs conversations, you can't just read and hope to learn. There still needs to be a teacher to have a relationship. I think a lot of teachers just use them as substitution, a word processor; so they're not developing science skills, they just cram science content.*

She realised that for students the teacher *"can really drive their motivation"*. Thus, Sue's comments reflected an adaption to the use of the laptop and technology tools, which acknowledged that central elements of the student-teacher relationship were unchanged, immutable.

Sue was positive in her estimation of the laptop effect upon her pupils. She believed that her low-ability grade 10 class had benefited from the learning around spreadsheet use and that, more broadly, the laptops provided *"opportunities to model higher-order stuff and skills … I've taught Year 9s to annotate PowerPoint notes at the bottom; teaching them those skills."*

Biology: Ben

Ben is an Anglo-Celtic-Australian, male, grade 10 science and grade 12 biology teacher in his mid-fifties with 33 years' teaching experience. Ben works in a large coeducational grade 7-12 school in a low-socioeconomic area of southwestern Sydney. Ben taught low-ability streamed grade 10 classes and mixed ability biology classes.

Over the two years Ben's students reported a decreased use of simulations (15%→0%), science software (23%→8%), wikis (31%→15%), internet research (100%→85%), and the LMS (62%→46%); but an increase in word processing (85%→100%), presentations (23%→54%), video editing (0%→15%), databases (0%→23%); and a dramatic increase in email (15%→69%) (see Table 2).

Table 6: Nine *higher-order thinking* activities/applications used by Ben and percentage of students in class reporting this use.

Table 6a: The more science specific higher-order thinking activities/applications

Activity	Spread sheets	Simulations	Science software	Databases	Data logging
Ben 2010	N-8%	N-15%	Y-23%	N-0%	N-0%
Ben 2012	N-15%	Y-0%	N-8%	N-23%	N-0%

(Y=yes used /N=not used)

Table 6b: Higher-order thinking activities/applications involving knowledge creation.

Activity	Wiki	Blogs	Video editing	Podcasting
Ben 2010	Y-31%	N-15%	N-0%	N-0%
Ben 2012	N-15%	N-8%	N-15%	N-0%

(Y=yes used /N=not used)

Ben reported never taking his laptop to class in 2010 but always doing so by 2012. This may go some way to explain some of the increased use of laptops in his class two years later.

At the outset, Ben reported being fairly confident regarding the laptop implementation, despite also saying "*I was definitely not an expert in any way and I'm still not*". Like some of the others, Ben's early expectations of what could be done with the laptops transformed substantially over the period:

> *I was expecting to use it as something on the side … now in real time I'm typing away and I Google; what I'm typing goes up on the screen and to the kids' laptops; I'm quite in awe of what it's doing*.

Similarly, he expressed awe at the students' capabilities with technology. He describes a particular class as follows:

> *… it was quite a low ability class and the first day they arrived with this thing [laptop] and they wanted to use it. It was clear that they were excited to use it and it was very much a matter of on the spot adapting to what was going on. That's how I felt about it. I had ideas before they walked in and they changed those ideas*.

He elaborated on using technology to motivate low-ability students and spoke of how he was also motivated to use the laptop because the students were excited about them. This enthusiasm from both students and their teacher was not based solely on novelty, as Ben reported ongoing enthusiasm for how the technology could help organise his students and his own work. He commented:

> *…it's quite amazing and they had it in their pocket and they could record video, they could put scales and …. they knew how to Bluetooth it. I'm still not an expert Bluetoothing*.

However, the reported enthusiasm for ICT was not always clearly matched with levels of use reported by students. While teachers, like Ben and Cora, were positive in their discussion around ICT, their students reported relatively low levels of use in their classrooms.

Cross-case comparison and discussion

In this section, a comparison is made between the teachers for each of the research questions. While the teacher's use of laptops was investigated during this study, it must be remembered that, being longitudinal, the study garners reflections as students go from grade 10 to grade 12 which culminates in a high stakes examination. During analysis it was revealed that teachers' experiences (RQ1) are largely affected by this. From the analysis of the interview data, the shift in working with grade 10 to grade 12 students did not overshadow the reflections on use of ICT. The teachers focused on use of ICT, even though the interview had two questions on experiences with grade 10 and 12 students - questions 4 and 6.

RQ1. What are science teacher's experiences of the implementation of the 1:1 laptops in schools?

From the survey data, it was possible to obtain a glimpse of the experiences of teachers and students via their self-reported use of ICT activities/applications in their classrooms. From Table 2 we see that, from amongst the standard ICT activities/applications associated with lower-order thinking, word processing and internet research are the only functions which all teachers indicated they used and more than 70% of their students also say they used. While all teachers specify that they used ICT for their own presentations, for Cora and Ben smaller percentages of students verify their use of them. In terms of communicating between teachers and students, interestingly, the use of LMS dwindled and none of the teachers said that they were using LMS in 2012. It should be noted that during this time the schools in question started to migrate from the incumbent LMS, MyClasses, to mostly Google Sites or wiki servers instead. Even amongst students, the use of LMS was reported as the lowest. Email appears to have been more popular than LMS for communications. Ben was the only teacher who indicated that he did not use emails in 2012, although 69% of his students indicated that they did. A possible reason for this is that the increased use of emails with students implies increased out-of-classroom communication. It is important to note that the 2010 data were about practices for and with grade 10 students and the 2012 with grade 12 students. Consequently, the increased maturity of the students in grade 12, and the immense importance to their futures of the HSC examinations, may account for the increase in email use.

When considering ICT applications associated with higher-order thinking and science specific applications, it is important to recognise that with the pressure of external examinations in 2012, teachers may not have been as adventurous. Peta was the most adventurous, using wikis, simulations, science software, podcasting and blogs, and her students reported using these in their classrooms in both 2010 and 2012. Peta adhered to the use of simulations mandated in the syllabus, but not the use of data loggers. Cora used spreadsheets and simulations in both years and showed a dramatic increase in the use of wikis. The sharp increase in the use of wikis (and the dramatic decrease in using a LMS) can be associated with her school acquiring wiki servers between 2010 and 2012; many schools invested in wiki servers to store and share materials remotely with students. Sue was reserved in that she indicated that she was not using ICT activities/applications, but her students indicated that she did. In fact, from amongst the four teachers, she had the largest percentage of students reporting the use of spreadsheets, science software, and data logging. Her students' use of these higher-order and science specific applications was impressive in 2010 and 2012. Ben was most reserved, although again there were some contradictions, with instances of Ben saying he did not use activities/applications while some of his students reported that he did, for example with spreadsheets, simulations and databases. The percentage of Ben's students reporting using databases was the best amongst the teachers. There is the possibility that like Sue and Ben, as teachers become more accustomed to using ICT technology, it becomes more of their normal practice and they report not using it when they are. This may mask the level at which ICT has actually been embedded into the system; a direct consequence of forcing the implementation of ICT through the DER. Nevertheless, it should be noted that adventurous teachers like Cora and Peta are exploring the cutting-edge novel applications, while reserved teachers like Sue and Ben are selective in using higher-order thinking and science specific applications.

Overall, the teachers were confident with laptop use, albeit with some concerns. Sue was concerned about dynamics in the classroom. Ben expressed not being an expert, but was comfortable that he would be able to adjust. Cora was concerned about her colleagues and maintaining consistency in use, while Peta was looking forward to increased communications with students. All of the teachers noted student enthusiasm for the laptops and that this lifted their own motivation for their use.

What can be seen is that the use of laptops in different activities (e.g. spreadsheets, word processing, internet research and simulations) shows haphazard shifts over time and is substantially different between the case studies. This may be related to different curricular demands; the syllabus for physics mandating two uses of simulations and suggesting two more, while chemistry suggesting two uses of simulations and biology and Senior Science making no suggestion of ICT use within knowledge and understanding contexts.

RQ2. How do teachers report their change in laptop use, and associated pedagogy, over the five years?

All teachers reported high levels of technical ability among their students. Notably, there were no reports of students struggling with the technology. Rather, the report of struggles and confidence related to teachers. Some of the teachers realised that the use of technology provided students with more independent learning opportunities. They reflected on the shift in power dynamics between the teacher and students that this necessitated. In the classroom, the teacher was no longer the sole provider of information, indeed students' access to information sources was now beyond teacher control; and some had to renegotiate their authority in terms of vetting information sources for the students. Others reported that students' technological expertise meant that students identified new sources of information and resources and provided these for the teacher and class. In essence, there was a shift in teachers' and students' roles as illustrated in the following comments:

> Cora: *They are more independent learners and they realise that it's important.*
>
> Peta: *To be honest at the beginning I resisted a little bit allowing students to be self-learners. At the moment I am more open to the idea that students actually can do it by themselves and I am guiding their learning.*
>
> Sue: *I've got these kids where I need them to be. They're understanding what learning is about.*
>
> Ben: *They [students] seem to be able to transfer the information; I was learning with them. I know that teaching is to learn with your students and be prepared to jump in areas where you don't know.*

Thus, most of the teachers describe a shift in their role to becoming more facilitative of independent learning (Story, 1985). Biesta notes this is a shift in educational philosophy which he describes as the "learnification" of education, with "redefinition of teaching as the facilitation of learning and of education as the provision of learning opportunities or learning experiences" (2009, p. 37). Only one teacher, Sue, commented on how the technology could be applied to promote higher-order thinking. For the others, their role as facilitators relates more to the development of skills. However, the literature suggests that some technologies, like simulations, are able to convey abstract concepts and help student to develop higher-order thinking (Huppert, Lomask, & Lazarowitz, 2002; Khan, 2010). This may also relate to the level of direction provided in each of the science subjects' curricula.

RQ3. What are teachers' perspectives on the impact of 1:1 laptops on overall student study habits and performances in the sciences?

There were more divergent responses from teachers in relation to this question. Cora was not sure about the impact on grade 10, but stated that laptops made grade 12 students more accountable. Peta was not sure about the impact of laptops beyond what was said above. Sue was positive and believed that her low-ability grade 10 class had benefited from the learning around spreadsheet use and that, more broadly, the laptops provided *"opportunities to model higher-order stuff and skills*". Ben spoke about impact beyond the classroom:

> *I encourage the kids to talk to parents, show them what you saw. Your parents probably want to know ... show them what you did in science, show them the video.*

Teacher's comments in relation to the impact on students were surprisingly tempered, with few direct claims. What was evident was their acknowledgement that the students were confident with using the laptops, often making suggestions for activity resources and trouble-shooting. Some went as far as to admit these were more related to students' experiences beyond the classroom. Here again, teachers described a reorientation of the education process, with a shift in power dynamics and re-invention of the teacher as a facilitator of thinking and learning.

Conclusion

In summary, the four teachers shared their trials and tribulations and have been on a steep learning journey with the rapid and ad hoc implementation of laptops in 2008 and 2009. They have adapted to the use of laptops and learnt *from* their students as well as *with* their students. The findings show a transformation in teacher stances; varied use of laptops and teacher comments reflect a reorientation of the teacher-student relationship through the technology.

As students and teachers adapt to new technologies, they will continue to disrupt and transform many dimensions of the educational process and in so doing, also challenge our conceptions of what education is and how it might best be achieved. This paper makes a contribution by providing commentary on transformations that are occurring at the classroom level. While embedded in a larger study, we examined four cases and make no claims as to generalisability. Further research providing teachers' and students' first-hand accounts of technology transformations is needed if we are to optimise the benefits of technology in education.

It is interesting to note that, at a grass roots level, the case study teachers acknowledge the shifts in their work towards 'facilitators of learning'. However, there is no consensus as to how this might best happen and practice is varied. This study offers the proposition that technology re-invents the opportunities for cultivation of higher-order creative thinking. However, in classrooms, technology is most commonly employed in lower-order thinking tasks which is broadly in line with syllabus directives. On the other hand, the research literature values highly the potential of laptops for evoking higher-order thinking through science education software and simulations. There is further potential to lift higher-order thinking through laptop use via teacher professional learning and the revision of syllabus documents. More importantly, there is a need for further research exploring how the incorporation of ICT re-invents classroom dynamics, student-teacher relationships and communications, impacting on students' learning.

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