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An investigation of senior secondary school teachers' experiences of integrating information and communication technologies into teaching and learning in the era of Australia's Digital Education Revolution

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Bachelor of Science

Graduate Diploma of Education

Graduate Certificate TESOL

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ABSTRACT

The integration of information and communications technologies (ICTs) affects teachers and their practice as well as students and their learning. This study investigated teachers' experiences of integrating ICTs into teaching and learning across a range of subjects in senior secondary education (Years 11 and 12) in New South Wales (NSW) at the time of Australia's Digital Education Revolution (DER). The DER was a national government initiative that provided digital technologies to students and raised expectations of enhanced learning and improved ICT capabilities. The study explored the challenges faced by teachers in aligning teaching practices and assessment regimes with the new tools provided to their students.

The research was a two-phase qualitative study – a preliminary policy analysis followed by an investigation of teachers' experiences of integrating ICTs into teaching and learning. The first phase reviewed policy related to ICT-integration into schools from 2008 to 2012, framed by Fullan's (2007) Characteristics of Intended Changes, to develop an understanding of the context in which senior secondary school teachers were working. The second phase used a phenomenological approach to develop an understanding of ICT-integration grounded in the experiences of practising teachers. Data were collected through interviews with 28 NSW Year 11 and/or Year 12 teachers who were integrating ICTs into specialist subject areas other than computing studies. The conceptual framing for this phase drew on the Technological Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006), which informed data collection about, and analysis of, the teacher knowledge that guides their ICT-integration practices. Additionally, an analytical framework developed from policy relating to the DER implementation (MCEETYA, 2008a) helped to characterise specific ICT-integration strategies employed by teachers.

Phase 1 identified key features of the policies that were shaping the context in which participants were working at the time of the study. The analysis identified a policy focus on contemporary learning outcomes to be realised through integrating ICTs into teaching and learning across the curriculum, as well as outcomes relating to students' ICT competencies. Further, there was a degree of complexity inherent in the reform objectives associated with developing teacher capacity, teacher professional learning,

and the multiple and concurrent education reform agendas. The practical implications were that teachers would need to develop knowledge and skills associated with the introduction of new ICTs and ICT-integration, and teaching strategies aimed at developing students' ICT capabilities within existing specialist subject curricula. Furthermore, schools would need to accommodate the increased time needed to enact the sustained and meaningful change called for in education policy.

The results of Phase 2 showed that teachers' integration of ICTs included: routine use of display technologies in combination with a range of teacher-created or teacher-curated digital resources; the use of subject-specific technologies in mathematics and creative arts; and the design of learning activities through which students created a range of digital artefacts. A common feature was that pedagogies integrating ICTs were aimed at maximising student meaning-making and the development of students' conceptual understandings of specialist subject content. When students were required to use ICTs, participant teachers valued students applying ICT-related knowledge and skills to higher-order cognitive processes, such as problem solving, analysis and representing subject content.

Participant teachers' experiences served to highlight contradictions between the policy objectives related to ICT-integration and the high-stakes assessment and prescribed content of senior secondary school. In some cases, ICT skills and knowledge were seen as extra content that was unnecessary in the context of teaching state-prescribed syllabi that did not explicitly require ICT knowledge and skills. This belief was particularly prevalent when school-based assessment processes mimicked external state-based examinations. This suggests a need for greater clarity about the subject-specific ICT skills and knowledge that students should achieve in the final years of secondary school. ICT-related outcomes must have clear connections to what is assessed so that their value is obvious to both teachers and students. This may require a reconceptualisation of the purposes and processes of assessment in the final years of schooling to ensure that the range of assessment tasks reflects student achievement across a broader range of learning outcomes.

The teachers in this study enacted specific domains of teacher knowledge when planning and implementing ICT-integrated lessons. Seven types of technological content knowledge (TCK) enactment were identified in practice, indicating that this construct, and TPACK generally, has value for exploring ICT-integration. The study makes a contribution towards TPACK's theoretical development through a focus on the TCK boundary construct, providing further clarification of the nuanced knowledge senior secondary teachers bring to the fore when they enact an ICT supported curriculum. One practical implication is that teacher professional development may benefit from teaching ICT skills that are firmly grounded in the representation of specific topic areas in order to develop teachers' TCK.

In summary, the policy analysis results suggested that the implementation of the DER would challenge teachers' knowledge of how to teach their subject content, as well as their knowledge of subject content related to explicit teaching of ICT skills and knowledge. This was consistent with teachers' actual experiences of ICT-integration as complex and situated. The senior secondary teachers in this study integrated ICTs in ways that promoted student learning of their specialist subject content and they invoked specialised knowledge when planning and implementing ICT-integrated learning activities. However, the highly prescribed nature of subject content knowledge posed a contradiction for some teachers who felt that the value of ICT-integration and teaching students ICT skills and knowledge was not reflected in the high-stakes exit examination system characteristic of the final years of school. The findings of this study help to inform future ICT-integration policy and strategy in senior secondary school by highlighting the particular contextual factors that need to be considered.

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This thesis is dedicated to mum and dad, Marcia and Reno Leo, who understood the importance of quality education long before its relevance became important for me also.

Candidate statement about the style of the thesis

This thesis is submitted as a "thesis by compilation". It includes four in-preparation journal manuscripts for future submission and four conventional thesis chapters. A synopsis explaining the purpose and content of each chapter is provided in the introduction chapter. The target journals for publication of the manuscripts are identified; these selected peer-reviewed journals publish papers that promote knowledge-sharing in the areas of education policy, information and communication technology integration in school education and teachers' professional-knowledge domains.

In a thesis-by-compilation format it is inevitable that there will be a degree of repetition resulting from the need for manuscripts to function as stand-alone pieces. In this thesis this occurs particularly in the explanations of the theoretical framework and the methodology of the study. For the purposes of the thesis, tables, figures, chapters and appendices are numbered sequentially from Chapter 1 through to Chapter 8, even though some of the chapters are intended for publication. Chapter titles will be eliminated and tables, figures and appendices will be renumbered in accordance with journal style guides in preparation for submitting to a journal.

The thesis-by-compilation format was chosen for this research on the advice on my supervisors for two reasons. First, this approach allowed me to develop an understanding of journal manuscript preparation during the period of my doctorate. This has given me the opportunity to work intensively on multiple papers under the close guidance of my supervisors, both of whom have significant publishing experience. This has been invaluable to my development as a researcher. Second, having these papers in an advanced state of preparation will enable me to contribute to the rapidly developing literature in educational technology in a timely fashion.

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CHAPTER 1: INTRODUCTION

1.1   Introduction

The integration of information and communications technology (ICT) in school education continues to be a focus for educators, governments and researchers. The integration of ICTs affects teachers and their practice and students and their learning. The broader societal role of ICTs in economic productivity, industry advancement and globalisation is reflected in government discourse in the forms of policy statements, government-funded initiatives and government-defined curricula that explicitly aim to integrate ICTs into schools (ACARA, 2012a; AICTEC, 2009b; MCEETYA, 2008c). The challenges associated with ICT-integration in school education have led to research into educational change management, teachers' knowledge requirements and impacts on student learning.

Effective ICT-integration is known to be complex and multifaceted for all levels of schooling. Factors affecting ICT-integration include leadership (Hayes, 2003; Lindberg & Sahlin, 2011), organisational issues associated with new infrastructure, specialist support staff and scheduling (Hayes, 2003; Tanaka-Ellis, 2010) , the types and quantities of ICTs available (Chang, 2001; Crawford, 2009; Solhaug, 2009; van Rooy, 2012), external factors such as national ICT education policy (Tearle, 2003; Tondeur, van Braak, & Valcke, 2007), the context within which teachers are working (Harris, Mishra, & Koehler, 2009), inclusion or omission of ICT-related outcomes in prescribed curricula (Handal, Cavanagh, Wood, & Petocz, 2011; Tondeur et al., 2007), teachers' capacity and beliefs (Handal et al., 2011; Hayes, 2003; Prestridge, 2008) and learners' dispositions and ICT skills (Bonvallet & De Luce, 2001; Tanaka-Ellis, 2010). There are specific challenges, too, in integrating ICTs into senior secondary school because of the tightly prescribed curriculum and high-stakes assessments.

This study investigated ICT-integration in New South Wales (NSW) senior secondary education (Year 11 and 12) during a period of rapid change associated with heightened national school-education policy activity in Australia. Specifically, the study focused on teachers' integration of ICTs to support teaching and learning across a range of subjects in senior secondary education in NSW. The study was conducted in two

phases: a preliminary policy analysis and an investigation of teachers' experiences of ICT-integration.

The first phase reviewed national policy related to ICT-integration into schools from 2008 to 2012. This was the period immediately prior to and in the initial stages of Australia's Digital Education Revolution (DER) (AICTEC, 2009b, 2009c; DEEWR, 2009b). The purpose of this preliminary phase was to characterise the changes advocated by Australian national government policy at the time. Fullan's (2007) Characteristics of Intended Changes was used to guide this analysis of the Australian policy context. The aim of this phase was not to evaluate the policy itself or specifically investigate its enactment, but to develop an understanding of how national government policy shaped the context in which senior secondary school teachers were working to integrate ICTs into their teaching.

The second, and main, phase of the study investigated NSW senior secondary teachers' experiences of integrating ICTs across a number of subject areas in the era of the DER, with data collection conducted in 2011. The research was conducted with teachers whose students were in Years 11 or 12. In 2011, Year 11 students in government schools had been provided with laptops as part of the DER. This phase adopted a phenomenological approach, which valued the subjective realities of the individual teachers to gain understanding of the phenomena under investigation. ICT-integration was examined through a framework that considered technological pedagogical and content knowledge – in other words, what teachers need to know in order to teach (Mishra & Koehler, 2006).

1.2   Background

Continuing advances in technology and its increasing importance for living and working in a digital world have seen student learning outcomes relating to information and communications technologies included in school curricula around the world (Commission of the European Communities, 2008; Department for Education, 2011; MCEETYA, 2008c; U.S. Department of Education, 2010; UNESCO, 2013). Australian schools are no exception. Student learning outcomes relating to ICTs were established in the 1989 National Goals for Schooling (Australian Education Council, 1989). This established a high-level, ICT-related outcome for students that continues

in present Australian national schooling goals (MCEETYA, 2008c) and curriculum frameworks (ACARA, 2012a, 2012c).

In 2008, the Australian National Government began an ambitious education reform agenda, of which the DER was a component (DEEWR, 2008c, 2008e, 2009b). The main funding component of the DER was the $1.2 billion National Secondary School Computer Fund (NSSCF). The DER National Education Agreement funded an influx of digital technologies for schools. Most visible were laptop computers; however, the DER also funded better connectivity for devices through the Fibre to the Schools initiative (DEEWR, 2008a), development of online curriculum resources (The Le@rning Federation, 2008) and professional development (DEEWR, 2010). Under the program, the states and territories made a commitment to "achieving a 1:1 ratio of computers to students by 31 December 2011" (DEEWR, 2009b, p. 6) targeted at Years 9 to 12 (the final four years of secondary school). This aspect of the program was largely implemented through laptop computer roll-outs (for example: NSW DET, 2009a). The outcome was that Year 9 to 12 students had increased access to a suite of mobile digital technologies and online content that was deployed in a relatively short period of time.

The DER policy-enactment period was significant for several reasons. First, the DER was a national government initiative that directly affected school education, which comes under the jurisdiction of state and territory governments. Thus, while the national government set the agenda and provided this funding, the various state and territory governments were required to determine the specific implementation strategy and manage it to meet the national government's requirements.

Second, the DER's overarching aim was to change teaching and learning through government ICT provision:

> The DER is a $2.207 billion investment by the Commonwealth Government over six years which aims to contribute *sustainable and meaningful change* [emphasis added] to teaching and learning in Australian schools to prepare students for further education, training, jobs of the future and to live and work in a digital world (DEEWR, 2009b, p. 2).

At the time, questions were raised about how teachers would be equipped with the skills needed to "effectively mobilise and integrate those technologies" provided in the DER rollout (Kerin, 2008, p. 25). Kerin (2008) observed "that extended time out for professional learning in digital literacies is perceived as a luxury within institutional settings" (p. 25). Another commentator criticised the positioning of ICT as the driver of change, arguing that it adopted a determinist view of technology that attributed positive education outcomes to injections of digital technologies, and underestimated the complexities of ICTs in school contexts and the roles of students and teachers in ICT-integration (Jordan, 2009). In addition, research suggests that change to teachers' practices with ICTs is gradual, multifaceted and more complex than simply developing teachers' digital literacies (Orlando, 2009). This suggests that significant change is unlikely to be achieved in a short timeframe.

Third, for senior secondary educators, the DER added a layer of complexity to teaching the specialist curriculum areas that are characteristic of the final school years. The DER higher-order outcomes – what are referred to as "outcomes of significance", (Spady, 1994a, 1994b) were the kind that focus on essential skills and knowledge important for the life-roles students are expected to assume post-secondary schooling. These DER outcomes included effective participation in society; productive contributions to the economy; successful transitions to work and further studies; applications of ICTs to question and enquire; collaborate, share and communicate; conceptualise, produce, create and acquire knowledge; solve problems and think critically; and manage information (AICTEC, 2009b; MCEETYA, 2008a). Within the senior secondary schooling context, teachers work in specialised subject domains defined by mandated course outcomes, syllabus content and assessment programs, culminating in high-stakes final examinations. The challenge for teachers in this context was to design learning experiences aimed at development of subject specific skills and content as well as abilities essential for post-school life roles.

In sum, DER policy was a large-scale, system-wide reform agenda underpinned by an expectation that teachers would design "challenging and stimulating learning activities" to integrate ICTs (DEEWR, 2008d, p. 4). The immediate challenge for all teachers was to align existing teaching practices and assessment regimes with the new

tools provided to their students through the DER implementation. It is within this contextual mix of increased access to ICTs, heightened expectations about digital pedagogies, mandated course content and high-stakes assessment that this study explored how ICTs are integrated in senior secondary education.

1.3   Significance of the research

The problem addressed in this study is significant because the effective integration of ICT into school education continues to challenge schools, teachers and teacher educators. This is because new technologies will continue to emerge, make their way into classrooms and potentially impact on teaching and learning (Johnson, Smith, Willis, Levine, & Haywood, 2011). In contrast, evidence suggests that teachers change of practice with ICTs is gradual and "intertwined with their contexts and identity" (Orlando, 2009, p. 39). It is necessary, therefore, that ICT-integration in schools is revisited as new technologies emerge and others are superseded.

The research is important because it contributes knowledge about how ICTs are integrated within subject disciplines at a specific level of schooling during a policy-enactment period. Research has shown that when teachers change how they teach in response to policy, they do so in terms of their existing knowledge structures, belief systems and practice (Cohen & Ball, 1990). Therefore, it is important that knowledge development around how ICT-integration manifests be grounded in experiences of teachers' practice.

Senior secondary schooling is a particular context, and the rapid introduction of new technologies via the DER into those classrooms during the study provided an opportunity to further develop understanding of ICT-integration. The DER policy agenda underway during this study affected Year 11 and 12 learning environments through increased access to laptops and heightened expectations relating to ICT-integration in teaching and learning. ICT-integration in senior secondary education is a worthy area of study because declining participation rates in senior secondary computing-studies subjects (Downes & Kleydish, 2007) means that for many students, their opportunities in the senior school for exposure to ICT-related knowledge, skills and values will depend on the integration of ICT into the teaching and learning associated with non-computing studies. This study extends the current knowledge base

through the use of the technological, pedagogical and content knowledge (TPACK) construct that was gaining acceptance during the early stages of this study. TPACK considered ICT use in terms of teachers' knowledge required for teaching with ICTs (Mishra & Koehler, 2006)

TPACK extends' the well-known Pedagogical Content Knowledge (PCK) framework grounded in research that observed changes in teachers' knowledge as they progressed from novice to expert (Shulman, 1986b, 1987). PCK foregrounded the importance of subject content and "the analogies, metaphors, examples, demonstrations, simulations, and the like" that are employed to support student's meaning-making when teachers represent their subject content (Shulman, 1987, p. 16). The addition of technological knowledge (TK) extended PCK's three constructs to seven. It is based on the premise that knowledge of technology and how it worked – technological knowledge (TK) – should not be thought of as an exclusive body of knowledge and that quality teaching requires an application of three intersecting knowledge bases of CK, PK and TK, called technological content knowledge (TCK), technological pedagogical knowledge (TPK) and TPACK (Koehler & Mishra, 2009; Mishra & Koehler, 2006). There is a focus on subject content knowledge in this context because Year 11 and 12 courses are the final stage of schooling in NSW, and teachers contain advanced subject knowledge in their specialisations. These teachers employ a number of strategies aimed at developing understanding, skills and knowledge for subject-specific content in time for external high-stakes assessments (Ayres, Sawyer, & Dinham, 2004). Although questions have been raised over the nature of the constructs and the knowledge they represent (Archambault & Barnett, 2010; Archambault & Crippen, 2009), in this study, TPACK offered a precise vocabulary to guide data collection and an analysis of practice involving ICT-integration, and enabled "scholarly dialogue about educational technology" (Mishra & Koehler, 2006, p. 1046).

While there are many examples of effective ICT-integration in schools, these are often associated with specific interventions, and tend not represent a general picture of ICT use in schools (Cox, Abbott, et al., 2004; Cox, Webb, et al., 2004; Selwyn, 2010). Scholars have prompted suggestions for further research within specific context areas and stages of schooling aimed at promoting understanding of the effects of ICT on

learning outcomes (Cox & Marshall, 2007; Selwyn, 2008, 2010). This study contributes information about practices and issues related to ICT-integration within the context of the senior secondary stage of schooling.

This study also contributes knowledge about the DER policy period – what Fullan (2010) would see as a large-scale reform agenda, as it involved all schools in the system working towards improved outcomes for students. This is an important contribution to the literature for several reasons. First, education-policy analysis explored the characteristics of changes advocated by the DER and implications for teachers and their practice, developing greater understanding of the context of the system within which teachers teach and researchers research (Welch, 2007). Policy analysis provides information to policy-makers when they research and debate educational topics (Creswell, 2012a). Second, deconstructing policy objectives as they relate to teachers provides insights into the enactment of that policy and highlights areas that need attention in future government-funded initiatives. And finally, policies do not sit in isolation despite having initiation and end dates. They interact with past education policies as well as concurrent interconnected policies, and can inform future directions.

1.4   Purpose of the research

The purpose of this research was to investigate ICT-integration within a context of increased access to ICTs and heightened expectations for ICT use across subject areas in the senior secondary school.

The aims of this study were to:

1. Systematically review the policy climate influencing ICT-integration in school education at the time of the DER.
2. Examine how ICT was being integrated to support teaching and learning in senior secondary education – a specific stage of schooling targeted by DER policy.
3. Explore implications for teachers' knowledge and practice relating to ICT-integration in senior secondary education.

The first aim identified for the current study was *to identify the key characteristics of intended changes relating to information and communication technologies envisaged through the Digital Education Revolution.* Governments are a key force in educational change, and have the ability to bring about widespread, system-level change (Fullan, 2007). Policy can describe the governments' aims, objectives and processes for intended change (Bacchi, 2009). Therefore, ICT education policy has the capacity to describe changes to education that governments are seeking. The purpose of the first phase of the study was to clarify governments' expectations for changes to ICT-integration in NSW schools brought about by the DER.

The second aim for the study was to explore ICT-integration in non-computing-studies subjects in the final years of schooling to better understand the role of technology in the senior school. The years of senior secondary schooling are important: young people are making decisions regarding their futures and schools are transitioning students to further education, training and employment. The challenge for teachers is that higher-order, less explicit outcomes relating to ICTs are expected to be integrated into courses characterised by prescribed content and high-stakes assessment.

The third aim acknowledges that teacher knowledge is critical in successful implementation of ICTs in schools. The aim in this case was to explore the knowledge domains that are invoked in technology-enhanced teaching and learning environments. In addition to knowledge of content and pedagogy, technological knowledge has become an important part of effective teaching (Mishra & Koehler, 2006). These three knowledge domains and their intersecting components are conceptualised in the Technological, Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006). This framework was explored in this study within the context of content-laden senior secondary education.

1.4.1 Research questions

Three research questions were developed to focus the study based on the aims.

1. What were the key characteristics of intended changes advocated in DER education policy
2. How do NSW senior secondary teachers integrate ICTs to support teaching and learning?
3. What forms of teacher knowledge are evident in senior secondary teachers' descriptions of their practice?

1.5 Research design

This qualitative study has adopted a phenomenological approach describing the lived experiences of senior secondary teachers (Creswell, 2012b). This approach looks for a common meaning for several individuals. In this research, the approach is used to develop an understanding of ICT-integration through a consideration of multiple perspectives of teachers through experiential data (interviews) from 28 senior secondary teachers describing their classroom practice integrating ICTs.

The researcher is positioned within the field of inquiry as an experienced senior secondary teacher with an additional responsibility of assisting secondary teachers with their ICT-integration. In developing knowledge on how teachers use technology in the context of senior secondary education, it is important that teachers contribute first-hand experiences of how they integrate ICT in their classrooms. For this reason, this study sits within an interpretive framework that assumes that reality is socially constructed, multiple constructions of that reality exist and the researcher and the object influence each other (Lincoln & Guba, 1985).

Phenomenology was selected as the methodology because this approach to investigation is grounded in its openness to the value of teachers' descriptions of their practice and the meanings those descriptions impart (Bradfield, 2007). Phenomenology describes a method of investigation as well as a philosophy valuing knowledge construction through exploration of human experience (van Manen, 1990). The research was undertaken in two phases.

The purpose of the first phase was to explore the policy climate affecting ICT in education during the data-collection period to better understand the context surrounding ICT-integration. "Policy" describes a national vision and processes for intended change. To better understand the context of the system within which senior secondary teachers were working, an aim for the study was to elucidate the key characteristics of intended changes relating to ICTs in school education. Policy analysis was framed by Fullan's (2007) model for the characteristics of change, and focused on policy relating to Australia's DER policy ensemble.

The second phase explored the phenomena of ICT-integration in senior secondary education by collecting data on teachers' experiences. Data relating to experiences of ICT-integration were collected and analysed from Year 11 and 12 non-computing-studies teachers from New South Wales (NSW) schools. These participants were selected because they were directly involved in the DER policy agenda that increased access to computers in the senior years.

The use of technology from a teacher's perspective was important in building understanding of ICT-integration phenomena. In phenomenology, this point of view is known as the *lived experience* (van Manen, 1990). The focus here was to understand how ICTs are used to support teaching, learning and high-stakes assessment practices through an exploration of teachers' classroom experiences with ICTs.

Two frameworks were useful in guiding the methodology. Inherent in the ICT-integration process are the knowledge ensembles enacted when teachers make decisions about subject content and pedagogical practices that maximise student learning. Teachers' technological, pedagogical content knowledge (TPACK) is a framework that is contributing to knowledge construction in the area of ICT-integration research (Mishra & Koehler, 2006). TPACK guided both data collection and data analysis in this study. Additionally, an analytical framework based on ICT-integration as it relates to personalising and extending student learning provided an organiser for describing teachers' experiences of integrating ICTs.

1.6   Definitions

In the context of this study the following terms have been used.

Australian Government: Australia is a federation composed of states and territories. The Australian Government is sometimes referred to as the Commonwealth Government, the Federal Government, the National Government and the Australian National Government. Constitutionally, Australian state and territory governments have responsibility for education; however, national goals and initiatives are formulated through intergovernmental agencies including the Standing Council on School Education and Early Childhood (SCSEEC; formerly the Ministerial Council for Education, Early Childhood Development and Youth Affairs – MCEECDYA), the Council of Australian Governments (COAG) and the Australian Curriculum, Assessment and Reporting Authority (ACARA).

Australian schooling: Schooling across Australia has a similar structure, with slight variations between states and territories. In NSW there are 13 years of schooling: kindergarten, six years of primary school (Years 1 to 6) and six years of secondary school (Years 7 to 12). In 2010, legislation came into effect increasing the minimum leaving age from 15 to 17 years of age. After Year 10, students must participate in senior secondary school education or vocational education.

Government schools are the major provider of school education in Australia (ABS, 2014). The majority of non-government schools have a religious affiliation; predominantly, the Catholic Church. Non-government schools are also called independent schools. Government schools are also called state schools or public schools.

Board of Studies, Teaching and Educational Standards NSW: The NSW statutory education authority that governs the implementation of curriculum and assessment in NSW schools.

Curriculum: States and territories implement curriculum through statutory education authorities. In NSW, the Board of Studies, Teaching and Educational Standards

(BOSTES) is responsible for curriculum implementation in all NSW schools. BOSTES commenced operation in 2014 and subsumed the functions of the Board of Studies NSW (BOS) and the NSW Institute of Teachers. BOSTES develops syllabi that mandate content to be taught. Syllabi are implemented across six key stages. Stages 1, 2 and 3 cover Kindergarten to Year 6 content; Stage 4 syllabi are for Years 7 and 8; Stage 5 syllabi are for Years 9 and 10; and Stage 6 covers senior secondary Years 11 and 12.

Digital Education Revolution (DER): An Australian national ICT education policy (2008-2013) aimed at the development of technology-enriched learning environments.

Education system: A division of education. In Australia, there are early childhood, school and tertiary education systems.

Government school: A school fully funded by the Government. The majority of Australian students are educated in a government school (ABS, 2014). Government schools are also referred to as state schools and public schools, as Australian states and territories administer and allocate funding to government schools.

Higher School Certificate (HSC): A credential awarded to NSW students at the conclusion of Year 12. The HSC also refers to the program of study undertaken in the final year of schooling in NSW.

ICT-integration (Information and communications technology integration): The use of a range of software and devices in classrooms as well as pedagogical approaches that use technology to support and enhance student learning (Lloyd, 2005).

Information and communication technologies (ICT): Contemporary and emerging digital technologies that are used for accessing, creating and communicating ideas, solving problems and working collaboratively in all areas of school and in students' lives beyond school (ACARA, 2012a); digital technologies are defined as any technology controlled using digital logic, including computer hardware and software,

digital media and media devices, digital toys and accessories and contemporary and emerging communication technologies (ACARA, 2013).

Key stage: a stage of NSW schooling. There are six key stages. Stages 1, 2 and 3 include Kindergarten to Year 6; Stage 4 includes Years 7 and 8; Stage 5 includes Years 9 and 10; and Stage 6 includes Years 11 and 12.

National Secondary Schools Computer Fund (NCSSF): The major funding element of the DER; an example of a Specific Purpose Payment (q.v.). This spending targeted establishing a 1-to-1 computer-to-student ratio in Years 9 to 12 in all Australian secondary schools.

National Education Agreement (NEA): An agreement between the Australian government and state and territory governments that sets out objectives and outcomes for schooling, the roles and responsibilities of each level of government and reporting frameworks (Harrington, 2011).

National Partnerships (NP): Agreements between national, state and territory governments that support the delivery of specified projects, facilitate reforms or reward jurisdictions that deliver on national reforms (http://www.federalfinancialrelations.gov.au/).

Non-government schools: Also called private or independent schools. They are not part of the government school system; however, NSW private schools must be registered and accredited with the Board of Studies, Teaching and Educational Standards NSW (BOSTES). Australian non-government schools receive government funds as capital grants and Specific Purpose Payments (q.v.).

School sector: A division of schooling based on governance and funding. In Australia these are the government, Catholic and independent school sectors.

Senior secondary education: The final years of schooling. In NSW these are Years 11 and 12, and include the Preliminary Higher School Certificate (Year 11) and the Higher School Certificate (HSC; Year 12) courses.

Specific Purpose Payments (SPPs): Grants the Commonwealth makes to the states in areas such as health and education, which the states administer; the payments are usually subject to conditions as to how the money is spent. The NSSCF was an example of an SPP (http://www.aph.gov.au/).

Stage: (see *Key stage*)

Structure of the school year: The school year varies slightly in each state or territory. In NSW, the academic year begins in late January or early February. There are four school terms of approximately 11 weeks' duration. A typical school-year breakdown is as follows:

- Term 1: Late January – early April (depends on Easter)
- Term 2: Late April – late June
- Term 3: Mid-July – mid-September
- Term 4: Early Oct – mid-December.

(Source: http://www.boardofstudies.nsw.edu.au/key_dates/vacations.html; retrieved 11 Nov 2014)

Syllabus: A NSW Board of Studies, Teaching and Educational Standards publication that identifies essential knowledge, understanding, skills, values and attitudes that students will acquire in each learning area (Board of Studies NSW, 2012). All NSW schools are required to deliver programs of study covering essential content outlined in syllabus documents.

Term: (see Structure of the school year).

1.7   A list of Australian Government agencies referred to throughout the thesis

The following descriptions are synthesised through data gathered from agency websites. Where possible, the uniform resource locator (website address) is provided that was current at the time of data collection. During the candidature, several organisations were discontinued and/or subsumed with changes to Australian governmental structures. These changes are noted where possible.

ACARA: Australian Curriculum and Reporting Authority. This agency is responsible for the national curriculum from Kindergarten to Year 12; the National Assessment Program and national data collection relating to reporting on schools (http://www.acara.edu.au/).

AICTEC: Australian Information and Communications Technology in Education Committee (http://www.aictec.edu.au). This was a cross-sectorial, national committee responsible for providing advice to Australian Ministers of Education and Training on the effective use of online technologies in Australian education and training.

COAG: Council of Australian Governments. This is an intergovernmental forum consisting of the Prime Minister, state and territory Premiers and Chief Ministers and the President of the Australian Local Government Association (ALGA). The role of COAG is to promote policy reforms of national significance, or those that need coordinated action by all Australian governments (https://www.coag.gov.au).

DEEWR: The Department of Education, Employment and Workplace Relations (http://deewr.gov.au). This department was responsible for national policies and programs relating to childcare; early childhood and school education; jobs; and fair, safe and productive workplaces. The department was also responsible for the Office for Youth, responsible for policies, programs and services affecting young people. On 18 September 2013 the Department of Education (http://education.gov.au/) and the Department of Employment (http://employment.gov.au/) were created out of the former Department of Education, Employment and Workplace Relations.

Education.au: Education.Au Limited (www.educationau.edu.au). This was a company owned by the Ministers of Education and Training in all States and Territories and the Commonwealth of Australia. Its focus was on fostering collaboration and cooperation between the education sectors and systems in relation to the use of the Internet in education and on EdNA (the Education Network Australia) as the major vehicle for this collaboration. Education.au and the Curriculum Corporation merged to become Education Services Australia (ESA) on 1 March 2010.

Education Council: As of 1 July 2014, the former Standing Council on School Education and Early Childhood (SCSEEC) became known as the Education Council (http://scseec.edu.au).

ESA: Education Services Australia (www.esa.edu.au) is a not-for-profit company established to support the delivery of national priorities and initiatives in schools, training and higher-education sectors. ESA works closely with the Australian, Curriculum and Assessment Authority (ACARA), the Australian Institute of Teaching and School Leadership (AITSL) and the Australian Children's Education and Care Quality Authority (ACECQA).

MCEETYA: Ministerial Council on Education, Employment, Training and Youth Affairs. In 1993 MCEETYA subsumed the roles and responsibilities of the Australian Education Council (AEC), the Council of Ministers of Vocational Education, Employment and Training (MOVEET) and the Youth Ministers Council (YMC). Functions of the Council include coordination of strategic policy at the national level, negotiation and development of national agreements on shared objectives and interests (including principles for Australian Government/State relations) in the Council's areas of responsibility, negotiations on the scope and format of national reporting on areas of responsibility, sharing of information and collaborative use of resources towards agreed objectives and priorities, and coordination of communication with, and collaboration between, related national structures. MCEETYA was superseded by MCEECDYA in July 2009 (http://www.mceetya.edu.au).

MCEECDYA: The Ministerial Council for Education, Early Childhood Development and Youth Affairs was established on 1 July 2009 and subsumed the roles and responsibilities of the Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA) and the Ministerial Council for Vocational and Technical Education (MCVTE). Membership of the Council comprises State, Territory, Australian Government and New Zealand Ministers with responsibility for the portfolios of education, employment, training and youth affairs. MCEECDYA was superseded by SCSEEC in January 2012 (http://mceecdya.edu.au).

Scootle: A national digital-learning repository that provides Australian teachers with access to digital-learning items aligned to core areas of the Australian Curriculum (https://www.scootle.edu.au).

SCSEEC: Standing Council on School Education and Early Childhood. It was established in January 2012 as one of 12 standing councils reporting to COAG. This council superseded MCEECDYA. SCSEEC provides a forum through which strategic policy on school education and early-childhood development can be coordinated at the national level, and through which information can be shared and resources used collaboratively towards achieving agreed objectives and priorities. SCSEEC was superseded by the Education Council in December 2013 (http://scseec.edu.au/).

The Le@rning Federation (TLF): This was superseded by *Scootle* – a Government funded initiative providing online content to Australian school teachers. Teachers were asked about its use (https://www.scootle.edu.au).

1.8 Structure of the thesis

The research is reported in the thesis-by-compilation format. It is presented as a combination of journal articles prepared for peer-reviewed education journals and traditional thesis chapters. This was an appropriate structure for a *second-career* part-time research student because it enabled the project to be divided into manageable sub-projects and developed practical skills in writing for peer-reviewed journals.

This thesis by compilation comprises four traditional thesis chapters and four in-preparation journal manuscripts. A signed declaration of contribution for each co-authored manuscript is provided in Appendix A. Table 1 shows the chapters and their contents.

Table 1: Chapter breakdown of the thesis

Chapter	Title	Format	Authorship of manuscripts*	Target Journals
1	Introduction	Thesis chapter		
2	Literature review	Thesis chapter (prepared in journal-article style)		Educational Research Review
3	Methodology	Thesis chapter		
4	Results: Australia's Digital Education Revolution – the characteristics of intended changes	Manuscript prepared for submission	DBourne: 90%; SBennett: 5% LLockyer: 5%	Australian Journal of Education
5	Results: Information and communications technology integration in senior secondary education	Manuscript prepared for submission	DBourne: 90%; SBennett: 5% LLockyer: 5%	Computers & Education
6	Results: ICT use in senior secondary high-stakes assessment	Manuscript prepared for submission	DBourne: 90%; SBennett: 5% LLockyer: 5%	Assessment in Education: Principles, Policy & Practice
7	Technology in school education – ICT-integration and teacher knowledge	Manuscript prepared for submission	DBourne: 90%; SBennett: 5% LLockyer: 5%	Technology, Pedagogy and Education.
8	Conclusion	Thesis chapter		

*Each manuscript was drafted by the first author and reviewed by the other authors.

Chapter 2 presents a systematic review of the empirical literature relating to technology integration in senior secondary education. The systematic approach described by Pickering and Byrne (2013) was adopted because it provides a structured method to identify questions to be asked of the literature, identification of relevant literature and a system to analyse the studies. The systematic review process has been found useful for early-career researchers. Additionally, this type of literature review results in a manuscript suitable for publication as a journal article, which aligned to the thesis-by-compilation model adopted by this study. The chapter contributes knowledge of the types of ICTs used in the senior secondary context and their contribution to teaching and learning. A key aim for this research was to investigate ICT-integration to support teaching and learning within the context of senior secondary education. Therefore, empirical studies relating to ICT-integration in senior secondary education were selected for review. It provided an understanding of how researchers view and define the concept of ICT-integration. It also synthesised knowledge on complexities associated with ICT-integration in the senor secondary level of schooling. Additionally an examination of methodologies and analytical frameworks provided insights into the range of research designs used by ICT-integration researchers and the ways they made sense of their datasets.

Chapter 3 details the methodology and is presented as a traditional thesis chapter. It begins by justifying the choice of a qualitative research approach. The two-phase research design is presented along with participant selection processes and data-collection and data-analysis methods. Conceptual and analytical frameworks are explained, and a consideration of ethical issues associated with the research is considered. The chapter concludes by justifying the quality of the study and a discussion of limitations associated with the research.

Chapter 4 is the first of three results chapters. It presents the findings of the first phase of the study, an education policy analysis focusing on Australia's Digital Education Revolution. The purpose of this paper is to gain an understanding of the context within which teachers were working and the expectations for ICT-integration and the implications. The paper answers Research Question 1 – *What were the key characteristics of intended changes advocated in DER education policy relating to*

information and communication technologies (ICTs) in school education? The analysis is presented through a change-theory perspective and focuses on the characteristics of intended changes advocated in DER policy. Through a "drill-down" process beginning with the national goals for schooling, then over-arching education agreements, then down to specific initiatives, insights into the scope and complexity of changes relating to classrooms and teachers were explored. The Characteristics of Change framework enabled a focus on a significant part of the system – the teachers and what a whole-of-nation strategy implied for these key actors in this policy context. This knowledge of policy informed contextual characteristics associated with Phase 2 of the research, which focused on ICT-integration. This paper has been prepared as a journal manuscript for submission to the *Australian Journal of Education* (AJE). This journal was selected because it publishes research that informs researchers, administrators and policy-makers about issues of concern in education. This paper is suited to AJE as it contributes insights via a policy analysis that reflects on the implications of past ICT education policy for teachers (education-policy actors). Issues raised by past education policy are of interest to AJE's Australian readership as well as to those engaged in international policy-making aimed at system-wide reform.

Chapters 5 and 6 present results relating to phase two of the study. These two papers answer Research Question 2: *How do NSW senior secondary teachers integrate ICTs to support teaching and learning?*

Chapter 5 presents the first set of results relating to phase two of the study, which explored ICT-integration. This paper contributes knowledge about how ICTs are used to support teaching and learning at a specific level of schooling: senior secondary education. Data collected from Year 11 and 12 NSW teachers was set against a backdrop of Australia's DER – a system-wide reform agenda increasing access to ICTs in classrooms and advocating high-level outcomes relating to changes to teaching and learning with ICTs. Adopting a phenomenological research design, an understanding of ICT use was grounded in specialist subject teachers' experiences of pedagogic practices. The TPACK construct provided a theoretical lens for data analysis that enabled a view of teaching experiences through component teacher-knowledge domains that are put into practice during the planning and delivery of lessons

integrating ICTs. This paper has been prepared as a journal manuscript for submission to *Computers & Education*, to which it is suited because it contributes understanding to the way digital technologies are used at a specific level of schooling. The pedagogical uses of digital technology identified in this research will be of interest to researchers and educators working in senior secondary school education – a level of schooling with specific contextual characteristics such as specialist subject domains, highly prescribed course content, high-stakes assessment and students exiting the school system.

Chapter 6 presents results relating to ICT-integration in senior secondary high-stakes assessment. This paper contributes knowledge on summative assessment and ICT-integration to support and enhance assessment processes. These are important because assessment is used to measure and report achievement and progress in learning. In Years 11 and 12, assessment, curriculum and pedagogy are closely linked, as instructional planning is aligned to mandated syllabus outcomes. Once again, the TPACK construct provided a theoretical lens for data analysis that enabled a consideration of teachers' knowledge of pedagogical practice-associated assessment within specialist content areas, and the ways ICTs are used in this environment. This paper has been prepared as a journal manuscript for submission to *Assessment in Education: Principles, Policy & Practice* because its focus is on promoting scholarly dialogue in educational assessment relating to policy and practice.

Chapter 7 presents a paper that explicates the theoretical foundation guiding the research. In its exploration of the TPACK construct's application in ICT-integration studies it offers a contribution towards TPACK's theoretical development through a focus on Technological Content Knowledge (TCK) – one of TPACK's constituent constructs. This paper has been prepared as a journal manuscript for submission to *Technology, Pedagogy and Education*. It is suited to this journal because it publishes articles concerned with the theory and practice of ICT in teaching and learning.

The Conclusion, presented in Chapter 8, is prepared as a traditional thesis chapter. This chapter responds to the research questions that guided the study and considers the implications for ICT-integration in schools. It consolidates the results chapters and

provides a deeper understanding of the ICT-integration phenomenon in senior secondary education. The chapter goes on to discuss implications for education policy-making and educational practice. Limitations to the study are acknowledged and suggestions are made for further research.

CHAPTER 2: INFORMATION AND COMMUNICATION TECHNOLOGY INTEGRATION IN SENIOR SECONDARY EDUCATION – A SYSTEMATIC REVIEW OF THE LITERATURE

2.1   Introduction

This chapter offers a structured review of literature exploring information communications technology (ICT) integration in senior secondary education. It investigates the ways education researchers define ICT-integration, the types of research problems addressed in this context and the methodologies employed in furthering understanding of this phenomenon. It also examines the uses and characteristics of ICTs in this context and the complexities associated with their use. The chapter concludes by highlighting gaps in the literature and areas for future research.

2.2   Background

Technology integration in education has been a part of government and research discourse for some time. The increasing ubiquity of digital technologies, along with their constant evolution and innovation means that their use in education contexts will continue to occupy space in the research discourse. While ICT-integration refers to the use of a range of software and devices in classrooms, it also reflects pedagogical approaches that use technology to support and enhance student learning (Lloyd, 2005).

Technology use in education is closely connected to the context within which the teaching and learning are situated (Harris et al., 2009; Koehler & Mishra, 2005; Mishra & Koehler, 2006). Senior secondary education is a particular school-education context that has its own set of characteristics and pedagogical requirements. It is reasonable to assume that ICT-integration in this context will likewise have its own unique characteristics.

Although ICT-integration is diversely implemented from country to country, and even across jurisdictions in the same country, there are some defining characteristics. Senior secondary students are teenagers, between 15 and 19 years of age (Le Métais, 2003). Their teachers, generally, are experienced in their subject area and are contending with increased numbers of students continuing through to the upper secondary years (Heath

& Sullivan, 2011; OECD, 2014). Students typically select combinations of subjects across disciplines in addition to mandated core subjects, such as the national language and mathematics, to make up a program of study that meets the requirements for an exit certificate or accreditation (Le Métais, 2003). These characteristics combine with a nexus of learning outcomes, learning design and high-stakes assessment. The senior secondary school context requires educators who are masters of their content knowledge to employ pedagogies that help students develop an understanding of the subject matter (Ayres et al., 2004).

As in all educational contexts, senior secondary education is undergoing changes associated with the ways technologies are present in the learning environment. The role of ICTs in this context is important because senior secondary education links students' secondary learning with higher-education and employment pathways. There is an expectation that schools will produce knowledge workers of the future – school leavers who are competent in using a suite of digital technologies – and this has seen education policies increasingly geared towards ICT-integration in schools (Le Métais, 2003; Macpherson, 2013). This literature review is set within this context.

2.3   Method

The review process used a systematic method to search and categorise the literature, as described in Pickering and Byrne (2013). It is systematic in assessing how papers were selected for inclusion, as well as assessing the gaps in the ICT-integration research. It reports on the different combinations of location of research, methodologies employed, participants from whom data was collected, research questions, and patterns in research results.

The starting point for the review was defining the topic and research question, followed by establishing criteria for including specific scholarly works in the dataset. Databases were identified for the search process, a table of keywords was established and studies were selected based on the inclusion criteria. A structured database for data analysis was established and data analysis was undertaken, followed by the writing process.

2.3.1 Selection of papers

This literature review forms part of a doctoral thesis – a study adopting an interpretive framework aimed at furthering understanding of ICT-integration. Typical of qualitative studies, the research approach involved sustained and extended engagement with the literature at different phases of the candidature. For this literature review, papers were purposefully selected based on criteria associated with their publication, participants and publication date.

Original research papers in English-language peer-reviewed educational journals were sought. Grey literature, such as government or business commissioned reports, newspaper articles and conference proceedings were excluded. The importance of grey literature to research (Lawrence, 2012) is acknowledged, and it is used elsewhere in this thesis. This exclusion of grey literature for the structured literature review helped define the scope of the dataset and ensured that the studies had been subjected to the quality-control process associated with scholarly peer-review processes that value methodological rigour.

This review sought studies where original data were collected from students and/or teachers at the senior secondary schooling level. This ensured that studies of ICT-integration were grounded in its practical applications by people working and learning in the context of senior secondary education.

Papers published between 2000 and 2012 are included in this review. Papers were selected to inform the writing of a doctoral thesis aimed at furthering understanding of ICT-integration in senior secondary education. A starting date of 2000 was selected because this marked the beginning of discourse associated with active participation in an information economy and a growing concern for pedagogical uses of ICTs (ANTA, 2000; International ICT Literacy Panel, 2002; Kearns, 2002; Kozma, 2005). The end date of 2012 marked the end of the data collection and beginning of the data-analysis period for the dissertation.

Papers were obtained from searches of the Scopus, Web of Science, A+ Education and EdITLib Digital Library electronic databases. These are large, comprehensive and

well-recognised scholarly databases used in education research. The variation in terminology relating to ICT-integration and senior secondary education is reflected in the large number of alternative keywords used to search databases (Table 2).

Table 2: Key terms used to search databases

ICT	Senior Secondary	Technology Integration
information and communication technologies	secondary	ICT enhanced learning
	upper secondary	technology enhanced learning
educational technologies	senior secondary education	computer enriched instruction (CEI)
educational technology	secondary education	technology enhanced curriculum
information communication and technology (ICT)	high school	computer assisted teaching (CAT)
information technology	senior secondary school	technology infusion
	Year 11 and 12	computer assisted learning
	Grade 12	technology augmented learning
		computer assisted instruction

Papers were downloaded into a reference manager (Thomson Reuter's EndNote) to facilitate recording bibliographic details including publication date, author details and the journal name, along with an electronic copy of the paper. An initial categorisation based on subject domain helped organise the papers for the pre-analysis. The pre-analysis involved reading abstracts and, if necessary, the methodology section to ensure that criteria associated with data collection and level of schooling were satisfied. Papers were sorted into subject areas during this phase (for example, mathematics, languages, chemistry etc.) in preparation for creating the database.

2.3.2   Constructing a database for analysis

QSR International's NVivo qualitative analysis software was used to structure a database of papers for analysis. The database was established with initial categories relating to the research questions outlined: ICT-integration definitions, areas of research, methodology, types of ICT use, characteristics and complexity. Additionally, contextual attributes, such as the country in which the study was situated, the level of schooling and the subject domain, were recorded.

2.3.3   Defining the focus of the literature review

Questions were identified to guide the literature review. Recommended areas of focus were the location of the research, the methodologies, subjects examined, variables measured, disciplines assessing the topic and patterns found in the results (Pickering & Byrne, 2013). Areas for focus in the context of ICT-integration also included the terminology associated with ICT-integration, types of ICTs in use and the characteristics of ICTs that make them useful to the teaching and learning process. The following focus questions guided the review of ICT-integration in senior secondary education literature:

- How are researchers defining ICT-integration?
- What problems are being investigated in the ICT-integration literature at the senior secondary level of schooling?
- What methodologies are used to investigate the phenomenon of ICT-integration?
- What types of ICTs are used in the senior secondary years?
- What are the characteristics and capabilities of ICTs in the context of senior secondary education?
- What barriers are associated with ICT-integration in senior secondary education?

These focus areas were used to establish an analytical framework to guide the reading and analysis.

2.3.4   Framework for analysis

The focus questions were used to formulate thematic codes that were constructed as *nodes* in the NVivo database. These codes were Terminology and definitions; Types of ICTs used; Methodology; and Findings (which encompassed characteristics of ICTs and barriers to ICT-integration). The analysis began by importing five papers across different subject areas typically studied in senior secondary schooling. These initial papers served to refine the structure of the database and develop a number of subcategories – for example, the categories *theoretical framework*, which informed the

research, and *analytical frameworks*, which related to data analysis, were added, as were further subdivisions related to methodologies. Additionally, the theme relating to "barriers" seemed too simplistic to describe findings associated with impediments to ICT use. A theme related to *complexity* was introduced. This was informed by an ICT-integration survey study (n = 280) with secondary mathematics teachers that categorised impediments to ICT-integration as instructional, curricular, and organisational (Handal, Campbell, Cavanagh, Petocz, & Kelly, 2013). Table 3 lists the final coding schema used to analyse ICT-integration literature. The remaining papers were imported and coding categories were populated.

Table 3: Database categories used in analysis of the ICT-integration literature

Database category (codes)	Description
Terminology and Definitions	Terminology relating to ICT use in school and the way that terminology was defined.
Types of ICTs used	Types of ICTs used
Problems researched	The area of research problematised
Methodology	Methodological approaches and perspectives adopted by researchers in executing the investigation.
Researcher design	
Theories informing research	
Participants	
Data types collected	
Research findings	Results relating to ICT use
Characteristics of ICTs (Affordances)	
Complexities	
Instructional	
Curricular	
Organisational	

2.4   Results

The results section begins by outlining the number and distribution of studies reviewed. It presents findings related to the definition of ICT-integration followed by a description of the way researchers have problematised the ICT-integration phenomenon. A review of the methodologies used by ICT-integration researchers is presented, followed by a synthesis of findings of the studies included in the review.

2.4.1   Number and distribution of papers located

Forty-five papers were located that complied with the inclusion criteria. A listing of papers included and a short description of each is presented in Appendix B. The

number of senior secondary ICT-integration papers published has increased in frequency over time and is likely a reflection of the increased prevalence of ICTs in secondary schools. Figure 1 shows the distribution of papers included in this review by publication date.
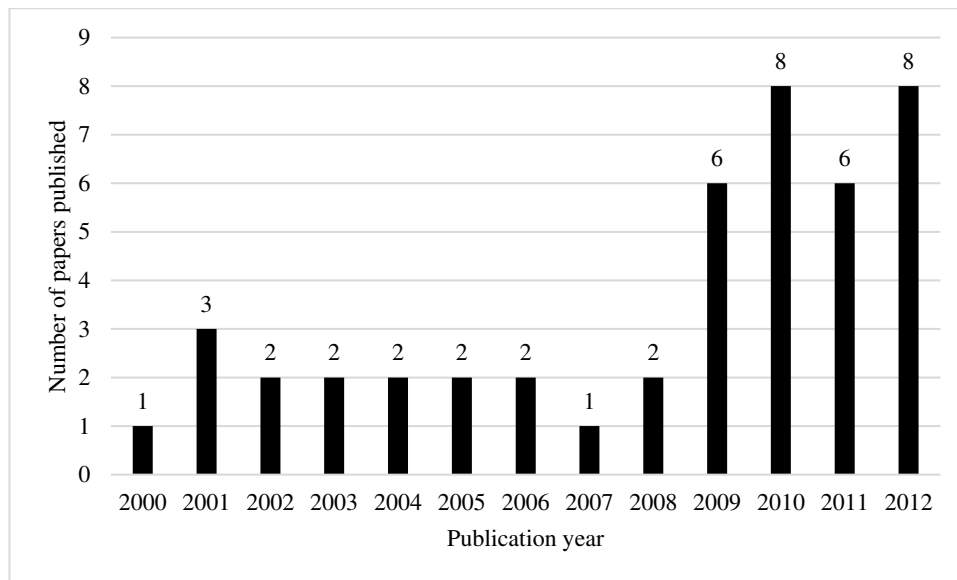
Figure 1: Number of senior secondary ICT-integration studies published 2000- 2012

The largest number of papers related to ICT use in senior secondary education by subject area were in mathematics (13), languages (6) and biology (5). Six general papers were also located that presented research in ICT in senior secondary education not pertaining to a specific subject domain. Figure 2 illustrates the distribution of papers included in this review by subject domain.
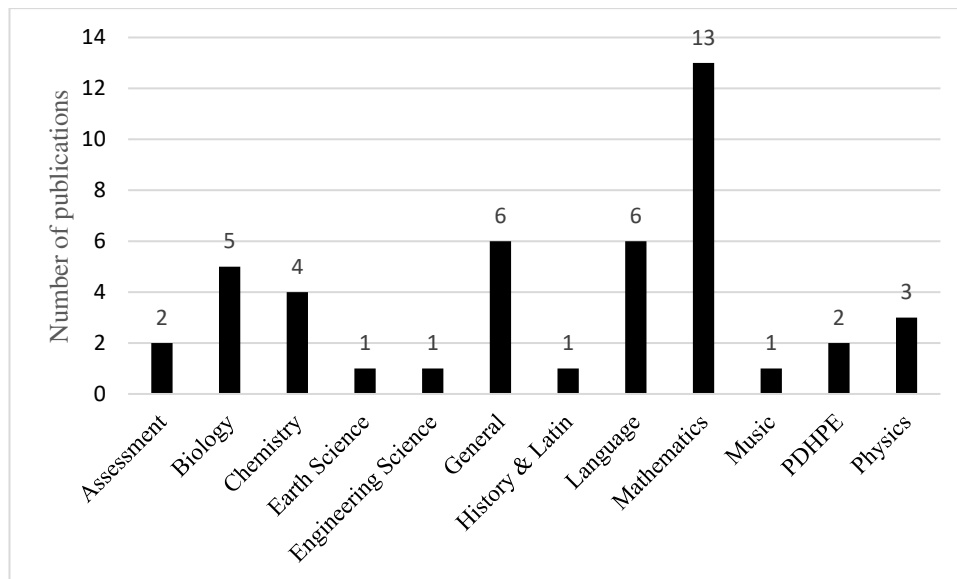
Figure 2: Distribution of papers by subject area

The studies reviewed were situated across 17 countries (Table 4). Thirteen papers were situated in the Australian context, six in Taiwan, four in Nigeria and the remaining 19 across 13 other countries.

Table 4: Distribution of location of research related to ICT in senior secondary education included in the review
Error! Not a valid link.

Of interest to the PhD study was research in the Australian context. Of the Australian publications, three did not specify the state, four were situated in New South Wales (NSW), four in Victoria and two in Western Australia (Table 5).

Table 5: Context of Australian senior secondary education ICT studies

Australian state	Number of studies
New South Wales	3
Queensland	1
Victoria	4
Western Australia	2
Unspecified	3
Total	13

The large number of papers drawn from Australia compared with numbers from other countries does not reflect Australia's domination of the field and is due to several factors. First, this study is situated in the Australian context with a focus on NSW

Higher Certificate (HSC) course teachers. Consequently, literature reviews undertaken when preparing results chapters as stand-alone journal articles targeted other work at HSC and Australian senior secondary level, and were part of the dataset of papers prior to undertaking the structured search specifically for the Chapter 2 literature review. Second, coinciding with the publication period included in the selection criteria (papers published between 2000 and 2012) was an Australian policy agenda, Learning for the Knowledge Society (ANTA, 2000), that adopted the *ICT-integration* nomenclature to describe the phenomenon of ICTs in school education. Because the terminology is so diverse in other countries (see section 2.4.2), extensive database searching did not locate large numbers of papers from a single country. A third factor contributing to the larger number of Australian papers located, was increased interest in the use of graphics calculators and computer algebraic systems related to changes in prescribed senior mathematics curriculum in two states (Ball, 2004; Goos & Bennison, 2008; Goos, Galbraith, Renshaw, & Geiger, 2000; Handal et al., 2011). This meant that several Australian research teams were focusing on the use of technologies in senior secondary mathematics during the publication period under review. As well as the 13 Australian papers, 32 international papers, representing a further 16 countries, are included in this review to ensure that bias of results towards the Australian context is minimised.

2.4.2 Terminology and definitions

Describing ICT-integration is necessary to communicate the nature of the phenomenon to others and to make sense of its diversity in different educational contexts. Twenty-one variations on terminology associated with ICT use in senior secondary education were used in papers identified in the dataset. Integration was a term that was used most frequently; however, it was not always combined with ICT. Integration of a technology, integrating technology, integration of ICT, integrate technology, technology-integrated learning and technology-integrated instruction were variations on the use of the phrase. Computer-assisted instruction and computer-aided instruction (CAI) were combined into one category; this was the second most common way to refer to the use of technologies in senior secondary education. The frequencies of various terms are listed in Table 6.

Table 6: Terminology used to describe ICT use in senior secondary education by papers included in the literature review

Terminology	Number of studies using terminology
Integration	24
Computer-assisted instruction	13
Computer-based instruction	9
Computer-mediated	5
E-Learning	5
21C learning	3
Computer-managed instruction (CMI)	3
Technology-enhanced learning (TEL)	3
CALL	2
Computer-supported instruction	2
Digital assessment	2
Educational technology	2
Media in education	2
Online learning	2
Tech-supported pedagogy	2
Technology-enriched classroom	2
Computer-based molecular modelling	2
Computer-simulated experiments	1
Computer-supported collaborative inquiry learning	1
Technology-augmented learning	1
Total	86

The total in Table 6 exceeds the number of studies reviewed, as many papers used more than one term to describe ICT use in the study.

It was difficult to ascertain patterns across time or subject domains with the relatively small number of papers located. Figure 3 shows the most commonly used terms categorised by subject and Figure 4 shows the distribution of terms over time.
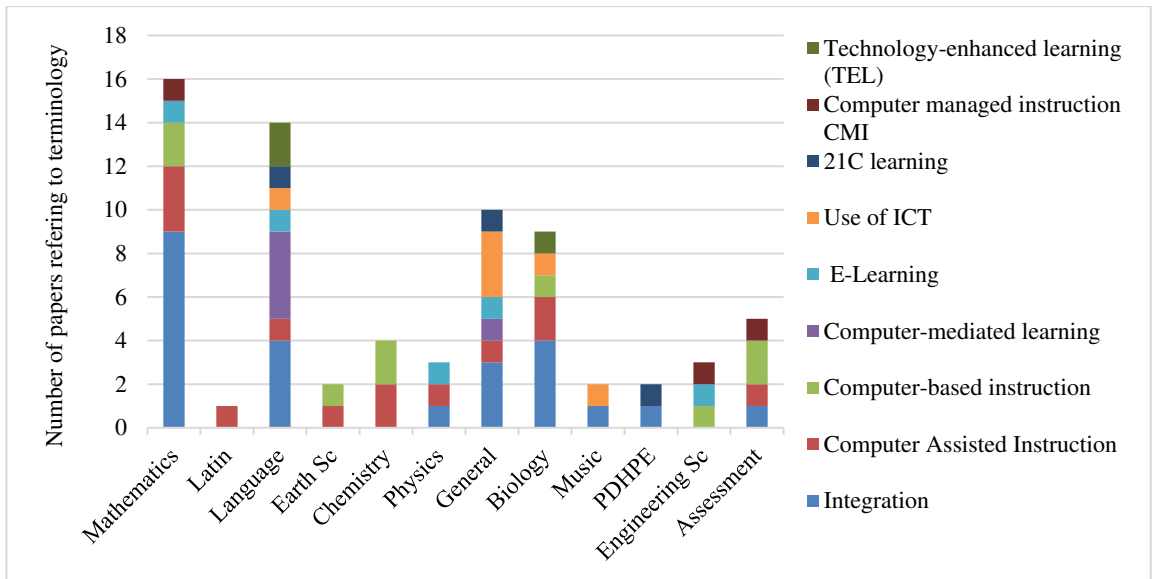
Figure 3: Distribution of terms used to describe ICT use in senior secondary education across subject area
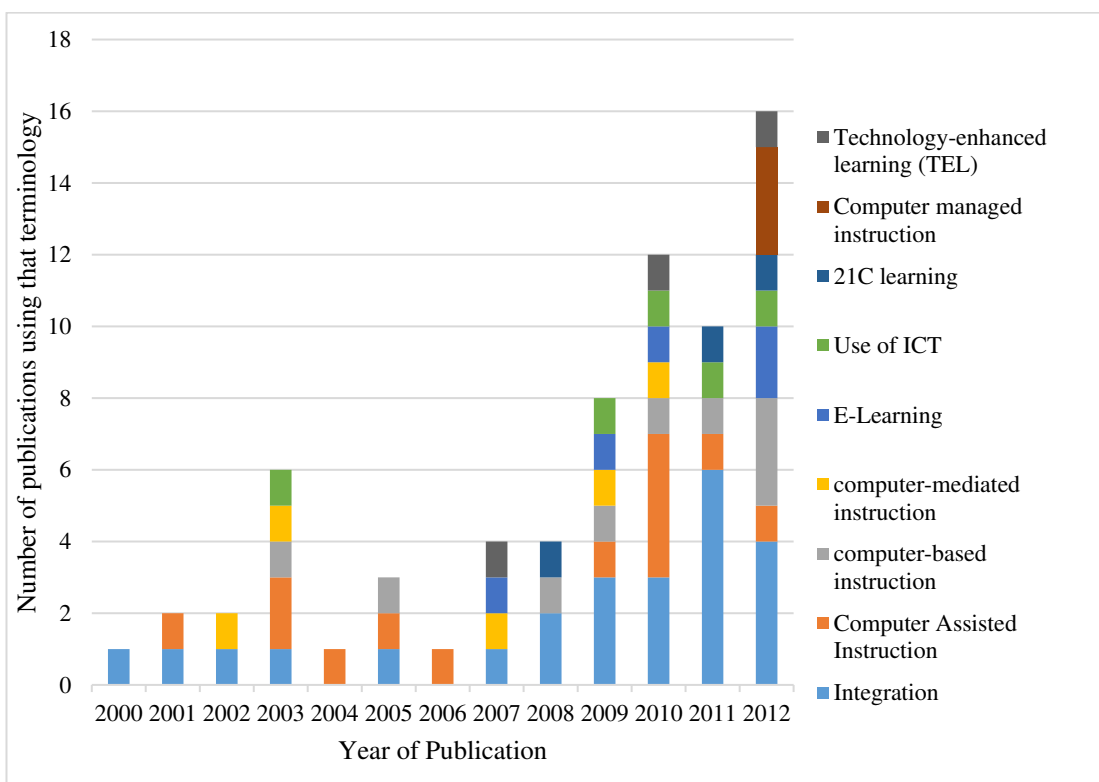
Figure 4: Distribution terms used to describe ICT use in senior secondary education between 2000 and 2012

Figure 3 shows that integration was the term most commonly associated with technology use in senior secondary education; however, computer-assisted instruction was more prevalent in the sciences. Figure 4 shows that 2003 marked the beginning of a number of terms appearing to describe ICT use in senior secondary education – a

trend that continued throughout the period under investigation. The Language subject area had the greatest variation of terms used to describe ICT use. Further complicating nomenclature associated with ICT-integration, was the fact that subject-specific journals often used subject-specific terminology. For example, in chemistry, terms included computerised molecular modelling (Aksela & Lundell, 2008; Kaberman & Dori, 2009) and computer-based science simulations (Udo & Etiubon, 2011); rather than more generic terminology such as ICT-integration.

Further analysis was undertaken on how journals or database repositories indexed the phenomenon of ICT-integration in schools. Keywords used by the journal to index each paper, when available, or keywords indexed by the cataloguing record in the research database were compared for the papers reviewed. By selecting only indexed terms relating to ICT use in education, 66 variations were located (Table 7).

Table 7: Terminology relating to ICT use in schools indexed by journal and database retrieval systems

Keywords	Number of studies	Keywords	Number of studies
Casyopee	1	electronic mail	1
collaborative learning	1	email	1
digital assessment	2	evaluation of CAL systems	1
educational technology	3	graphing calculators	1
MOO	1	ICT	2
technology integration	2	ICT education	1
access to computers	1	ICT in education	1
calculator	1	ICT-integration	2
communication technologies	1	ICT use	1
computer/s	4	information and communications technology	1
computer algebra systems	2	information technology	1
computer animation	1	information-communication technologies	1
computer anxiety	1	interactive learning environments	1
computer-assisted instruction	6	international collaboration	1
computer knowledge	1	internet	3
computer-managed learning	1	learning management system	1
computer science	1	learning technology	1

computer-simulated experiments	2		Learning object	1
computer software selection and evaluation	1		Mathematics – study & teaching	1
computer uses in education	3		mathematics – computer applications	1
computer utilisation	1		media	1
computer-assisted classroom	1		media in education	2
computer-based instruction	1		multimedia	1
computer-based science simulations	1		multimedia systems	1
computer-mediated communication	1		online learning	2
computer simulations	1		software environment	1
digital representations	1		technology	3
dynamic geometry	2		technology integration	2
educational games	1		technology-enhanced language learning	1
educational software	1		use of ICT	1
educational technology	3		virtual reality	2
elearning	3		Vroma	1
electronic learning	1		web-based instruction	1

The large variation in nomenclature presented in Table 6 and Table 7 illustrates the difficulty in performing searches for ICT-integration literature. This is reflective of the diversity in studies associated with different subject domains and the range of technologies used. The specific nature of most studies identified for this study meant that very specific terminology was adopted to describe ICT use, rather than the more generalisable term "ICT-integration". Further compounding this problem was the differing terminology associated with the senior secondary years of school. Despite this, 45 papers were located for inclusion in this review.

2.4.2.1 The naming of senior secondary education

Senior secondary education is named differently in different countries. For example, Australia uses terms such as "upper secondary" and "senior secondary", as well as "Year 11" or "Year 12". Schools in the US, Turkey and Taiwan use "high school" (Chang, 2004; Cuban, Kirkpatrick, & Peck, 2001; Sengel & Ozden, 2010). "Upper secondary" was favoured terminology in Germany (Scherer & Tiemann, 2012; Urhahne, Schanze, Bell, Mansfield, & Holmes, 2010), Finland (Aksela & Lundell, 2008), France (Lagrange, 2010), Norway (Solhaug, 2009) and Sweden (Lindberg &

Sahlin, 2011). "Form four" is the final year of school in Kenya (Ayere, Odera, & Agak, 2010). In Holland and Israel, authors referred to the final school year as Grade 12 (Bokhove & Drijvers, 2012; Kaberman & Dori, 2009). For this study, papers were selected that described teaching with students who were in their final years of secondary schooling. This included students described as senior secondary, upper secondary and high school. Students were included from Years 10, 11 and 12 and who were 16 years of age or older.

2.4.2.2   How ICT-integration is defined

ICT-integration is the use of technology to support teaching and learning in subjects other than computing studies. In some studies, technology use is described in the context of working towards a particular end-state, such as the attainment of *21st century skills* or *21st century learning* (Kaufman, Sauve, & Renaud, 2011; Yang & Wu, 2012). Outcomes of 21st century learning include information literacy, global literacy and media and technological skills, as well as cognitive skills such as critical thinking, problem-solving, communication, collaboration, creativity and innovation (Kaufman et al., 2011; Yang & Wu, 2012). In other cases ICT-supported learning outcomes were associated with subject-specific meaning-making of course content or topics (van Rooy, 2012; Xu & Moloney, 2011; Yusuf & Afolabi, 2010).

Research in ICT-integration in this dataset describes the development of these types of knowledge in the context of learning environments with access to technologies. These ICTs are digital, and often "emergent" – a term used in management and policy discourse to describe technologies characterised by their novelty, rapid uptake, impact in a particular context and unanticipated use (Halaweh, 2013; Rotolo, Hicks, & Martin, 2015). In the studies reviewed, examples of ICTs were varied and numerous. They included:

- Generic technologies such as internet technologies (Crawford, 2009; Cuban et al., 2001; Love, 2002; Yang & Chen, 2007; Young, 2003)
- Multimedia authoring tools (Chang, 2004; Tanaka-Ellis, 2010; Yang & Wu, 2012)
- Video conferencing systems (Yang & Chen, 2007)

- Instructional technologies such as learning management systems (Awodeyi & Tiamiyu, 2012; Lindberg & Sahlin, 2011; Solhaug, 2009; Williams, 2009) and display technologies (Chang, 2004; van Rooy, 2012; Xu & Moloney, 2011)

- Digital media (Bonvallet & De Luce, 2001; Penney, Jones, Newhouse, & Cambell, 2012; Williams, 2012; Yang & Wu, 2012)

- Subject-specific technologies such as mathematical analysis technologies (Ball, 2004; Crawford, 2009; Goos & Bennison, 2008; Goos et al., 2000; Handal et al., 2011; Varsavsky, 2012)

- Topic-specific technologies; for example, technologies that support learning about asthma education within health education (Kaufman et al., 2011), natural disasters within earth sciences (Chang, 2003), ecology within biology (Yusuf & Afolabi, 2010), astronomy (Taasoobshirazi, Zuiker, Anderson, & Hickey, 2006) and chemistry (Kaberman & Dori, 2009)

- Computer simulations and virtual realities (Bonvallet & De Luce, 2001; Hauptman, 2010; Sengel & Ozden, 2010; Udo & Etiubon, 2011)

- Leaning objects (reusable integrative tools supporting learning of specific content (Kay & Knaack, 2005)

- Desktop and laptop computers (Crawford, 2009; Solhaug, 2009; Yang & Chen, 2007) .

The list suggests that a broad range of ICTs are in use in senior secondary schools.

In many cases, terminology relating to ICT-integration was not explicitly defined. Rather, examples of the practice of ICT-integration were implicit within the investigation being described. Tools that enhanced collaboration between students across European countries in teaching content (Lindberg & Sahlin, 2011), the use of e-materials supporting online learning models (Ayere et al., 2010), new types of learning afforded by computer-mediated communication (Young, 2003) and scientific problem-solving using virtual laboratories (Scherer & Tiemann, 2012) are examples.

As well as describing the ICTs and their use, the papers focused on the pedagogies enhanced by the technologies and how they supported the learning of particular contents areas. For example, in a study of mathematics teachers' use of ICTs,

delineation between "procedural aspects of [teachers'] learning to use technology" and the integration of technology was evident (Goos & Bennison, p. 114). Another example was the close attention to pedagogies made possible by an interactive whiteboard that enhanced students' learning of specific aspects of Chinese language (Xu & Moloney, 2011). In another case, the researchers reported on the *learning design* employed by teachers in ICT-supported science learning environments (Urhahne et al., 2010). These examples support an ICT-integration definition that encompasses the use of a range of devices, software and online technologies, as well as the pedagogical approaches employed in the use of ICTs to support student learning (Lloyd, 2005).

The terminology used to label technology use in senior secondary education research is diverse, which is a reflection of the interdisciplinary nature of the ICT-integration phenomenon. ICT-integration encompasses notions of technology use in schools and pedagogical practices associated with its use. While the term "integration" was most often associated with technology use in the studies reviewed, it was by no means exclusive, with almost half of the papers located for this review adopting different nomenclature. Furthermore, scholarly databases, too, have indexed the ICT-integration literature using highly specific and very diverse terminology. This has created a challenge in bringing together the scholarship on the ICT-integration phenomena for this literature review.

2.4.3   Problematising ICT-integration

This section of the results investigated the types of problems under investigation in the area of ICT-integration research in senior secondary schools. The problems can be broadly categorised into those concerning learning environments; development, adoption and implementation of a new technology; the effects of teachers' or learners' dispositions on ICT adoption; and ICTs in the context of high-stakes assessment. As well, a number of studies focused on the capabilities offered by ICTs for teaching and learning specific course content and the impact on learning outcomes.

One area of research focused on problems associated with the learning environment and ICT adoption or effect on learning. This included the implications for computer

configurations, such as laptops versus laboratory-based desktops, and its effect on learning (Solhaug, 2009). Two studies considered levels of access to computers, infrastructure and electronic resources and implications for ICT-integration implementation at a systemic level (Ayere et al., 2010; Goos & Bennison, 2008), while other research explored how teachers were adapting to challenges associated with limited resources (Chang, 2001; Crawford, 2009; van Rooy, 2012). In addition to a lack of resources, one study investigated problems associated with a lack of quality and skilled teachers in addition to poor access to resources (Awodeyi & Tiamiyu, 2012; Yusuf & Afolabi, 2010). The deployment of ICTs in the form of e-learning modules and tutors was aimed at supporting both teachers and learners in senior mathematics classes in a developing country with limited resources (Awodeyi & Tiamiyu, 2012), and at improving science learning in the context of "poor quality" teachers in a Turkish study (Yusuf & Afolabi, 2010, p. 62).

Another line of research explored issues associated with the adoption and implementation of new technologies. For example, senior mathematics curricula in three Australian states were revised to include, and in some cases mandate, the use of graphic calculators (Ball, 2004; Goos & Bennison, 2008; Handal et al., 2011). In these studies, changes to pedagogical practice in senior mathematics were needed. Ball (2004) reported on the experiences of four Australian (Victorian) senior secondary mathematics teachers as they worked with researchers in developing new pedagogies enabled by computer algebraic system (CAS) or graphic calculators included in a new Year 11 and 12 Victorian (Australia) curriculum. A larger-scale study in Queensland examined pedagogical practices and beliefs related to a new syllabus mandating the use of graphics calculators in advanced mathematics courses (Goos & Bennison, 2008). They found that while access to technologies was an important factor affecting their uptake, teachers indicated that professional learning of pedagogies that align technology use with the development of mathematical concepts was needed (Goos & Bennison, 2008). In NSW, another study of the use of graphic calculators associated with a new syllabus investigated stages of adoption (Handal et al., 2011). In other countries, an Israeli study outlined ICTs developed to support senior chemistry curricula reform (Kaberman & Dori, 2009) and in the United States, Cuban et al. (2001) investigated ICT (non) use in two Californian high-tech high schools. Also

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included in this category were studies focusing on the design, and development of learning objects and virtual environments (Hauptman, 2010; Kay & Knaack, 2005).

Several studies considered teachers' and/or learners' dispositions and their effect on technology use. For example, in a mathematics study involving calculators, teacher dispositions related to the adoption of graphic calculators included competence, attitudes, interest, location, access to training and gender (Handal et al., 2011). In language instruction, the teacher's positive attitude towards the use of new ICTs was important in the successful integration of an interactive whiteboard in Chinese language teaching, while Olatoye's (2009) study explored barriers associated with student anxiety and digital competency in Nigerian senior secondary schools.

Several studies focused on the advantages offered by ICTs related to high-stakes assessment and the assessment process itself. Important in the context of high-stakes qualifications are challenges associated with assessment of learning. A US study explored the use of technology-supported learning tasks in the context of accountability associated with high-stakes assessment (Taasoobshirazi et al., 2006). Curriculum and learning activities aimed at developing scientific reasoning were designed around a virtual observatory for a high-school astronomy classroom (Taasoobshirazi et al., 2006). The research demonstrated that development of scientific reasoning skills and gains in the high-stakes criterion-referenced tests typically used in school accountability measures could be aligned. Another assessment study was based in Scotland, where a large-scale project explored the problem of awarding partial credit in computer-based assessment and the effect of changing the medium from paper to computer for test delivery (Ashton, Beevers, Korabinski, & Youngson, 2005, 2006).

These studies offer examples of assessment regimes conforming to existing testing practices or the development of computerised versions of paper tests. In contrast, an Australian project focused on the problem of assessing senior secondary course outcomes that do not lend themselves to being assessed with traditional pen-and-paper examinations (Penney et al., 2012; Williams, 2012). The study contributes to understanding problems associated with aligning course intentions to high-stakes summative assessment in the context of standardised external exit examinations.

Assessment processes were supported with ICTs that captured practical performance and exam outputs as digital representations in engineering studies (Williams, 2012) and physical education (Penney et al., 2012).

Teaching and learning associated with specific course content was a common area of research associated with ICT-integration studies at senior secondary level. Researchers contend that ICT-rich environments offer capabilities that have implications for how teachers teach and how students learn, and have framed models for the roles of technology in terms of teaching and learning interactions and the way technology is used (Goos et al., 2000; Yang & Wu, 2012). A problem identified is that technology is often applied in ways that target traditional instructional goals, such as simple presentation of content digitally or the use of technology that makes existing tasks more efficient (Yang & Wu, 2012). In response, a number of studies investigated ICT-supported pedagogies that targeted learning of particular content, promoted high-order cognitive processes and improved learning outcomes (Chang, 2004; Hauptman, 2010; Solhaug, 2009; Yang & Wu, 2012). In particular, collaboration, communication and co-construction of meaning were ICT-supported activities highly valued in senior secondary education (Bonvallet & De Luce, 2001; Goos et al., 2000; Taasoobshirazi et al., 2006; Tanaka-Ellis, 2010; Young, 2003).

Several studies investigated the challenges associated with the potential for pedagogies to promote authentic inquiry-based learning to support sense-making of concepts and theories. Computer simulations, modelling and virtual reality offer alternatives to traditional inquiry-based learning in senior secondary education (Hauptman, 2010; Sengel & Ozden, 2010; Taasoobshirazi et al., 2006; Udo & Etiubon, 2011); they also offer opportunities to employ student-centred pedagogies (Udo & Etiubon, 2011). Questions relating to whether simulations and virtual environments can help students acquire proficiency in science and mathematics were explored. In other studies, computer-based learning environments or tutorials targeted student meaning-making in a collaborative environment.

In summary, the ICT-integration studies reviewed were spread across a number of research areas. These included investigations into the implementation of a new

technology as a result of changes to mandated curricula; the feasibility of involving ICTs in new assessment processes; and issues with the adoption of ICTs, such as resourcing and teacher or student dispositions.

2.4.4   Methodologies used to investigate ICT-integration

This section of the literature review reports on the ways problems relating to ICT-integration were researched. It includes data about the theoretical frameworks guiding the research, the methodologies employed in the investigation, the types of data analysed and the analytical frameworks employed.

2.4.4.1   Theories, models and conceptual frameworks

Researchers used a range of theories, conceptual tools, frameworks and models in the production of knowledge relating to ICT-integration in senior secondary education. These theories and frameworks were used to clarify the problem at hand and inform research design, and provided a lens through which to interpret results.

Fifteen out of 45 studies explicated the theories and/or conceptual models informing their study. Table 8 summarises the theories used to inform the research reviewed. Where possible, the theory's origin reference is included.

Table 8: Summary of theories informing problematisation and/or analysis

Study	Theory, model or conception	Use/s
Aksela and Lundell (2008)	Diffusion of innovation/characteristics of implementation (Fullan, 2007; Rogers, 2003; cited in Aksela & Lundell, 2008)	Problematised the adoption of new ICT-supported teaching innovation (computer-based molecular modelling in chemistry)
Crawford (2009)	Constructivist theories of learning (Piaget, 1954, 1973; cited by Crawford, 2009)	Problematised pedagogical change needed for music learning in contemporary learning environments
Cuban et al. (2001)	'Slow revolution' of technology adoption; based on observations by economics research discussing the lag between the change in technology and realisation of associated benefits. Cuban proposes a conceptual framework associated with the 'historical residue' of modern comprehensive high schools	Framed and conceptualised explanations of teachers' underuse of technologies to support teaching and learning.
Goos et al. (2000)	Sociocultural theory (Wertsch, 1988; cited in Goos et al., 2000)	Mathematics learning – a focus on the tool-mediated aspect of learning – four roles of technology are theorised and used as an analytical lens for classroom observations
Handal et al. (2011)	Six stages of learning to use a technology (described by Russell, 1995 and then adapted by Christensen, 1997; cited by Handal et al., 2011)	Model of adoption was used as a framework to gauge and describe NSW Year 11 and 12 mathematics teachers' (lack of) uptake of graphics calculators
Hauptman (2010)	Constructivism (Duffy & Jonassen, 1992; cited in Hauptman, 2010)	Problemetised the design of "teaching processes" – simply providing the virtual learning environment is insufficient
(Kaberman & Dori, 2009)	A number of authors including Bloom's taxonomy (Bloom, 1956; cited in Kaberman & Dori, 2009).	Clarified definitions of higher-order thinking skills under investigation such as question posing, scientific inquiry, modelling; targeting of these skills was part of the design of chemistry computerised learning units.
Karlsson (2010)	Socioconstructivistic perspective (Vygotsky 1934/1986; cited in Karlsson, 2010)	Problematisation of learners' meaning-making of phenomena depicted in computer animations; interpreting human-computer interaction and human-human interactions
Kaufman et al. (2011)	Games learning	Theorised how games promote *structuring* and *integration* of knowledge
Lagrange (2010)	Frameworks of perspectives of learning involving *settings*, *registers of representation,* and *instrumental genesis,* along with theory of didactical situations	Language – Informed the design of an online learning environment and design of learning activities. Elements of the framework were used as an analytical lens for interpreting classroom observations
Love (2002)	Halliday's model of register (Halliday, 1978; cited in Love, 2002)	Language – proposed a method for systematic analysis of online discussion and evaluating the pedagogical effectiveness of discussions
Scherer and Tiemann (2012)	PISA's conceptualisation of the problem-solving process and conceptualisations of types of problems drawn from literature	Chemistry – conceptualisations were used to design a computer-based assessment tool aimed at measuring problem-solving knowledge
Solhaug (2009)	A conceptual theory of critical reflection. Draws on Critical Theory and others	Proposed a conceptual framework around variables of self-efficacy, motivation, grades, gender and cultural capital, and

Study	Theory, model or conception	Use/s
		developed a questionnaire to investigate development of critical reflection.
Yang and Wu (2012)	Social constructivist theory (Vygotskiĭ & Cole, 1978; cited in Yang & Wu, 2012)	Language learning – designed ICT-supported learning activities guided by constructivist principles
(Williams, 2009)	Constructivist theory of learning (Piaget)	Designed a sequence of biology learning activities guided by "constructivist principals"

Research investigating adoption of technologies was informed by theories relating to diffusion of innovation and change (Aksela & Lundell, 2008). Constructivist and sociocultural theories were employed in studies exploring ICT-supported instructional strategies, examining the role of technology in reshaping classroom interactions, designing a sequence of learning tasks and investigating teacher-student-technology interactions (Goos & Bennison, 2008; Goos et al., 2000; Yang & Wu, 2012).

Lagrange (2010) drew on several frameworks conceptualising perspectives of learning in the design of software aimed at algebra learning, and employing the Theory of Didactical Situations in the design of learning activities to use with the software. Similarly, (Bokhove & Drijvers, 2012) also drew on conceptualisations of algebraic competence and formative assessment to design a digital practice tool and a formative assessment tool to support mathematics learning. Two studies exploring cognitive processes invoked different theories to inform their design. A study elucidating factors affecting critical reflection drew on several theories to problematise the research and design of an instrument (Solhaug, 2009); Scherer & Tiemann's (2012) study used PISA's conceptualisation of the problem-solving process to design a computer-based assessment tool.

In sum, theories were not specific to ICT-integration in schools, coming instead from a number of areas including learning theories, theories that conceptualise cognitive processes and change theories. What is also notable is that the majority of papers reviewed in this study did not explicitly describe the theoretical underpinnings of their inquiry.

2.4.4.2 Research methods

The review sought to gain knowledge around the processes used to investigate ICT-integration. There is a close relationship between researchers' philosophy and underlying assumptions and the methodologies and methods they employ in the inquiry processes of educational research (Creswell, 2012b). Research approaches explicated in the papers included survey research, case study, ethnography and experimental design. Where the approach was not explicit, the term "descriptive research" was adopted. Although descriptive research is commonly associated with health-care research (Lambert & Lambert, 2012; Sandelowski, 2010), in this study it helped to categorise the diversity of naturalistic inquiry techniques that did not clearly fit one of the more established methodologies. Even though authors identified with a particular research approach, such as case study or experimental design, there was a great deal of diversity in how each approach was applied. A feature of all peer-reviewed studies included in this review was that authors included descriptions of participants, sampling techniques and data-collection and data-analysis processes.

Table 9 summarises the papers reviewed for this chapter by research approach and includes information about their data-collection techniques.

Table 9: Summary of research approaches and data types collected

Research Approach	Study	Data types
Case study	Xu and Moloney (2011)	Q, O, I
	Lindberg and Sahlin (2011)	I, D
	Aksela and Lundell (2008)	Q
	Handal et al. (2011)	Q
	Karlsson (2010)	O, I
	Yang and Chen (2007)	Q, I, E, D
	Young (2003)	T, E, O, I, L
Descriptive research	van Rooy (2012)	I, O
	Ghosh (2011)	Q
	Bonvallet and De Luce (2001)	O
	Gaudioso, Hernandez-del-Olmo, and Montero (2009)	O, Q
	Cuban et al. (2001)	O, I, S, D
	Love (2002)	E
	Goos et al. (2000)	O, I
	Urhahne et al. (2010)	Q
	Ball (2004)	O, E
	Penney et al. (2012)	Q, O, A, I
	Kay and Knaack (2005)	Q
	Ayere et al. (2010)	S, I
	Tanaka-Ellis (2010)	E, A, O, I
	Ashton et al. (2006)	O, T, A
	Lagrange (2010)	O
	Scherer and Tiemann (2012)	T
	Awodeyi and Tiamiyu (2012)	O, I, Q
	Kaufman et al. (2011)	T
	Taasoobshirazi et al. (2006)	T, O
Ethnographic research	Crawford (2009)	I, J, D
	Williams (2012)	T, O, I, A
Experimental research	Sengel and Ozden (2010)	T
	Ashton et al. (2005)	T
	Solhaug (2009)	Q, I
	Yang and Wu (2012)	T, Q, I
	Udo and Etiubon (2011)	T
	Williams (2009)	T, A, Q
	Hauptman (2010)	T
	Yusuf and Afolabi (2010)	T
	Bokhove and Drijvers (2012)	Q, L, T
	Chang (2003)	T, Q
	Kaberman and Dori (2009)	Q
	Chang (2004)	T, O
	Macintyre and Forbes (2002)	T, I
Survey research	Olatoye (2009)	S
	Varsavsky (2012)	S
	Goos and Bennison (2008)	S, Q

In summary, in the studies reviewed, the methodological approaches employed by researchers in ICT-integration studies in senior secondary schools were diverse and not specific to the ICT-integration phenomenon. They were diverse in terms of their philosophical orientations, as evidenced in the number of theoretical foundations employed. Theory was drawn more from general education theories, as such as the constructivist theory of learning and sociocultural theory. Cognitive theories associated with problem-solving and critical thinking were employed, and change theories associated with modelling predictions of human social behaviour or the uptake of an innovation were employed. Equally diverse were the research approaches and the range of investigative techniques employed within each approach.

2.5   Synthesis of findings relating to ICT-integration research

The final part of the literature review presents a synthesis of main research findings of papers selected for review. In the context of senior secondary education, these are categorised as *affordances of ICTs* in their role in the teaching and learning process; and *complexity* associated with ICT use or adoption. Each of these is detailed in the following sections.

2.5.1   Affordances of ICTs in the context of senior secondary teaching and learning

A common feature of the papers describing affordances related to the ways in which technologies supported teaching and learning. They were grouped according to the type of pedagogy or type of learning that was a focus or was noted in the reviewed studies. Themes relating to affordances were classified on the pedagogical advantage they provided.

The combined findings of the research reviewed overwhelmingly support the enabling role ICTs have in education. The term "affordance" is associated with the properties of an object in the context of human interactions (Koehler & Mishra, 2008) and acknowledges the social dimension of technology use. In this literature review in the

context of senior secondary education, affordances are the characteristics of an ICT associated with supporting teaching and learning processes. These affordances were categorised according to the type of teaching (pedagogy) that was being supported. Table 10 lists the types of pedagogies identified in the literature and their characteristics, and what ICT affords that particular pedagogical practice. Some of these are elaborated in the paragraphs following the table.

Table 10: Coding of characteristics of ICTs in senior secondary education

Pedagogy	Characteristics of ICTs (affordances)	No of references	Reference
Assessment	Efficiency in marking and delivery; increased means to assess outcomes; immediate feedback; performance capture; electronic quizzes; analytics; new ways to assess higher-order thinking skills; improving achievement.	9	(Ashton et al., 2005, 2006; Bokhove & Drijvers, 2012; Gaudioso et al., 2009; Kaberman & Dori, 2009; Penney et al., 2012; Taasoobshirazi et al., 2006; Urhahne et al., 2010; Williams, 2012)
Authentic pedagogies	Contemporary ICTs used by professionals are commonplace in schools (e.g. music-making software; multimedia and web-authoring tools); simulated inquiry environments	8	(Bonvallet & De Luce, 2001; Crawford, 2009; Lindberg & Sahlin, 2011; Penney et al., 2012; Taasoobshirazi et al., 2006; Urhahne et al., 2010; Yang & Chen, 2007; Yang & Wu, 2012)
Communication and collaboration	Computer-mediated communication tools afford electronic forms of discourse; co-creation of digital artefacts; interaction across geographical locations; interaction with experts; mediation of interactions	10	(Bonvallet & De Luce, 2001; Goos et al., 2000; Kaufman et al., 2011; Lindberg & Sahlin, 2011; Love, 2002; Urhahne et al., 2010; van Rooy, 2012; Xu & Moloney, 2011; Yang & Chen, 2007; Young, 2003)
Engagement and motivation	Immediate feedback; immediate realisation; learner control; creation of digital products; interaction with eLearning objects; active learning; learner control; real-time graphing and computation; Open-door students (Cuban et al., 2001) – computer used enhanced self-confidence and motivation to do well in school	12	(Aksela & Lundell, 2008; Crawford, 2009; Cuban et al., 2001; Ghosh, 2011; Goos et al., 2000; Hauptman, 2010; Macintyre & Forbes, 2002; Scherer & Tiemann, 2012; Sengel & Ozden, 2010; Udo & Etiubon, 2011; Urhahne et al., 2010; van Rooy, 2012; Williams, 2012; Xu & Moloney, 2011; Yang & Wu, 2012)
Meaning-making	Creation of digital artefacts such as reports and multimedia presentations;; visualisation – connections between theory and practice; making higher-level concepts accessible to all levels (CAS; music-making software); animation of unobservable phenomena; 'making sense of the invisible and untouchable'	12	(Aksela & Lundell, 2008; Chang, 2004; Crawford, 2009; Cuban et al., 2001; Ghosh, 2011; Goos et al., 2000; Kaberman & Dori, 2009; Karlsson, 2010; Macintyre & Forbes, 2002; Penney et al., 2012; Taasoobshirazi et al., 2006; van Rooy, 2012; Xu & Moloney, 2011; Yang & Wu, 2012)
Visualisation	"Amplifier" – making higher-level concepts accessible; fast-tracking of science investigations; virtual reality to promote spatial thinking; visualise symbolic expressions	8	(Aksela & Lundell, 2008; Ghosh, 2011; Handal et al., 2011; Hauptman, 2010; Kaberman & Dori, 2009; Karlsson, 2010; Macintyre & Forbes, 2002;

	graphically (CAS); introduce visual and modelling dimensions (CAS), illustration of unobservable phenomena and abstract concepts; digital media can facilitate students' to deconstruct and reconstruct content; Constructing and manipulating computerised atomic and molecular models developed 'representational competence'		Sengel & Ozden, 2010; van Rooy, 2012)
Higher-order thinking skills	Real-time graphing and computations, learner control, response-checking, immediate feedback; Question-posing, inquiry & modeling skills in chemistry; improved assessment methods to track development of higher-order thinking skills	5	(Ghosh, 2011; Kaberman & Dori, 2009; Macintyre & Forbes, 2002; Scherer & Tiemann, 2012; Sengel & Ozden, 2010; Young, 2003)
Investigations	Simulation as a replacement for costly hands-on first-hand investigations; sensors and computer software lessened time required for data collection, measurement and documentation enabling a focus on inquiry skills and analysis	5	(Chang, 2004; Kaberman & Dori, 2009; Sengel & Ozden, 2010; Udo & Etiubon, 2011; van Rooy, 2012)

Affordances related to assessment practices were reported by nine papers (seven studies) reviewed (Ashton et al., 2005, 2006; Bokhove & Drijvers, 2012; Gaudioso et al., 2009; Kaberman & Dori, 2009; Love, 2002; Penney et al., 2012; Scherer & Tiemann, 2012; Urhahne et al., 2010; Williams, 2012). Two assessment studies focused on a "proof-of-concept" – the role for ICTs in high-stakes senior secondary assessment programs. Enhancements included more-efficient assessment delivery and marking (Ashton et al., 2005, 2006) and increased means to assess outcomes that are not measurable in pen-and-paper tests (Penney et al., 2012; Williams, 2012). An Israeli study informed changes to national chemistry matriculation examinations that now include items that test for higher-order thinking skills as well as content (Kaberman & Dori, 2009) These studies demonstrated the potential for ICTs in improving processes and achievement in large-scale exit examinations characteristic of the senior secondary context.

Closely related to the idea of performance capture was the study demonstrating the integration of assessment and computer-based simulation (Scherer & Tiemann, 2012). As well as informing further refinement of the chemistry problem-solving construct, ICTs afforded the capture and analysis of students' interactions with objects within a

virtual chemistry laboratory, facilitating a problem-solving competency measure. In English, online discussions afforded the capture of student reasoning and students' writing of responses to literary texts (Love, 2002).

Formative assessment is another area that ICTs can enhance. Pretesting and topic tests were found to be easily implemented with electronic-quiz features typical of eLearning systems (Gaudioso et al., 2009; Taasoobshirazi et al., 2006; Urhahne et al., 2010). A physics tutorial system provided an example of the kinds of reporting and analytics that are available in purposefully designed e-learning systems (Gaudioso et al., 2009). As well as providing data on background knowledge through pre-testing, the analytics recommend groupings of students based on attributes relating to system interactions such as exercises completed, content coverage and performance. The affordance of the E-learning system in this case is greater transparency around students' learning processes, as opposed to summative grades generated at the conclusion of a topic or course.

Authentic pedagogy refers to teaching, learning and assessment practices that involve constructing knowledge through disciplined inquiry that has value beyond school (Newmann, Marks, & Gamoran, 1996). In eight studies, researchers reported on ICTs supporting authentic models of pedagogy (Bonvallet & De Luce, 2001; Crawford, 2009; Lindberg & Sahlin, 2011; Penney et al., 2012; Taasoobshirazi et al., 2006; Urhahne et al., 2010; Yang & Chen, 2007; Yang & Wu, 2012). Contemporary ICTs used by real-world professionals afforded students' authentic multimedia and art and music-making practice (Crawford, 2009; Yang & Wu, 2012). The collaborative processes afforded by communication technologies provided authentic environments where listening, speaking, comprehension, communication and collaborative skills were developed (Lindberg & Sahlin, 2011; Yang & Chen, 2007; Yang & Wu, 2012). Web 2.0 ICTs such as blogs gave larger audiences access to student-created works, as opposed to students preparing work simply to be judged by a teacher (Bonvallet & De Luce, 2001), and ICTs enabled inquiry and design to be embedded in real-world scientific problems and investigations (Taasoobshirazi et al., 2006).

Affordances related to communication and collaboration tools were reported by 10 studies. Online writing, discussion and communication tools afforded means for discourse in foreign-language courses (Bonvallet & De Luce, 2001; Yang & Chen, 2007; Yang & Wu, 2012; Young, 2003). Product-orientated tasks relying on ICTs, such as script-writing, multimedia production, game-playing and science inquiry e-Labs, afforded opportunities for peer feedback, communication in a second language and shared knowledge-building (Kaufman et al., 2011; Love, 2002; Urhahne et al., 2010; Yang & Wu, 2012; Young, 2003). ICTs also enabled collaboration between learners and access to educators and experts across geographic locations (Bonvallet & De Luce, 2001; Lindberg & Sahlin, 2011), and ICTs such as display technologies mediated student-student and student-teacher interactions (Goos et al., 2000; van Rooy, 2012; Xu & Moloney, 2011).

Twelve studies also attributed engagement and motivation to ICT-integration. Active learning through the creation of digital artefacts or through manipulating objects in simulated or eLearning environments was a characteristic of ICT-integration (Aksela & Lundell, 2008; Urhahne et al., 2010; Yang & Wu, 2012). ICTs that mediated class discussions and educational games were found to promote interactivity, student engagement and motivation (Goos et al., 2000; van Rooy, 2012; Xu & Moloney, 2011; Yang & Chen, 2007). Participants in a creative arts study used the term "immediate realisation" in discussing the affordances of music-making software: "the realisation of their musical efforts is immediate" (Crawford, 2009, p. 482). Characteristics of ICTs such as learner control, response checking, immediate feedback and computational processing encouraged engagement and facilitated cognition, problem-solving and critical thinking (Ghosh, 2011; Hauptman, 2010; Scherer & Tiemann, 2012; Sengel & Ozden, 2010).

Educators highly value meaning-making, the development of students' conceptual knowledge and its application (Ayres et al., 2004). Eleven studies identified characteristics of ICTs that support students' meaning-making. Examples include co-construction of meaning when students collaborated in the production of digital artefacts (Yang & Wu, 2012) and when they participated in ICT-mediated discussions and activities (Chang, 2004; Goos et al., 2000; Xu & Moloney, 2011). Researchers

reported that ICTs reduced the need for time-consuming and repetitive calculations so that the emphasis shifted towards observations of numerical and graphical output (Ghosh, 2011). In other examples, multimedia technologies enabled the visualisation of phenomena at the atomic level, enhancing students' conceptual understandings of science phenomena (Aksela & Lundell, 2008; Kaberman & Dori, 2009; van Rooy, 2012).

While high cost was often considered a barrier to ICT-integration, studies examining its use in science noted positive attributes related to reduced costs (Chang, 2004; Sengel & Ozden, 2010; Udo & Etiubon, 2011; van Rooy, 2012). Simulated laboratory environments and the increasing availability of online resources enabled first-hand investigative learning experiences for students where the cost of materials and the amount of time needed to collect results would otherwise be prohibitive.

Overall, the types of ICTs in use were varied, as were the pedagogical applications reported in the literature. The pedagogies reported on were consistent with those that would be expected at the senior secondary level of schoolings. The term *affordance* of ICTs was appropriate, as the technology use was bound to the content and the instructional practice (the social aspect) underway in the course of the study.

2.5.2   Complexity associated with ICT-integration

The second section relating to results of this review concerns the complexities associated with ICT-integration. The term "complexities" encompasses notions such as barriers to ICT-integration, impediments to effective implementation and conditions that support or work against teachers' adoption of ICTs to support teaching and learning. A framework, offered by an Australian mathematics ICT-integration study (Handal et al., 2013), was adapted for analysis for this section of the literature review. This study organises complexity associated with ICT-integration under three categories: instructional, curricular and organisational issues.

- Instructional issues concern complexities associated with the integration of ICTs with the practice of teaching and learning. They also include knowledge, perceptions and dispositions of teachers and learners.

- Organisational issues concern the logistics associated with ICT-integration.
- Curricular issues include complexities associated with state- or school-based curricula, such as the way ICT-integration is expressed (or not) in state-mandated curricula or assessment processes.

Instructional, organisational and curricular issues acknowledge the importance of context in developing an understanding of ICT-integration. Teachers make decisions about their use of technology to support learning activities within the context in which they are situated. The three areas of complexity - instructional, organisational and curricular issues provided a framework to organise contextual constraints and affordances associated with senior secondary teachers' ICT-integration identified in the literature.

2.5.2.1 Instructional issues

Effective or purposeful pedagogical practice was most commonly associated with successful learning outcomes related to ICT use in classrooms. Learning design, a concept that is increasingly connected to ICT implementation in education, refers to the processes of designing units of learning, learning activities or learning environments (Cameron, 2009). It has emerged as an important theme in the implementation of technology, with much of the research reviewed here indicating that successful ICT-integration is dependent on teacher actions, planning, knowledge and skills. Table 11 lists instructional issues associated with the complexity of ICT-integration. It provides a summary of each instructional issue and implications for the realisation of learning outcomes associated with ICT-integration. It also lists examples of shortcomings in instructional practice that hindered ICT-integration and examples of instructional practice that promoted effective realisation of learning outcomes associated with ICT-integration.

Table 11: Instructional issues associated with complexity ICT-integration

Instructional issue	Ineffective realisation of learning outcomes	Effective realisation of learning outcomes
Teacher's knowledge of learners	- Failure to assess learners' inadequate ICT skills or allow sufficient time for learners to develop ICT skills required to undertake a learning activity (Bonvallet & De Luce, 2001; Tanaka-Ellis, 2010) - Lack of students' subject content knowledge (Tanaka-Ellis, 2010; Yang & Chen, 2007) - Learners' lack of confidence in participating in an ICT-enabled learning activity or anxiety associated with ICT use (Olatoye, 2009; Yang & Chen, 2007) - A perception that learners will be de-skilled or that pen-and-paper learning is needed for students to construct knowledge or develop subject-specific skills (Handal et al., 2011)	
Learning and teaching resources	- Lack of prepared instructions and teaching materials relating to the ICT for teaching (Bonvallet & De Luce, 2001);	- Instructional resources that connect ICT use with content-related course outcomes (Ball, 2004; Urhahne et al., 2010) - Consideration of cultural and semiotic processes when selecting (Karlsson, 2010)
Learning design – instructional planning and implementation	- Inadequate classroom management relating to learners off-task (Tanaka-Ellis, 2010) - Unguided construction of meanings from digital animations can lead to misconceptions (Karlsson, 2010); students have negative perceptions of usefulness if learning objects are poor quality (Kay & Knaack, 2005)	- Interactive, well-organised teaching strategies (Chang, 2003, 2004; Yang & Wu, 2012) - Scaffolding ICT use (Yang & Wu, 2012) - An emphasis on student collaboration and production of digital artefacts (Goos et al., 2000; Yang & Wu, 2012) - Well-defined learning tasks (Aksela & Lundell, 2008; Chang, 2003) - Active role of the teacher (Aksela & Lundell, 2008; Bokhove & Drijvers, 2012; Urhahne et al., 2010; van Rooy, 2012) - Close monitoring of students' progress in online learning environments (Gaudioso et al., 2009; Urhahne et al., 2010) - Explicit teaching of visual-spatial thinking supported students' use of computerised molecular modelling (Kaberman & Dori, 2009)
Teacher's ICT skills and dispositions	- Teacher anxiety related to technology use (Tanaka-Ellis, 2010) - Limited or inadequate professional development (Crawford, 2009; Goos et al., 2000)	- Perception of self-competence (Handal et al., 2011) - Targeted professional learning that aligns technology use to specific subject content and instructional practice (Ball,

Instructional issue	Ineffective realisation of learning outcomes	Effective realisation of learning outcomes
	- Limited ICT skills (Aksela & Lundell, 2008; Yang & Chen, 2007) - Limited ability to deal with technological issues (Tanaka-Ellis, 2010) - A need for more pedagogical and technical training (Aksela & Lundell, 2008) - "Generic training available was irrelevant to teachers' specific needs (Cuban et al., 2001)	2004; Goos & Bennison, 2008; Handal et al., 2011; van Rooy, 2012) - Awareness of ICT's capability and how it can facilitate active learning and knowledge construction (Young, 2003) - Teachers' ICT skills and competence (Handal et al., 2011; Young, 2003) - Teachers' enthusiasm (Young, 2003)

In analysing the literature reporting realisation or enhancement of learning outcomes associated with ICT use, it is apparent that good teaching is at the heart of successful ICT-integration. Examples of pedagogies associated with successful integration include interactive and well-organised teaching strategies (for example, organised presentation sequences), use of audio and visual stimuli, an emphasis on student collaboration, well-defined learning tasks, scaffolding ICT use, the active role of the teacher in monitoring, intervening when necessary and helping students to link and apply knowledge during learning (Aksela & Lundell, 2008; Chang, 2003, 2004; Goos et al., 2000; Urhahne et al., 2010; van Rooy, 2012; Yang & Wu, 2012).

By contrast, limited success with ICT-integration was linked to shortcomings in instructional practice or teachers' knowledge. For example, learners' lack of second-language proficiency meant that computer-mediated learning activities were of limited value, as students experienced anxiety associated with conversing using synchronous computer communication tools (chat and video conference) (Tanaka-Ellis, 2010; Yang & Chen, 2007). Moreover, teachers' perceptions that pen-and-paper learning was needed for students to construct knowledge or develop subject specific skills (Handal et al., 2011), inadequate classroom management relating to learners off-task (Tanaka-Ellis, 2010) and teachers' limited ICT skills (Aksela & Lundell, 2008; Crawford, 2009; Yang & Chen, 2007) affected their confidence with using ICT in the classroom and their effectiveness in supporting students' learning with ICT.

In sum, the research reviewed aligned with the view that ICT-integration has an enabling role in senior secondary school education. The literature provided many examples of affordances of ICTs in supporting teaching and learning. The affordance

of the ICT aligned to the pedagogical practices typical of senior secondary education, such as assessment, communication and collaboration, meaning-making and visualisation. These affordances were described in the context of teaching specialist subject knowledge typical of senior secondary content. The literature review also showed that the realisation of these affordances in terms of positive impacts on learning outcomes was dependent on teacher actions, planning, knowledge and skills in the planning and delivery of ICT-integrated learning sequences.

2.5.2.2   Organisational issues

Organisational issues are concerned with the logistics of ICT use and implementation in schools. They include resourcing, scheduling, technical support and time-related issues. Some studies featured lack of resources as an issue associated with ineffective ICT-integration, often manifested as a lack of access to technology at school or at home, insufficient levels of infrastructure and inadequacy of existing infrastructure or its configuration. This results in fewer opportunities for ICT use (van Rooy, 2012; Young, 2003); lower levels of ICT use (Ayere et al., 2010; Goos & Bennison, 2008); teachers discouraged from planning to use technology; and students reluctant to use technology (Crawford, 2009; Handal et al., 2011). In contrast, research suggests that high levels of access to technology, is not in itself, sufficient for successful ICT-integration and several contextual factors influence teachers' pedagogical decision making with respect to educational technology use (Cuban et al., 2001). In developing countries and schools within low socioeconomic areas reported poor access to resources (Awodeyi & Tiamiyu, 2012; Ayere et al., 2010). Inequalities relating to home computer or internet access persisted in some cases (Young, 2003; Yusuf & Afolabi, 2010). In other cases the expectation that students would be accessing online resources or participating in computer-mediated communication seemed to be normalised (Aksela & Lundell, 2008; Bonvallet & De Luce, 2001; Crawford, 2009; Hauptman, 2010; Love, 2002; Tanaka-Ellis, 2010; van Rooy, 2012; Xu & Moloney, 2011).

Human resources relating to technical support also affected ICT-integration. For example, problems with the school network or workstations affected task outcomes, as ICTs were not available (Tanaka-Ellis, 2010; Yang & Chen, 2007); moreover,

where technical support was available, it was not timely, affecting available time with ICTs (Cuban et al., 2001; Tanaka-Ellis, 2010). Another researcher commented that ICT-integration was a "multi-disciplinary activity" requiring "a great deal of effort" from varying personnel within a school, and that this could be a potential constraint (Chang, 2004). A study trialling ICTs in the context of performance assessment noted that cooperation with schools' technical staff was essential for success, and that in some cases workarounds were implemented when technical problems such as slow Internet speeds could not be overcome (Penney et al., 2012; Williams, 2012).

Another example of an identified organisational issue related to logistics associated with scheduling and timetabling (Lindberg & Sahlin, 2011). In cases where computer communication was planned between schools in different countries, logistical challenges around school calendars and class timetables and the need to coordinate work with other schools needed to be overcome (Bonvallet & De Luce, 2001; Lindberg & Sahlin, 2011). In other cases, the limited time associated with a senior secondary lesson (typically 40 to 60 minutes) affected ICT-integrated learning (Kaufman et al., 2011; Yang & Chen, 2007) and the laboratory-based configuration of computers meant that it was difficult to book classes in to use those resources (Handal et al., 2011).

Leadership was an organisational attribute that affected teachers' use of ICT. A shared vision for ICT (Lindberg & Sahlin, 2011) positively affected teachers' use of, or intentions to use, ICTs. A lack of encouragement to use ICTs or a perceived lack of enthusiasm for ICTs discouraged teachers from using them in the classroom (Crawford, 2009; Handal et al., 2011).

A significant area of concern for senior secondary teachers integrating ICTs concerned time, such as time needed for preparing or sourcing digital resources and preparing ICT-supported units of work (Chang, 2004; Cuban et al., 2001; Goos & Bennison, 2008; van Rooy, 2012; Williams, 2009; Yang & Chen, 2007; Young, 2003) or additional time needed to respond to computer-mediated communications with students. For example: "In general, preparing a network session plus taking care of the after-class online activities demanded up to three to four times the class time that a traditional session required" (Young, 2003, p. 459). Teachers were also concerned that

adequate time would not be allocated to professional learning (Goos & Bennison, 2008).

"Historical legacy' was a term suggested by Cuban et al. (2001, p. 827) to explain uneven use of new technologies by teachers in two well-equipped Silicon Valley high schools. The high school context was characterised by organisational structures involving separate departments, teachers with specialist academic training and teaching time segmented into short periods in order to accommodate prescribed curricula. These structures, argues Cuban et al. (2001), act as barriers to adoption of innovations and school reform.

In sum, organisational issues connected with the logistics associated with ICT implementation were evident in the literature review. Issues such as the lack of ICT resources, insufficient technical support, school-timetable constraints, school leadership and insufficient time affected ICT-integrated teaching and learning at the senior secondary level of schooling.

2.5.2.3 Curricular issues

Curricular issues included complexities associated with state- or school-based curricula, such as the way ICT-integration is expressed (or not) and assessment processes that interact with it.

Assessment affects all teaching and learning because it influences what teachers and their students most value in the curriculum (McGaw, 2006). Senior secondary education typically entails students undertaking a prescribed course of study to meet requirements for an exit certificate or accreditation (Le Métais, 2003). School-based summative assessment and external assessments are characteristic of this context. Notions of the impact of assessment on ICT use, the impact of ICT use on achievement and ICT use that improves the processes of assessment were areas of focus for studies included in this review.

Issues associated with high-stakes exit examinations and ICT use were succinctly expressed by one study, which asserted that "separating learning from assessment

appears to be a major stumbling block" (Macintyre & Forbes, 2002, p. 50). The prescribed curriculum refers to the knowledge and skills set out in curriculum guides and education standards produced by education boards to which teachers' pedagogies, content representations and assessments are to be aligned. The prescriptive nature of the curriculum is intensified in senior secondary school, where exit examinations are externally set by the education authority. Participants in some studies did not see the need for ICTs in the context of high-stakes assessment that did not permit their use. Because of this, teachers felt ICTs were irrelevant and they gave low importance to ICT-integration (Handal et al., 2011; Macintyre & Forbes, 2002). Conversely, in a study where graphics calculators were prescribed in curriculum documents, a survey revealed they were the dominant technology, with most respondents using these ICTs sometimes or frequently to support learning (Goos & Bennison, 2008).

Much of the reviewed research lends support to ICTs' role in benefiting student learning in ways that translate to student achievement. Students learning through computer-simulated laboratory experiments and well-designed classroom instruction scored higher in an achievement test than a control group who learnt the same content through hands-on experiments (Sengel & Ozden, 2010; Udo & Etiubon, 2011). Another line of research prepared an astronomy unit of work that supported "significant test gains" in its second implementation year, and concluded that ICT-integration and raising high-stakes achievement scores were compatible (Taasoobshirazi et al., 2006, p. 394), In biology, computer-assisted instruction improved performance in an achievement test (Yusuf & Afolabi, 2010), and biology students undertaking an ICT-supported unit of work showed gains in post-test scores. Similarly, in languages, ICT project-based learning improved learner achievement in a second language (Yang & Wu, 2012). What these studies have in common is that ICTs *and* teaching strategies were aligned to discrete areas of prescribed course content, and therefore supported pedagogies and/or content representation to improve students' conceptual understanding of key concepts.

Curricular issues associated with time to complete the course were evident. Research reported teachers' concerns that ICTs would affect their time to cover the course (Aksela & Lundell, 2008; Williams, 2009), and that ensuring that students learned to

use the technology was an additional curriculum item to be included into course work (Goos & Bennison, 2008). Because ICTs were not part of the prescribed curriculum, their inclusion would take additional course time and affect teachers' ability to complete coursework.

In sum, the curricular issues encountered in the review of ICT-integration in senior secondary schooling concerned the way in which ICT-integration was expressed (or not) in senior secondary curricular documents, and a perceived mismatch between traditional pen-and-paper, high-stakes exit assessment practices that were devoid of ICTs and ICT-integration across the curriculum.

The reviewed studies demonstrate that the reasons for success in applications of ICT in supporting senior secondary education are complex. *Complexity* was purposefully selected as an overarching theme for the preceding section because simply overcoming a barrier or impediment may not be enough to ensure successful integration. Additionally, an examination of complexities, rather than a focus on impediments to ICT-integration, enabled the identification of practices that positively affected ICT-integration. Successful implementation depends on an array of factors relating to instructional practice, teachers' knowledge, curriculum issues and organisational factors.

2.6 Conclusion and further research

This final section of the literature review outlines gaps in research related to ICT-integration in senior secondary education and identifies areas for further research.

The research domain that this review covered, ICT-integration in senior secondary education, is generally underrepresented in the literature. What literature is available is difficult to locate, and therefore difficult to situate, because of the wide variation in terminology associated with ICT-integration and senior secondary education. Therefore, the relatively small number of empirical studies located (45) may be a result of challenges in database searching rather than a reflection of the quantity of studies within the senior secondary ICT-integration context. Relevant literature is easiest to locate when researchers are explicit about the contexts in which they are researching – the level of education, age groups of student participants and subject areas under

investigation. Clear and consistent terminology describing the phenomena under investigation (e.g. ICT-integration; technology-enhanced learning) would also enable specific studies of ICT-integration to be more easily positioned within the general field under inquiry.

Much of the literature analysed in this review was situated within a relatively controlled context, with researchers and teachers working together to implement an ICT intervention or pilot. Many of the studies were conducted with one specific technology and within one specific subject domain. While such studies provide valuable knowledge on a variety of ICTs and how they are used effectively in supporting learning-specific content, they do not create a general picture of ICT use in schools because they are disconnected from each other due to their diversity. What they do not reveal is how ICTs are being used in senior secondary education beyond these particular projects. Research into ICTs that are routinely used by senior secondary educators and how those ICTs enhance learning would be valuable contributions to the ICT-integration knowledge base. This aligns with calls for research into the "state-of-the-actual" of ICT-integration that acknowledges the socially constructed nature of technology use (Selwyn, 2010, p. 69). Context-rich accounts of ICT use acknowledging the social influences associated with the complex nature of teachers' work are needed to develop knowledge around what is actually taking place in schools, rather than what is possible (Selwyn, 2010).

In Australia and elsewhere, technology integration and technology competencies have been embedded across subject areas (Balanskat, Blamire, & Kefala, 2006; BECTA, 2006; Commission of the European Communities, 2008; Department for Education, 2011; MCEETYA, 2008c; U.S. Department of Education, 2010; UNESCO, 2013). As well as supporting and enhancing learning, ICTs are important in contemporary society for research, communication, working and socialisation. Literature located for this review was mainly confined to the mathematics and science disciplines. Few studies were included from the creative arts, and only one study was included from the humanities (Latin). Therefore, research focusing on how ICTs are used to improve student learning in specific subject areas that are relatively underrepresented would be a valuable contribution to the ICT-integration literature. Further research that includes

multiple subject areas (i.e. across disciplines) would be helpful in identifying commonalities and differences.

Teachers' knowledge is a worthy area for further research in the context of senior secondary education. Research shows that successful implementation of technologies is highly dependent on teachers' preparation of materials, their enactment of ICT-supported learning and their perceptions and attitudes towards students' knowledge construction. Teaching in senior secondary is not the same as teaching other levels of schooling. It is content-laden and constrained by prescribed curricula and high-stakes assessment. Thus, ICT use within this context will have its own particular set of characteristics, and research into the knowledge base of teachers within this context is a vital area for further exploration to develop understanding of how to support teachers in integrating ICTs effectively.

This chapter has presented a systematic review of the ICT-integration literature focusing on ICT use in the final years of secondary education. It was systematic in how papers were selected and offers a synthesis of findings related to ICT use and identified gaps in the literature. ICT-integration is defined very broadly in senior secondary education, and a diverse nomenclature set is used by researchers when describing the ICT-integration phenomenon. The methodologies used to investigate ICT-integration span both qualitative and quantitative methods, and there is great variation within the studies' specific methodological designs and investigative techniques. When theories were employed, they were important in problematising the research, analysing results and drawing conclusions. A number of research areas are being pursued in the senior secondary school context across assessment, implementation of ICTs, factors affecting ICT-integration and studies describing innovative uses of specific technologies relating to teaching and learning of subject content knowledge and skills. The enabling role ICTs have in senior secondary education was evident in the literature reviewed; however, affordances associated with ICTs in senior secondary teaching and learning depended on purposeful instructional strategies and learning activities, suggesting that teachers' knowledge is an important factor in ICT-integration. Identified gaps in the literature include the relatively small number of studies situated in the senior secondary schooling context and research into

teachers' knowledge and its manifestation within this particular context. There is a need for context-rich accounts of ICT-integration to develop knowledge around what is actually taking place in senior secondary school education and the social influences that affect practice. Additionally, identifying the knowledge structures that teachers require in this particular context would lead to improved understanding of effective ICT-integration practices that positively affect student outcomes.

CHAPTER 3: METHODOLOGY

3.1   Introduction

The purpose of this research was to investigate educators' uses of ICT to support teaching and learning within a context of increased access to ICTs and heightened expectations for ICT-integration in schools. This chapter presents the methodology for this qualitative study. It begins by justifying the choice of a qualitative research approach. The two-phase research design is presented along with data-collection and data-analysis methods. The chapter concludes by justifying the quality of the study and discussing limitations associated with the research.

3.2   Research Approach

This qualitative research sits within an interpretive framework that assumes that reality is socially constructed, that multiple constructions of that reality exist and that the researcher and the object influence each other (Lincoln & Guba, 1985). This approach enabled an understanding of ICT-integration to develop through a consideration of multiple perspectives of teacher-participants. Qualitative methods enable the inquiry processes to emerge, be sensitive to and include both inductive and deductive analysis in identifying themes pertinent to the phenomenon (Creswell, 2012b). In the case of this study, the interpretive approach enabled an understanding of ICT-integration to be developed through the perspective of teacher-participants' classroom experiences.

3.2.1   Positioning the researcher

Interpretive inquiry recognises the value of the researcher's subjectivity in the inquiry process (Lincoln & Guba, 1985). In phenomenological inquiry, it is important for researchers to articulate presuppositions and biases so that the reader is aware of the perspective from which the research was conducted (Hein & Austin, 2001). This inquiry was led by a researcher who is an experienced senior secondary teacher and has an additional responsibility for assisting secondary teachers with their ICT-integration. The researcher believes that effective ICT-integration is essential in contemporary education environments, and must be focused on enhanced student learning. In addition, this researcher is of the opinion that questions about ICT in education have moved beyond asking *should we* use technology in the classroom toward questions focusing on *how* we can best use ICTs in order to support and

enhance student learning. Despite the positive assumptions articulated, personal experience in working with ICT in secondary schools for more than 20 years suggests that effective ICT-integration remains ill-defined and a source of frustration for many secondary teachers.

The researcher's background can afford an "empathetically led method of engaging intersubjectively with the other" (Bradfield, 2007, p. 5). The intersubjective character in a phenomenological investigation means that the researcher's own experiences are the possible experiences of the participants, and the participants' experiences are the possible experiences of the researcher (van Manen, 1990). This insight afforded by the researcher's experiences provides a reference point to orientate the researcher to the phenomenon and stages of investigation (Tesch, 1987; van Manen, 1990). In this study, the researcher's background in ICT education provided an informed viewpoint from which to converse with participants who were using ICT to support teaching and learning, and to read what others, including governments and other researchers, had written on the subject of ICT-integration.

3.3   Research design

The research was designed as a two-phase qualitative study (Figure 5). The conceptualisation of the overall research project originated during a period of intense policy activity concerning ICT in school education. Phase 1 focused on Government policy associated with Australia's Digital Education Revolution (DER) – a policy field within which the research was situated. Phase 2 of the research explored the range and types of ICT use in non-computing studies in NSW senior secondary schools. Years 9 to 12 were the schooling years targeted by the DER. This provided an opportunity to examine ICT-integration during a period of increased access to ICTs and heightened expectations about the role of ICT in supporting teaching and learning in the senior secondary schooling years.
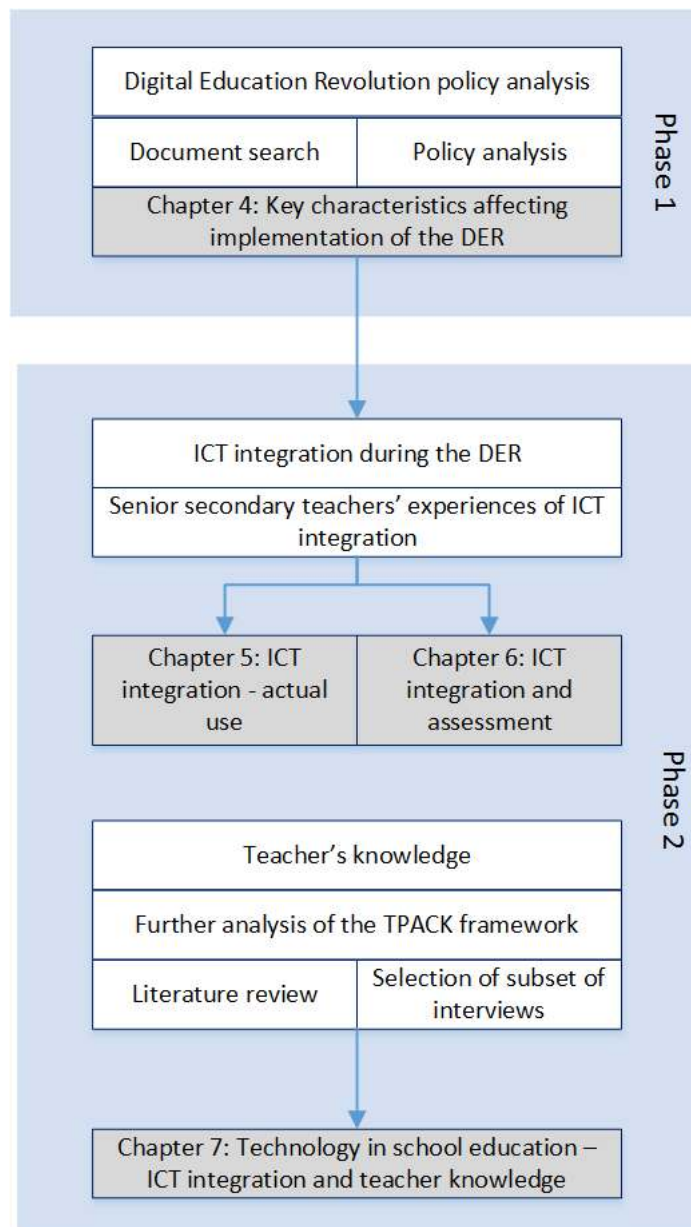
Figure 5: Graphic organiser illustrating the organisation of Phases 1 and 2 of the research process

3.3.1 Phase 1 – Australian ICT education policy analysis

Phase 1 of the project involved a document analysis of Australian Government education policy concerning ICT-integration. Document analysis is an established qualitative procedure involving the examination and interpretation of texts and images contained in printed and electronic documents (Bowen, 2009). Documents can provide data on the context within which the research was situated, as well as providing a valuable data source from which to elicit meaning and develop empirical knowledge

(Bowen, 2009). The aim for Phase 1 of the project was to analyse ICT-integration policy documents to better understand the context of the system within which senior secondary teachers work. The first problem identified for the current study was "*What were the key characteristics of intended changes advocated in DER education policy?*" Governments are a key force in educational change, and have the ability to bring about widespread, system-level change (Fullan, 2007). Policy describes a national vision and processes for intended change (Bacchi, 2009). In this case, ICT education policy has the capacity to describe the changes to education that governments are seeking; it provided the data source for this part of the research.

Data collection for the second phase of the study was undertaken during 2011; therefore, it was important to understand the policy climate of that time period. The study was situated within an intense education policy field known as Australia's Education Revolution (DEEWR, 2008c). A component of this reform, originating in the hype of a national election campaign, was the Digital Education Revolution (DER) that (amongst other initiatives) funded access to computers for every Australian secondary school student in Years 9 to 12 (DEEWR, 2009b; Rudd, 2007).

The methodology related to Phase 1, the policy analysis, is detailed in Chapter 4. The following provides a brief overview of the method used in this phase of the research.

A network of government agencies contributed to the education-policy field between 2008 and 2012. This time period spans the DER policy period and is inclusive of the data-collection period for Phase 2 of the study. Policy documents were sourced primarily through Internet searches of the websites of government agencies concerned with education policy. The National Goals provided a point of origin, beginning specifically with the National Goals for Schooling in the Twenty-First Century (The Adelaide Declaration, MCEETYA, 1999). Documents for this study were primarily sourced from those released between 2008 and 2012. Appendix D includes a visualisation of the policy field during the DER as well as a complete list of policy documents informing this study.

Policy analysis was framed by Fullan's (2007) model for the Characteristics of Change. Fullan (2007) describes nine implementation factors across categories of Change Characteristics, Local Characteristics and External Factors. These factors are important because they focus attention on the types of things that would have to change if the DER reform were to be fully implemented. Figure 6 (Chapter 4) depicts a graphic organiser that illustrates Fullan's (2007) factors related to implementation. The Change Characteristics are factors related to the innovation itself (Fullan, 2007). These four factors framed the DER policy analysis because they relate to teaching, learning and classroom practice. The model characterises the change process under the headings of Need, Clarity, Complexity and Quality and Practicality (Table 18). These characteristics and the way they were used in data analysis are further explained in Chapter 4.

3.3.2   Phase 2 – an exploration of ICT use in senior secondary education

Phase 2 of the project explored the range and types of ICT use in non-computing-studies subjects in the final years of schooling to better understand the role of technology in the senior secondary school. In Phase 1, implications for senior secondary school teachers were identified. Improved learning outcomes, ICT competencies and quality teachers were priority areas targeted by the Digital Education Revolution. Technology education became the responsibility of teachers in all the key learning areas (KLAs) as well as computing-studies teachers. Within this context of change, the study investigated how technology was being used by senior secondary school teachers in NSW schools. This was explored by eliciting experiences of participants teaching within this level of schooling.

The thesis-by-compilation format adopted for this study has meant that some repetition relating to the Phase 2 methodology and theoretical framework is evident in Chapters 5, 6 and 7. This is because some information has to be repeated to allow the manuscripts contained in these chapters to function as stand-alone pieces. The methodology for Phase 2 included in this chapter contains more detail than the methodology sections in Chapters 5 to 7.

3.3.2.1 Phase 2 research approach – phenomenology

This phase of the study adopted a phenomenological inquiry approach. Phenomenological methodologies are grounded in the writings of German philosopher Edmund Husserl (1859-1938) and the philosophers who expanded on his work, such as Heidegger (1889-1976), Sartre (1905-1980) and Merleau-Ponty (1908-1961) (Giorgi & Giorgi, 2003). This philosophical stance values knowledge creation through explorations of subjective descriptions of the lived world as people experience it (Bradfield, 2007). Phenomenology explores phenomena by studying the lived experiences of participants (van Manen, 1990). This is a suitable approach to guide the current investigation and the questions it seeks to explore because phenomenology is grounded in its openness to the value of teachers' descriptions of their practice and the meanings those descriptions impart (Bradfield, 2007).

Phenomenological research methodologies have been used widely in psychology and psychiatry (Bradfield, 2007; Giorgi & Giorgi, 2003); nursing (Reiners, 2012), and in education (van Manen, 1990). Within education, phenomenology has informed research into challenges for teachers with little training in the subject area they are required to teach (Bulman, 2008). Bourke (2008) argues that phenomenological studies make a valuable contribution in understanding inclusive education; Giles (2007), as a researcher in teacher education, explored the contribution of phenomenology in understanding teacher-student relationships. In a similar vein to the current study, Richardson's (2009) study demonstrated the use of a phenomenological approach in exploring instructional planning with technology in US schools through explorations of teachers' experiences.

The research design for Phase 2 of the study was guided by activities suggested by a number of phenomenological researchers including Bradfield (2007), (Giorgi, 1997), Tesch (1987) and van Manen (1990). The major components of the research are listed; however, it is important to note that this qualitative research process was inductive – shaped by the researcher's experiences in working in the field, researching the phenomenon and analysing the data. This is consistent with phenomenological methods (Creswell, 2012b).

The key components of the method in this research were:

1. A clarification of the problem under investigation.

   Clarifying the problem involved clearly defining the phenomenon under investigation (Creswell, 2012b). The phenomenon in this study was ICT-integration in senior secondary education. Engagement with the research literature and conceptualisations of ICT-integration were undertaken to explicate its meanings and manifestations in secondary education. This engagement with the literature was ongoing throughout the research process.

2. Exploration of the essential characteristics of the context within which the research was situated.

   A deep understanding of the context was aided by drawing on personal experiences the researcher brought to the study in helping senior secondary teachers with their technology integration, as well as her personal experiences of teaching senior secondary classes. This afforded an increased awareness of the phenomenon, as the researcher was "immediately and naturally in the activity" (van Manen, 1990, p. 36). In addition, Phase 1 of the study had elucidated the key characteristics of the policy climate during the time data was collected.

3. Examination of personal biases and knowledge that may prejudice data collection and analysis.

   Phenomenology challenges the researcher to acknowledge and identify previous understandings that might come into play, and to "bracket" (put aside) past knowledge, presumptions, preferences and inclinations about the phenomena being described (Giorgi, 1997; van Manen, 1990). The researcher is situated within the context of the current study in that she has over 20 years' experience as a teacher, with most of that time spent involved in senior secondary education in NSW schools. Currently, the researcher is a full-time teacher in a rural senior high school in NSW. The researcher is also responsible for assisting other teachers in use of technologies to support learning. Assumptions regarding personal beliefs that ICT should be considered an

essential element of modern teaching practices in ways that support and enrich learning experiences are acknowledged.

4. Elicitation of senior secondary teachers' experiences of ICT use as described by participants in semi-structured face-to-face interviews.

   Teacher-participant interviews were the means of gathering experiential data for the study (van Manen, 1990). Teacher-participants were drawn from NSW schools that were using ICT to support the delivery of their courses.

5. Systematic data analysis involving identification of essential key themes.

   Here, the term "theme" refers to a dimension or aspect of the phenomenon (Tesch, 1987). Data analysis began inductively through reading and re-reading transcripts to identify themes relating to ICT use. Further engagement with the literature and Phase 1 results identified frameworks and constructs that were useful in further identification of themes emerging from the data.

6. Writing descriptions of ICT use and reflection on the meanings of those descriptions.

   van Manen (1990) writes that "the aim of phenomenology is to transform the lived experience into a textual expression of its essence" (p. 36). These descriptions are elicited through results presented in research papers in Chapters 5, 6 and 7 of this dissertation.

3.3.2.2   Participants, ethics and recruitment

The University of Wollongong Human Research Ethics Committee granted approval to collect data from teacher-participants for this research (HE11/072; Appendix H). Permission was granted through the State Education Research Approval Process (SERAP) to contact NSW government schools to recruit teacher-participants (Appendix GAppendix GAppendix G). A similar approval process was completed prior to contacting Catholic diocesan schools. Participants were sought from government and non-government NSW schools. Government and non-government school principals were contacted by phone and asked if teachers may be available to participate. Teacher professional associations were also contacted and asked if any

association members who taught senior secondary subjects would participate. In total, 30 schools drawn from metropolitan and rural centres in NSW were contacted, of which 14 replied. No Catholic diocesan schools replied to requests to participate; consequently, they were not represented in the dataset.

From the pool of teachers who expressed an interest in participating, criterion sampling (Creswell, 2012b) was used to identify teachers who were actively using ICT to support teaching and learning in their subject areas. Teachers who exclusively taught information-technology or computer-studies subjects were excluded, as ICT is explicit in the concepts and skills taught in those courses. Upon initial contact, usually via email, principals and participants were forwarded an information pack explaining the purpose of the study and an outline of the interview procedure (Appendix I). Table 12 summarises participants by subject area and school type.

Table 12: Breakdown of participants by subject area and school type

Subject area	Number of participants (Government)	Number of participants (Non-government)	Total
Visual Arts	3	0	3
Music	0	2	2
English	1	1	2
Business Studies	1	0	1
Economics	1	0	1
Modern History	0	1	1
Languages	0	2	2
Mathematics	3	3	6
Science	5	1	6
Agriculture	2	0	2
Design and Technology	1	1	2
Totals	17	11	28

3.3.2.3 Phase 2 data collection

An interview protocol was designed to elicit descriptions of how and why teachers used ICTs to support teaching and learning (Appendix C). Guiding questions were informed by two areas of research, as well as the researcher's background in senior secondary education. The Technological Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006) informed questions relating to pedagogical content knowledge and technologies used to support content delivery and pedagogic

practices. As the second phase of this research was beginning, TPACK (Mishra & Koehler, 2006) was gaining acceptance as a framework for exploring ICT-integration (Agyei & Voogt, 2011; Archambault & Barnett, 2010; Archambault & Crippen, 2009; Graham, Burgoyne, et al., 2009; Harris & Hofer, 2009; Niess, 2011). The framework describes the relationship between core components of teachers' knowledge that come to the fore when teachers teach with ICTs – technological knowledge, pedagogical knowledge and content knowledge (Koehler & Mishra, 2008; Mishra & Koehler, 2006).

It is important to note that while TPACK was gaining momentum as a framework for ICT integration, potential issues relating to clarity of the construct and difficulties with its measurement were coming to the fore (Angeli & Valanides, 2009; Archambault & Barnett, 2010; Archambault & Crippen, 2009; Burgoyne, Graham, & Sudweeks, 2010; Graham, 2011; Graham, Cox, & Velasquez, 2009). These issues were not new to TPACK and were somewhat inherited from the parent pedagogical content knowledge (PCK) framework.

Shulman (1986) introduced the concept of pedagogical content knowledge (PCK) as a theoretical framework to conceptualise the knowledge base of teachers. PCK described categories of knowledge related to what teachers needed to know in order to teach particular subject matter content and emphasised the relationship between content knowledge and general pedagogical knowledge (Shulman, 1986b, 1987). While PCK scholars continued to build on Shulman's conceptualisation, issues with PCK related to a lack of consistent definitions of the domains of knowledge and related categories, which, in-turn posed challenges to their measurement and assessment of their development (Baxter & Lederman, 1999a; Gess-Newsome & Lederman, 1999).

Challenges associated with clarification of definitions of the constructs and associated complexities of measuring ill-defined constructs of TPACK are noted. In this study, TPACK provided a vocabulary that framed discourse with teachers about their uses of ICT to support teaching and learning; as well as an interpretive lens that enabled a deeper understanding of the ICT-integration phenomenon. Quantification was outside the scope of this study; and an important contribution of this study is that examples of

ICT-integration that align to TPACK's constructs are useful in further clarifying the framework and its manifestations. .

The second research area informing guiding questions related to policy analysis and the Australian Government's aims for ICT as an enabler of personalised and extended learning opportunities for students (AICTEC, 2009a; MCEETYA, 2008a). The data collection period for this study coincided with Australia's Digital Education Revolution enactment period (AICTEC, 2009b; DEEWR, 2008d). The Australian Information and Communications Technology in Education Committee stated that the Digital education – making change happen document (MCEETYA, 2008a) would be of value as an ICT planning guide in supporting ICT-integration in schools (AICTEC, 2009a). Elements of the Making change happen document most relevant to the Year 11 and 12 context where aspects from Elements 1, 5, 6 and 8 that directly related to teaching and learning with ICTs (MCEETYA, 2008a).

Semi-structured face-to-face interviews were undertaken in NSW school Terms 3 and 4 in 2011 at a time and place convenient for teacher-participants. Prior to the interviews, participants were provided with hard-copy information and consent forms (Appendix I). Informed consent for data collection and digital recording of interviews was obtained as required by ethics approval. At the conclusion of the interview, participants were afforded an opportunity to ask questions and were provided with contact details for follow-up questions or concerns after the interview. Participants were free to withdraw from the study at any time during the interview process or thereafter. Interviews lasted approximately 40 minutes and were conducted in a manner that encouraged natural dialogue between the researcher and teacher-participants. All interview audio was digitally recorded and transcribed into digital word-processed documents by the researcher. The interview protocol is presented in Appendix C.

The purpose of the interview was to obtain first-person descriptions of participants' experiences of teaching and learning with ICT. The development of the protocol was informed by definitions of TPACK constructs: in Table 17

- content knowledge (CK) – knowledge about the subject matter that must be taught (Mishra & Koehler, 2006). In NSW, subject matter is prescribed in syllabus documents published by the state education authority known as the Board of Studies.
- pedagogical knowledge (PK) – instructional processes or teaching strategies (Cox & Graham, 2009b; Mishra & Koehler, 2006); and
- technological knowledge (TK) - How to use emerging technologies (Cox & Graham, 2009a)
- pedagogical content knowledge (PCK) - combines knowledge of activities (or strategies) and knowledge of representations to facilitate student learning (Cox & Graham, 2009a).
- technological content knowledge (TCK) - knowledge of how to represent content with technology; knowledge of how representations are independent of the pedagogy (Cox & Graham, 2009a)..
- technological pedagogical knowledge (TPK) - knowing how instructional practice can be supported by using particular technologies (Mishra & Koehler, 2006) and
- technological pedagogical and content knowledge (TPACK) – "a knowledge of the technology-pedagogy-content interaction in the context of content-specific instructional strategies" (Cox & Graham, 2009b).

Questions were designed to elicit data on teachers' enactments of these constructs. They are further defined in Table 17. In addition, questions were designed to collect data on the following

- Context, including the type of ICTs available and the demographics and background of students.
- Implementation of Australian government policy initiatives such as the use of laptops in schools, information regarding parent portals, flexible learning environments and use of government funded online resource repositories.

The interview protocol was piloted with three participants to review the data collected, refine questions and familiarise the interviewer with the protocol. Interviews were

audio-recorded and transcribed. The transcripts were imported into qualitative data analysis software and coded using the framework described in the next section.

3.3.2.4 Phase 2 data analysis

Data analysis for the second phase of the study involved making sense of the large data set collected. The process began with transcribing the audio recordings to produce 28 electronic transcripts. Transcription by the researcher afforded the beginnings of an *immersion* process aligning with Tesch's (1987) idea that "analytical activities begin with an immersion in the data as a whole" during the phenomenological-analysis process (p. 232). During transcription, the texts were segmented by electronically highlighting the main questions outlined in the interview protocol. Research notes were included (usually after each question) to record reflections as they occurred during transcription. Directly after transcription, a short summary of the interview was included at the end of the transcript. This process marked the beginning of what has been called a spiralling motion of data analysis, where distinct phases of data analysis are not obvious (Creswell, 2012b; Tesch, 1987). In this study, the process of transcribing, reading and annotating that were followed for each interview helped the researcher gain an overall sense of the teacher-participants' personal experiences.

Transcripts were then imported into a qualitative data analysis computer program (QSR International's NVivo). A first-level pass through a subset of the data established a coding scheme that largely reflected the question areas included in the protocol (Table 13).

.Table 13: First-level coding scheme used to organise data

Code Descriptors	Description

Context
    Type of students
    ICT at the school
    Number of students in class
	Contextual characteristics of the teacher, such as the year level of classes (Year 11 or 12), number of students in their class, relevant demographic information about the students generally and students' access to ICTs.

Access to personal computer Access to IWB for all lessons	Teacher's access to ICTs (shared/desktop/laptop) Whether the teacher had access to an interactive whiteboard in his/her teaching location/s.

Teacher ICT levels and confidence
    Communicate or interact with colleagues, students or parents using ICT
    Use of ICTs to create resources or in planning
    Comfort and confidence
	Coded questions concerning teachers' skill and confidence in using ICTs.

Topics you are teaching	Specific question about topics that were currently being taught in Year 11 and/or Year 12 courses.

ICT to support delivery of topics
    How ICT supports learning of topic
    ICT use for efficiency or productivity
    Moving beyond efficiency
    Limitations and affordances
    Internet resources
    Types of ICT used
	These codes were initially designed to analyse teachers' talk about their ICT use. Teachers typically did not talk about specific ICTs in an order or at a particular part of the interview. Interview transcripts were read and specific references to ICTs and their use were tagged with these initial categories.

Teaching strategies to support those topics	This code was used to tag teachers' talk about pedagogies and identify instructional strategies used to teach topic content.
Assessment strategies	This code was used to categorise the types of ICTs used to support school-based assessment practices.
Unit planning	ICT use involved in planning a unit of work.
Student ICT skills	Teachers were asked about their students' ICT skills.
TLF or SCOOTLE	The Learning Federation (TLF) was superseded by Scootle – a Government-funded initiative providing online content to Australian school teachers. Teachers were asked about its use.
Potential uses of ICT	Teachers were asked if they would like to do something with ICTs in their class that they were not currently doing
Benefits to teachers in integrating ICTs	Teachers were asked if they saw any benefits to integrating ICTs in their subject area
Benefits to students	Teachers were asked about benefits to students in technology use in their subject area

From this initial *orientation* to teachers' descriptions of their ICT use, it became apparent that elements of the Phase 1 policy analysis as well as the TPACK model

would be helpful in organising the large amount of qualitative data collected. An analytical framework was developed drawing on elements from the Australian government policy document *Digital Education, Making Change Happen* (MCEETYA, 2008a). This document was developed by the *ICT in Schools Taskforce* to support planning for ICT-integration, and was intended to provide a framework for ICT implementation under the *Digital Education Revolution* policy (AICTEC, 2009b). These frameworks are discussed in the next section.

3.3.2.4.1 Analytical framework for ICT-integration

A guide for DER implementation, *Digital Education, Making Change Happen* (MCEETYA, 2008a), describes ICT use across 10 elements of quality schooling. Descriptors under each element are framed in terms of a continuum from Developing School through Accomplished School, and finally to Leading School. The elements of the framework most relevant in the context of teaching and learning in NSW Year 11 and 12 are:

- Element 1: Personalising and extending student learning
- Element 5: Improving student assessment and reporting
- Element 6: Developing, measuring and monitoring digital literacies
- Element 8: Providing, accessing and managing teaching and learning resources.

Element 1 is concerned with personalising and extending student learning; within this element, ICT uses relating to classroom practices are categorised (MCEETYA, 2008a, p. 7). Definitions for these ICT-use categories were developed specifically for this study (Table 14).

Table 14: Element 1 categories of ICT use in supporting student learning

Students use ICT to	Description
Collaborate, share and communicate	Collaboration involves formal and informal learning activities where students work together to achieve a common goal, such as developing understanding of content, acquiring a new skill or completing a group assignment. Sharing involves students accessing shared resources, and communicating refers to electronic mail or use of discussion forums.
Conceptualise, produce, create and acquire knowledge	These activities are part of knowledge-acquisition processes. Conceptualisation (to form concepts and ideas) is a part of cognition where abstractions are used to organise and make sense of new information (Woolfolk & Margetts, 2010). Uses of ICTs in this context included use of visualisation technologies and students producing and creating artefacts such as presentations, reports and other digital media.
Question and enquire	This category involved students searching for answers to teacher-generated or self-generated questions in research tasks, science and agriculture experiments and major projects associated with HSC practical examinations.
Solve problems and think critically	Activities falling into this category include students applying knowledge, connecting interrelated concepts, thinking things through, asking their own questions, analysing data and interpreting information rather than reproducing facts (Ayres et al., 2004). Critical thinking is a component of the problem-solving process, along with creative thinking and metacognition (Sale, 2001).
Manage information	This category refers to technologies used to access, acquire, organise, store and distribute learning resources.

Element 5, relating to student assessment and reporting, was important because of the nature of high-stakes assessment in NSW Years 11 and 12. Element 6, concerning student ICT capabilities, was included because student competency with ICT had become the responsibility of all teachers. Element 8 was concerned with the use of new teaching and learning resources and the use of digital repositories – an area targeted by government funding in the lead-up to and during the Digital Education Revolution. These elements are described in Table 15.

Table 15: Elements relating to student assessment, digital literacies and teaching resources

Element	Description
Element 5: Improving Student Assessment	Students are encouraged to use a range of ICTs to demonstrate connections between the curriculum, personalised learning goals, assessment criteria and learning. ICT products may be used as evidence of learning (MCEETYA, 2008a, p. 11)
Element 6: Developing and monitoring digital literacies	Students demonstrate high levels of engagement, confidence and skill in using ICT in their learning.
Element 8: Teaching and learning resources	The use of systems (e.g. content management systems) that enable creation of digital teaching and learning resources; the use of nationally developed digital content in the school.

Additionally, data was collected during the Digital Education Revolution, when students in NSW government schools were provided with laptop computers (NSW DET, 2009b). This afforded an opportunity to investigate ICT-integration in the context of one-to-one mobile computing in schools. A code was added so that dialogue relating to DER laptop computer use and ICT-integration could be analysed

These elements were then added as thematic codes to the database for data analysis. A more thorough pass through the data was undertaken. When analysing the data using the codes outlined above, it became apparent that certain technologies were associated with each of the coding categories. These technologies are included under each code, and the final coding scheme is presented in Table 16.

Table 16: Coding scheme used to analyse ICT use described in teacher-participants' experiences

Element	Name	Description
Element 1	Personalising and extending student learning	
	Collaborate, share and communicate	ICTs described in teachers' experiences associated with collaboration, sharing and communication
	Email	
	Intranet	
	Presentation	
	Shared drive	
	Social media	
	Video conference	
	Other	
	Conceptualising, producing, creating and acquiring knowledge	ICTs described in teachers' experiences associated with conceptualising, producing, creating and acquiring knowledge
	Creating products	
	Maths apps	
	Visualisation	
	VR (virtual experiences)	
	Other	
	Managing information	ICTs used to manage data and information
	Questioning and enquiring	ICTs used for question and inquiry activities
	Solving problems and thinking critically	ICTs that supported problem-solving
	Drilling and practising	ICTs used for reinforcement and exam preparation
Element 5	Improving student assessment and reporting	Use of ICT to support school-based assessment practices
	Enhancing assessment	
	Streamlining with ICT	
Element 6	Digital literacies	Teachers' awareness of digital literacies – need for student skills, improving students' ICT skills
	Engagement and motivation	
	Planning for DL	
	Skill level and acquisition	
Element 8	Teaching and learning resources	
	Collaborating and networking	
	Digital resources	
	TLF – Scootle – digital content	
	Non-use	Specific mention of ICTs not being used
	Laptops	Reference to DER laptops

To deconstruct the data, a "selective or highlighting approach" (van Manen, 1990, p. 93) was used, in which the transcript texts were read several times to select phrases that were then electronically highlighted and "tagged" with the descriptive terms set out in Table 16.

The highlighting and tagging approach revealed that excerpts relating to Elements 1, 6 and 8 produced considerable overlap, and that teacher-participants described digital literacies and teaching and learning resources within the context of uses explicated under Element 1. Therefore, phenomenological themes were conceptualised as "structures of experience" (van Manen, 1990, p. 79) relating to collaboration, sharing and communicating; conceptualising, producing, creating and acquiring knowledge; questioning and enquiring; problem-solving and critical thinking; and managing information (Table 14). In addition, a further theme relating to impediments to ICT use emerged. Results relating to these areas of the data analysis were prepared as a journal article for publication, titled *Information and communications technology integration in senior secondary education*. This paper is presented as Chapter 5.

In considering the data relating to Element 5 (improving student assessment and reporting), further engagement with the assessment literature was required to help with sense-making. Literature relating to the role of assessment in teaching and learning and the nature, purpose and impacts of high-stakes summative assessment was considered. Findings relating to this part of the data analysis were prepared as a journal article for publication, titled *ICT use in senior secondary high-stakes assessment*. This paper is presented as Chapter 6.

3.3.2.4.2   Analytical framework for teacher knowledge (TPACK)

Interpretation of qualitative data involves "abstracting out beyond the codes and themes to the larger meaning of the data" (Creswell, 2012b; Kindle Locations 3579-3580). The questions that framed Phase 2 of this research are about how and why teachers use technologies during the teaching and learning process. Inherent in this process are knowledge ensembles that come into play when teachers make decisions about the content they will cover and appropriate pedagogical practices that optimise student learning. The technological pedagogical content knowledge (TPACK) framework (Mishra & Koehler, 2006) provided an interpretive lens that enabled a deeper understanding of the ICT-integration phenomenon. In addition, interpretation within the TPACK construct enabled the research to be positioned within a broader

context and a larger knowledge base concerning ICT-integration (Anyon, 2008; Creswell, 2012b).

The TPACK framework added knowledge bases to Shulman's (1986b) Pedagogical Content Knowledge (PCK) model. It is based on the premise that knowledge of technology and how it works – technological knowledge (TK) – cannot be thought of as a mutually exclusive body of knowledge, and that quality teaching involves an application of the three intersecting knowledge bases of CK, PK and TK. The areas of intersection are called technological content knowledge (TCK), technological pedagogical knowledge (TPK) and technological pedagogical content knowledge (TPACK) (Koehler & Mishra, 2009; Mishra & Koehler, 2006).

Since its inception, a conceptual analysis of the TPACK framework involving interviews with "leading TPACK researchers" enabled a refinement of the construct's definitions (Cox, 2008, p. 31). The refinement included a technical analysis that resulted in expansive definitions; however, it was noted that they were "too broad to facilitate the classification of examples of teacher knowledge" (Cox, 2008, p. 66) and therefore, "précising" definitions were crafted (Cox, 2008; Cox & Graham, 2009b). The intent of this process was to "make the definitions very precise and clear while also reducing them to their simplest form to facilitate consistent use" (Cox & Graham, 2009b, p. 4043). Cox and Graham (2009a) illustrated the use of their précising definitions with case-study examples; these definitions were used in this study. The analytical framework that comprised the TPACK constructs and their definitions is described in Table 17.
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Table 17: Definitions of the TPACK constructs used in interpreting the data (adapted from definitions described by Cox & Graham, 2009a, 2009b)

TPACK construct	Definition
TK	How to use emerging technologies – Cox and Graham (2009a) narrowed the TK definition to *emerging* technologies – technologies that are not yet transparent in the teaching and learning context.
CK	Topic-specific representations, independent of pedagogical activities or how one might use those representations to teach; e.g. a model of electron flow.
PK	General pedagogical activities that can be used with any content – may include strategies for motivating students, communicating with students and parents, presenting information to students, classroom management; these strategies could be applied across all content domains; other examples include discovery learning, cooperative learning, problem-based learning etc.; pedagogical activities that could be generalised for use with multiple topics across multiple subject areas.
PCK	Combines knowledge of activities (or strategies) and knowledge of representations to facilitate student learning; pedagogical activities are content-specific rather than general. They can be subject-specific activities used across topics, or topic-specific activities used to teach that topic. Includes knowledge of how the activity can facilitate understanding.
TCK	Knowledge of how to represent content with technology; knowledge of how representations are independent of the pedagogy.
TPK	General pedagogical activities that a teacher employs with emerging technologies – e.g. how to motivate students using technology; how to engage students in cooperative learning using technology – independent of specific content because they could be used in any subject area.
TPACK	A teacher's knowledge of how to coordinate the use of subject-specific or topic-specific activities with topic-specific representations using emerging technologies to facilitate student learning.

TPACK constructs were used in interpreting teachers' experiences of ICT-integration; these are reported in the papers on ICT use (Chapter 5) and ICT use and assessment (Chapter 6). TPACK also forms the basis of the results presented in Chapter 7. This research paper offers an example of TPACK's use in guiding a research project focusing on ICT use by senior secondary teachers. In the context of content-laden senior secondary education, a particular focus on one construct, TCK, was adopted in an effort to contribute to TPACK's theoretical development.

In summary, TPACK constructs were used in the following ways in Phase 2 of the research:

- They informed the development of questions for data collection via interviews.
- They provided a way to analyse teachers' experiences with ICT-integration. TPACK constructs used as codes and examples of manifestations of teachers' knowledge domains were identified.
- In a contribution towards TPACK's theoretical development, the study enabled definitions of the TCK construct to be explored with examples of senior secondary teachers' practice.

This contribution to TPACK's theoretical development was prepared as a journal article for publication titled *ICT-integration and teacher knowledge*. This paper is presented as Chapter 7.

3.4 Ethics

The University of Wollongong Human Research Ethics Committee (HE11/072; Appendix H) and the NSW Department of Education and CommunitiesAppendix G (Appendix G) granted ethical approval for commencement of the study and for data collection. In addition, ethics approval was sought and granted by the Catholic Education Offices; however, no Catholic-system schools participated in the study.

Participants were sought via a number of avenues, including direct contact to the school and through teachers' professional associations. Upon initial contact, usually via email, principals and participants were forwarded an information pack (Appendix I). All interviews were conducted at a time and place convenient for the teacher, ensuring that disruptions to school business were kept to a minimum.

Prior to the interviews, participants were provided with hard-copy information packs and consent forms. Informed consent (Appendix I) for data collection and digital recording of interviews was obtained. At the conclusion of the interview, participants were afforded an opportunity to ask questions and were provided with contact details

for follow-up questions or concerns after the interview. Participants were free to withdraw from the study at any time during the interview process or thereafter.

During transcription, all interview data was de-identified and real names of the participants and their schools were not reported in any results. All hard-copy interview consent forms were kept onsite at the University of Wollongong in a secure location in the supervisor's office. Digital audio files and word-processed transcriptions were stored on password protected hard-disk drives and password protected cloud-based storage drives.

3.5   Quality of the study

Individual studies in education contribute incrementally to the knowledge base of pedagogy, learning and teacher education (Kervin, Vialle, Herrington, & Okely, 2006). The quality of a study depends on the trustworthiness of the contribution to that knowledge base (Lincoln & Guba, 1985). The variation among education inquiry processes is great, and the perspectives on quality in research are similarly varied (Creswell, 2012b; Oancea & Furlong, 2007). Central to these perspectives are methodological and theoretical soundness, which, in turn, are grounded in assumptions related to the nature of knowledge and inquiry and the context within which the inquiry sits (Oancea & Furlong, 2007). This is important because epistemological assumptions shape the formulation of the problem and how the information is sought in answering those questions (Creswell, 2012b).

This inquiry adopted a phenomenological approach to inquiry that explored the reality of ICT-integration through descriptions of human experience. Human-centred approaches to technology research emphasise the importance of human choice behind the use of technical artefacts (Ciborra, 1998). The phenomenological approach adopted in this study enabled an exploration of how technologies are actually used by people in "real-world" educational settings. This was an appropriate way to build an understanding of the ICT-integration phenomenon because it grounded the use of technology in schools in teachers' experiences.

Experiences were collected and analysed through a systematic and methodical process outlined in this chapter. Creswell (2012b) suggests the use of multiple strategies to strengthen the validity of qualitative studies. The following strategies were employed in this study.

3.5.1 Prolonged engagement

Prolonged engagement and learning the culture are techniques that increase the likelihood that credible findings and interpretations will be produced (Lincoln & Guba, 1985). In this study, data collection involved prolonged engagement with participants in the field and with the raw data. This is demonstrated through establishing initial contact via email with participants, follow-up email contact that elicited information about subjects taught; further email contact that provided background information to the research project; and in-depth interviews at times and in locations that were selected by the participant. The interview technique developed rapport and established trust that enabled experiences of ICT-integration to be reported through natural dialogue guided by purposefully designed open-ended questions. Engagement was further prolonged through the researcher's multiple listenings of audio recordings of the dialogue and careful transcription of all 28 of the 40-minute interviews by the researcher.

"Learning the culture" (Lincoln & Guba, 1985, p. 301) was afforded by the researcher's extensive experience in teaching in a similar context. "Membership" of senior secondary teachers' "cultural and linguistic community" meant that the researcher and participants shared a vocabulary (Hein & Austin, 2001, p. 14). This enabled the communication of experiences in a similar and consistent manner by teacher-participants during the interview process. It was also an important factor in contributing to meaning-making arising from phenomenological descriptions through *intersubjectivity* (Moustakas, 1994) – a concept that is important in developing shared meanings; in this case, between the researcher and the participants.

3.5.2 Peer debriefing

Peer debriefing was ongoing throughout the research process and is a valued technique in establishing credibility (Creswell, 2012b; Lincoln & Guba, 1985). The process

involved the researcher engaging in dialog with a peer – "someone who knows a great deal about both the substantive area of inquiry and the methodological issues" (Lincoln & Guba, 1985, pp. 308-309). The peers in this case were the researcher's doctoral supervisors, who were highly experienced educational-technology researchers. They constantly challenged thinking on "methods, meanings and interpretations", as suggested by Creswell (2012b; Kindle locations 4667). Debriefing sessions included discussions on methodological design and steps in the analytic process. Written and audio notes were recorded during meetings.

3.5.3   Clarifying the researcher bias

The researcher's position is articulated in section 3.2.1 of this chapter. This enables the reader to understand the researcher's position and the biases and assumptions inherent in the study (Creswell, 2012b). This process of making assumptions explicit is also important for phenomenological research so that the assumptions appear as clearly as possible to the researcher (Hein & Austin, 2001). This enables a process of phenomenological reduction where personal beliefs are *bracketed* (held at bay) throughout the research process so as to allow the experience of ICT-integration to be presented through the words of participants (Bradfield, 2007; van Manen, 1990). Bracketing was accomplished in this study through the use of a carefully crafted interview protocol that guided the researcher during the interview process and reduced the temptation to pre-empt or influence answers relating to technology use in classrooms. The thematic-analysis process is carefully described so that understandings of ICT-integration presented are grounded in teachers' experiences with ICTs.

3.5.4   Rich, thick description

Detailed description of the context, participants and analysis process is provided so that the reader can make a judgement about transferability to other contexts (Creswell, 2012b; Lincoln & Guba, 1985). Contextual information is available in descriptions of teaching and learning in NSW schools; the nature of high-stakes exit and summative examination systems; the participants and their schools; and heightened expectations relating to ICTs provided through an active ICT education policy period. Additionally,

details of the frameworks employed to guide data collection and to organise results are explicated.

3.6   Summary

The methods chapter has described the two-phase research design used in this qualitative study. Phase 1 involved a document analysis of government policy related to Australia's Digital Education Revolution (DER). The document analysis was an appropriate strategy to use to develop knowledge of the change processes affecting teachers during the DER enactment period. The examination of policy texts was framed by a model that considers *the characteristics of change* as important factors affecting implementation of a change agenda (Fullan, 2007). The DER policy analysis provided important background information for Phase 2 of the study.

Phase 2 explored the range and types of ICT use in non-computing-studies subjects in the final years of schooling to better understand the role of technology in the senior secondary school. A phenomenological approach enabled knowledge of ICT-integration to be developed through an exploration of teachers' experiences with ICT. The researchers' personal experiences in teaching NSW senior secondary subjects and supporting teachers with ICT-integration afforded a natural dialogue between the researcher and teacher-participants during the semi-structured interviews, which were designed to collect first-person descriptions of teaching and learning with ICT. An analytical framework that incorporated the TPACK model and elements of DER policy was important in developing an understanding of the phenomenon of ICT-integration in senior secondary education. The phenomenological approach was appropriate because it enabled an understanding of how ICTs are actually being integrated in NSW senior secondary education, rather than focusing on potential benefits of ICTs in educational contexts.

CHAPTER 4: AUSTRALIA'S DIGITAL EDUCATION REVOLUTION – THE CHARACTERISTICS OF INTENDED CHANGES

Abstract

This paper provides a policy analysis of Australia's Digital Education Revolution (DER) – a component of a nation-wide reform agenda directed at teachers and their practice. The study examined a whole-of-nation approach to changing tools, resources and practices associated with the implementation of an information and communications technology (ICT) education policy. Contents of documents were analysed through a change-theory perspective that considered factors affecting implementation: need, clarity, complexity and quality and practicality of policy implementation. This framework enabled a focus on the types of changes needed by teachers for the DER to be fully implemented. Australia's productivity agenda was linked to a need for human capital, which was to be achieved through education reform. This reform required a focus on contemporary teaching and learning and therefore, the reform process involved identifying the needs relating to teachers' capacity to integrate ICT. For the DER vision to be realised, students were required to creatively and productively use ICTs within flexible learning environments supported with increased access to digital technologies. Teachers were required to know how to use digital resources, laptop computers and learning activities to support students' construction and expansion of subject knowledge. The reform represented a degree of complexity on three fronts. First, the Australia-wide policy was large in scope, targeting all secondary schools. Second, sustained and meaningful change to teachers' practice associated with ICT-integration was expected; and third, successful implementation required clear and detailed articulation of the way this teacher capacity was to be developed. Whether high-quality change takes place, and whether changes have a positive impact, can only be ascertained if monitoring and evaluation are embedded throughout the policy process; however, DER policy did not specify an evaluation framework. Areas for further research include a need for greater understanding of how high-level goals relating to ICT-integration articulated in national policy are implemented within the context of school-based curricula. Furthering understanding of approaches to evaluation of whole-of-system reform agendas is also suggested so that useful measures are in place to inform future policy development, and in particular, those specific to ICT-related initiatives.

4.1 Introduction

Information and communications technology (ICT) integration in education is a process influenced by a myriad of factors, not least of which are national education agendas. The Digital Education Revolution (DER) was a component of a broader education reform known as Australia's Education Revolution (DEEWR, 2008c). The DER was a major initiative – a "once-in-a-generation opportunity" building on a 20-year history of Australian ICT education policy (DEEWR, 2008e, p. 3) . What made this policy cycle significant was the large financial investment, targeting ICTs in schools, and its ambitious scope, targeting all Year 9 to 12 Australian secondary students. The Government described the DER as a "landmark initiative", affecting all facets of school education from teachers' professional development through to curriculum, assessment and community engagement (Group, 2013, p. 5). The DER policy period and associated funding ceased in 2013; however, rapid change in ICTs and their prevalence across society, business and education means that ICT will continue to feature in national education agendas. The analysis presented in this paper is part of a broader study that examined ICT-integration in senior secondary school education (Years 11 and 12). The broader study examined senior secondary teachers' use of ICT during the DER policy-enactment period. This paper reports on Australian Government policy informing ICT-integration in senior secondary classrooms during the data-collection phase in 2011.

Public policy analysis enables the documentation and review of initiatives that are aimed at widespread, system-level change. An examination of DER policy is important for several reasons. First, it provides insights into a large-scale, system-wide reform agenda. Whole-system reform involves all schools in the system working towards improved outcomes for students (Fullan, 2010). The "system" involved with this reform was Australian schools that implemented Year 9 to 12 curricula. A further reason for this research is that DER policy analysis provided a context for an exploration of ICT-integration during a period of rapid technological change and increased access in schools. Deconstructing policy objectives as they relate to teachers provides insights into the enactment of that policy and highlights areas that need attention in future government-funded initiatives. In addition, policy does not sit in

isolation despite having initiation and end dates. It interacts with past ICT policy, as well as concurrent interconnected policy, and can inform future directions.

A study of policy is a study of change aspirations. This paper presents an analysis of Australia's DER policy that was current in between 2008 and 2012 through a change-theory perspective. The national vision for learning technologies has evolved since the 1980s, as have ICTs themselves. Necessarily, that vision has shifted emphasis as ICT in schools has evolved from few, high-cost, stand-alone desktop computers towards access to highly connected, multimedia-enabled mobile devices. For teachers, this has meant changes to their beliefs, tools, resources and pedagogy. This study examined the characteristics of the intended changes that were articulated through the DER policy agenda.

4.2 Policy and change

Public policy includes documents, statements, frameworks and strategic plans produced by governments and political parties. They are more than documents of text and images; they are both a product and a process:

> Policy is more than simply the policy text; it also involves processes prior to the articulation of the text and the processes which continue after the text has been produced, both in modifications to it as a statement of values and desired action and actual practice (Taylor, Rizvi, Lingard, & Henry, 1997, p. 28).

In this sense, policy as process is describing change – what Rizvi & Lingard (2010) have termed "an imagined future or state of affairs" (p. 5). It is through policy that governments describe the changes they want, the people who are to change, aspirations for how the changes should come about, how the change process is to be evaluated and commitments of financial resources. In the Australian context, these changes are described in texts such as National Education Agreements, Ministerial announcements, funding agreements (such as Specific Purpose Payments), Strategic Plans and official communiqués of government meetings and departmental websites. Policy is also pre-empted through position papers produced by political parties leading into federal elections (for example, Rudd & Smith, 2007). Furthermore, processes of policy are also captured through performance audits and commissioned evaluations.

The Digital Education Revolution (DER) was a component of a broader education-policy initiative known as the Education Revolution that began with the change of Australian Government in 2007. Aligning with the definitions above, DER policy consisted of a number of texts or documents produced by joint ministerial councils and government agencies. As well as policy, the DER terminology was associated with processes and actions of providing laptop computers to secondary schools through the National Secondary School Computer Fund (DEEWR, 2008b).

Constitutionally, Australian state and territory governments have responsibility for education; however, national goals and initiatives are formulated through intergovernmental agencies including the Standing Council on School Education and Early Childhood (SCSEEC; formerly the Ministerial Council for Education, Early Childhood Development and Youth Affairs – MCEECDYA), the Council of Australian Governments (COAG) and the Australian Curriculum, Assessment and Reporting Authority (ACARA). The Commonwealth exerts its influence through conditional funding called Specific Purpose Payments. National Education Agreements between the federal and state and territory governments set policy directions for schooling and the roles and responsibilities of each level of government (COAG, 2009a, 2012). In addition, agreements include objectives, outcomes and performance indicators. In this way national agendas, such as the DER, are targeted at government as well as non-government schools, through conditional funding that is provided to all Australian schools. (Harrington, 2011).

The National Secondary School Computer Fund (NSSCF), the major funding element of the DER, was an example of a Specific Purpose Payment. This spending targeted establishing a 1-to-1 computer-to-student ratio in Years 9 to 12 in all Australian secondary schools (DEEWR, 2008b). The National Partnership Agreement stated that the aim of the DER was to contribute to "sustainable and meaningful change to teaching and learning in Australian schools [to] prepare students for further education, training and to live and work in a digital world" (DEEWR, 2009b, p. 1). The Agreement and accompanying NSSCF Specific Purpose Payment had an impact on teachers and their students through the provision of ICTs and digital resources directly to Australian schools.

To achieve a large-scale reform initiative, such as that advocated by the DER, governments are essential (Fullan, 2007). Fullan (2007) declares that "only small-scale, non-lasting improvement can occur if the system is not helping" (p. 235). He suggests that whole-system change requires a tri-level approach where school, district and state are working towards collective capacity building across the whole system (Fullan, 2007, 2009, 2010). The Australian DER provides an example of this tri-level approach with the involvement of a national government, state or territory governments and local, school-level systems. Governments, Fullan (2007) asserts, can "push *accountability*, provide *incentives* (pressure and supports,) and/or foster *capacity building*" (p. 236; emphasis in original). The DER implementation was a policy ensemble that included accountability, financial incentives and capacity-building initiatives directly affecting teachers and their practice.

4.3   Previous policy analyses

The national ICT education policy field leading into the 1999 revisions of national goals for Australian schooling was one in which states and territories were each framing system-wide approaches towards similar aspects of ICTs in schools (Finger & Trinidad, 2002; Meredyth, Russell, Blackwood, Thomas, & Wise, 1999). These aspects included whole-school strategic planning; infrastructure; connectivity both locally within the school and connecting schools to department wide area networks; specialist ICT-related positions; and improving computer-to-student ratios, teacher capabilities and competencies, ICT-integration and curriculum frameworks for ICT use (Meredyth et al., 1999). States had a strong focus on equity, particularly in remote locations where ICT was seen as a way of increasing learning opportunities and broadening curriculum offerings (Meredyth et al., 1999).

The appointment of a ministerial Information and Communication Technologies in Schools Taskforce in 2001 was the beginning of a strengthened national approach towards planning for ICTs in school education (Finger & Trinidad, 2002). This period was characterised by an increasingly globalised policy field – one in which national and international economic priorities were connected with the role for school education (Kearns, 2002; Rizvi & Lingard, 2010). A policy response emerged that aligned education policy to broader economic frameworks for the information

economy and knowledge society; goals for schooling advocated for competence in the use of technologies as essential for working and living (Kearns, 2002; Kearns & Grant, 2002; Moyle, 2005).

The alignment between economic and education policies continued through to the DER, the roots of which were embedded in Australia's 2008 revised National Goals for Schooling (MCEETYA, 2008c; Moyle, 2010). Cutler explained the link between the labour market and education: "Building high quality human capital requires attention at all levels of education: from early childhood education and schooling, through vocational education and training and higher education, and into the workplace" (Cutler, 2008). Teachers were framed in education policy discourse as needing ICT skills so that learners could benefit and be prepared for future industry and workforce needs (Jordan, 2009).

Along with a focus on ICT skills, a shift towards a broader role for technologies in education associated with transformed learning environments became evident (Kearns & Grant, 2002; Moyle, 2005). Kearns (2002) referred to this period as a "mainstreaming phase" in both Australian and international education policy. Following the initial rollout phase focusing on increasing access to computers, the mainstreaming phase was concerned with "…integrating ICT into the work of schools and vocational education and training (VET) based on the overall strategic directions for these institutions, and with a deepened concern for learning outcomes" (Kearns & Grant, 2002, p. 1).

This phase became increasingly concerned with teachers, pedagogy, student learning and whole-school change. Moyle (2005), in reviewing the *Learning in an Online World* policy suite, identified key themes aligning with the mainstreaming phase in which ICTs were seen as:

- A tool to improve or "transform" teaching and learning;
- [An enabler] of individual student learning plans;
- [An agent for improvement in] standards and students' learning outcomes (Moyle, 2005, p. 5)

To this end, ICT policy included goals relating to curriculum and pedagogy (what was taught and how it was taught), and training and skilling of teachers became a recurring focus for reform that continued through to the DER period (Jordan, 2009; Moyle, 2005, 2010). Teachers' innovative use of technology in driving student learning across all Australian schools was advocated (Moyle, 2010). The inclusion of ICT use as a general capability, and ICT as one of the eight learning areas, established curriculum reform as another priority policy area (MCEETYA, 2008c; Moyle, 2010).

ICTs in schools have been a part of government discourse for some time, and a growing concern for the integration of ICTs in pedagogies, students' learning and whole-school change has been consistently evident in Australian education policy (Moyle, 2005, p. 5). The key focus of DER was change to teaching and learning through ICT-integration by increasing access to technologies in Australian schools (DEEWR, 2009b). Through a policy analysis, this research seeks to understand the key characteristics associated with intended changes advocated by DER policy and implications for teachers.

4.4 Method – DER policy analysis

The research question framing this study was "*What were the key characteristics of intended changes advocated in DER education policy?*" The DER implementation involved putting into practice the aims and changes set out in policy. A number of factors can affect implementation; Fullan (2007) calls these factors *characteristics* of intended changes. This study applied a framework conceptualising the characteristics of intended changes of the DER in terms of Fullan's (2007) characteristics of need, clarity, complexity and quality and practicality of intended changes implied in the DER policy suite. Each of these elements will be discussed in the following section.

4.4.1 Document selection

A search for policy documents relating to ICT education began just prior to the DER initiative.. At this time, the 1999 National Goals for Australian Schooling were current, and Goal 1.6 had informed policy directions relating to ICT in school education:

> ...when students leave school they should be confident, creative and productive users of new technologies, particularly information and

communication technologies, and understand the impact of those
technologies on society (MCEETYA, 1999).

The National Goals are important, as they provide a point of origin and a foundation for education-policy processes in Australia. There have been three iterations of the national goals. The original goals, agreed in 1989 (also known as the Hobart Declaration), were superseded in 1999 by the National Goals for Schooling in the Twenty-First Century (Adelaide Declaration), which in turn were superseded by the Educational Goals for Young Australians (Melbourne Declaration, MCEETYA, 2008c). National Goal 1.6 (MCEETYA, 1999) informed policy for ICT in education preceding and in the early stages of the DER (for example, (MCEETYA, 2008a, 2008b). The revised national goals reiterated ICT as an area of focus for schools, stating that successful learners should be "creative and productive users of new technology, especially ICT, as a foundation for success in all learning areas" (MCEETYA, 2008c, p. 8).

The search for relevant documents required the identification of the network of government agencies that had contributed to the education policy field between 2008 and 2012. At this time, the Ministerial Council for Education, Employment, Training and Youth Affairs, consisting of state and territory education ministers, was the entity coordinating policy-making relating to Australian school education. MCEETYA was superseded by the Ministerial Council for Education, Early Childhood Development and Youth Affairs (MCEECDYA) in 2009, then by COAG's Standing Council on School Education and Early Childhood (SCSEEC) in 2012. In addition, the Department of Education Employment and Workplace Relation's website (DEEWR) hosted documents relating to the Education Revolution from 2008. From 2009, COAG's Standing Council on Federal Financial Relations website linked to National Education Agreements and documents relating to Specific Purpose Payments. Additionally, from 2008, the Australian Curriculum, Assessment and Reporting Authority (ACARA; initially established as the National Curriculum Board) published documents relating to the development of the Australian Curriculum.

Policy documents were sourced primarily through Internet searches of websites of the agencies listed above. Documents selected for the study included strategic

frameworks, action plans and national education agreements that were significant in illuminating the Government's aspirations and expectations for ICT in school education. Goal 1.6 from the 1999 National Goals provided a background to contemporary policy; however, documents for this study were primarily sourced from those released between 2008 and 2012. Appendix D includes a visualisation of the policy field during the DER, as well as a complete list of policy documents informing this study. Documents were downloaded and saved to a local hard drive and catalogued using a citation manager.

4.4.2 Analytical framework

The contents of the documents were analysed using a framework based on the *Characteristics of Intended Changes*. Fullan (2007) describes nine factors that can affect implementation. These factors are important because they focus attention on the types of things that would have to change if the DER reform were to be fully implemented. These factors, shown in Figure 6, are categorised as Change Characteristics, Local Characteristics and External Factors.
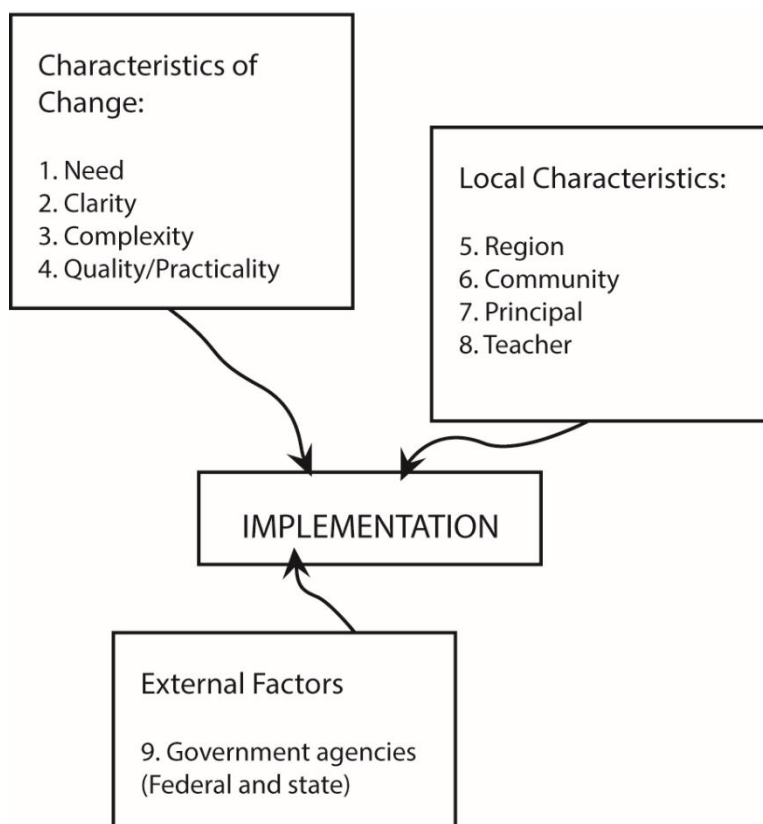
Figure 6: Interactive factors affecting implementation (Fullan, 2007, p. 87)

These factors form an interactive *system of variables* (Fullan, 2007, p. 86) Local factors are those concerned with the local school system (Fullan, 2007). In the Australian context, this includes sectors of the NSW Department of Education responsible for a number of Government schools; or a Diocesan Catholic School Authority that provides administrative and educational support to schools within a particular Catholic Diocese. Local factors also refer to school-level factors (Fullan, 2007), such as actions and dispositions of school leaders, teachers or students; school-based ICT implementation strategies; or support from community groups such as parent and friend associations. Fullan (2007) categorises external factors as those that may be defined by federal agencies and departments of education. In the Australian context this would include the National Department of Education, Employment and Workplace Relations (DEEWR) or the Council of Australian Governments, which establishes National Agreements that affect schools nationally.

The are factors related to the innovation itself (Fullan, 2007). These four factors framed the DER policy analysis because they relate to teaching, learning and classroom practice. The model characterises the change process under the headings of need, clarity, complexity, and quality and practicality. These characteristics are described in Table 18.

Table 18: The characteristics of intended changes related to the DER implementation

Code Label	Explanation
Need	Policy discourse that articulates why an ICT-related innovation is necessary or the purpose of the proposed changes to practice, beliefs, tools and resources.
Clarity	Policy discourse that describes the outcomes of proposed changes and the process for the required change relating to ICT use in education – what teachers should do differently.
Complexity	Policy discourse that articulates or implies a degree of difficulty or complexity for the individual (changes to beliefs and skills) implementing new processes and ideas relating to ICTs in teaching and learning.
Quality and Practicality	Policy discourse related to the worthiness of the changes associated with ICT use and the practicalities of implementation.

These characteristics provided a theoretical foundation upon which to base the policy document analysis.

The field of education policy research is varied as are the approaches to policy analysis (Taylor et al., 1997). The qualitative method adopted in this study is described as a

document analysis that involved a systematic process of sourcing documents, reviewing and thematic coding of document text. The method aligns with what education policy scholars have categorised as an *organisational* study that considers research questions associated with policy intent, and analytical processes that include document analysis and thematic coding (Cohen, Fuhrman, & Mosher, 2007). This is appropriate because the purpose of this study is to describe intended changes advocated by Australian ICT-related education policy.

A change theory perspective is adopted with a focus on policy content rather than policy discourse. This means that the analysis focused on the descriptive aspects of policy text that aligned with the characteristics of intended changes and was less concerned with searching for hidden meanings within and behind the language of policy discourse analysis that aims to uncover (Peräkylä, 2008).

The policy analysis involved classification and interpretation of data into codes and themes (Creswell, 2012b). Documents were located through Internet searches of Australian Government agencies' websites. They were downloaded as PDF (portable document format) files to the local hard drive.

Analysis began with a thorough read-through of each PDF document. This was followed by a hybrid process of theme development (Fereday & Muir-Cochrane, 2006) beginning with a deductive approach using the 'priori template of codes' based on theory associated with the characteristics of intended changes outlined in Table 18, followed by an inductive, second layer analysis within each characteristic to identify its essential features (p. 4). This was achieved using the following tools:

- Deductive coding
    - First, a PDF editor's text highlighting tool was used to segment the text. Each code in Table 18 was allocated a unique colour and a highlighting tool was used to highlight textual elements that aligned to definitions of the four characteristics of change... Additionally, research notes were added in the margins of the policy document

where appropriate. An example of this process is illustrated in the policy document in Appendix E.

- o Second, a Microsoft Excel spreadsheet was used to create a matrix. Text relating to each characteristic from a single document was condensed by summarising key ideas relating to each characteristic. This text was transcribed into the matrix. The columns of the matrix represented an individual document. The four rows of the matrix represented each characteristic of intended changes. An excerpt of this matrix is included in Appendix F.

- Inductive coding
  - o Reading across a single row of the matrix allowed text related to a single characteristic of change to be compared across different documents. For example, by reading across the row related to Need, text that had been identified as relating to *The Need for Change* from all policy documents were compared.
  - o Analysis here involved further coding the text by annotating when a unit of meaning or an aspect of the phenomenon became apparent. This enabled patterns of meaning of intended changes of ICT education policy to emerge.
  - o an analysis matrix grid using Microsoft Excel. The matrix then facilitated a deductive second-layer of analysis within each characteristic to take place.

This process is consistent with Creswell's (2012b) idea of an analysis spiral rather than a fixed linear approach to data analysis. In sum, the data was organised into computer files, then converted into text units and categorised for analysis. The final step is to describe and interpret the data. These themes and implications for teachers are described in the results section.

4.5   Results

The characteristics of changes related to the DER implementation are described and are organised under four headings: Need, Clarity, Complexity and Quality and Practicality. Each section begins with a definition of the characteristic, followed by the analysis of policy relating to that characteristic. This policy analysis focuses on the

characteristics of change associated with education reform agendas aimed at ICTs in school education between 2008 and 2012.

4.5.1   Need for change

This characteristic of innovation is associated with the importance of the perceived need for the change (Fullan, 2007). According to Fullan (2007), it is important that the needs of a system align to the intended innovation or change. Factors that can complicate need include overloaded improvement agendas, poorly defined needs at the onset of complex change agendas and the influence of other interrelated factors affecting implementation (Fullan, 2007). These needs, according to Fullan (2007), should clearly relate to decisions concerning implementation. The Australian education reform agenda began with the election of a Labor government in 2007. According to policy, changes were needed for three interdependent reasons – a need to support Australia's productivity agenda; which meant a need for improved learning outcomes for students; and in turn, a need for a teaching workforce with pedagogical knowledge of how ICTs were to improve student learning.

The Australian government explicitly linked the need for educational reform to economic prosperity. The incoming Labor Party's election policy *New Direction Paper* argued that economic prosperity was dependent on a "human capital revolution", and that investment in Australia's human capital would be via educational programs to ensure an "innovative and productive workforce" (Rudd & Smith, 2007, p. 4). Following the 2007 election, and against the backdrop of the global financial crisis, COAG's productivity working group was charged with driving changes across a number of economic and social reform agendas, including education. The DER was born out of COAG's agenda for "developing human capital and productivity" (DEEWR, 2008e, p. 3), and was aimed at improving Australia's future skills base (AICTEC, 2009b).

Productive contributions to society were linked to high-quality learning outcomes associated with COAG's productivity agenda: "…technology enriched learning environments to assist students to achieve high quality learning outcomes and productively contribute to our society and economy" (DEEWR, 2009b, p. 5).

The DER was linked to the productivity agenda and called for changes to teaching practice and student learning to achieve those goals. The DER agreement between the national and state and territory governments demonstrates this link:

> [The Agreement] is designed to contribute sustainable and meaningful change to teaching and learning in Australian schools to prepare students for further education, training and to live and work in a digital world. Successful implementation of this Agreement will be critical to the achievement of the aspirations, objectives and outcomes set out in the National Education Agreement. (DEEWR, 2009b, p. 1)

There were implications for teachers' knowledge and skills in discourse connected to quality learning outcomes. These were associated with a focus on contemporary learning outcomes that would be realised through incorporating ICT into teaching and learning programs across the curriculum (AICTEC, 2008). To achieve this, teachers and school leaders needed to develop their capabilities in integrating ICT to develop students' ICT skills: "21st century schools require 21st century programs and educators capable of using 21st century resources and strategies for learning" (DEEWR, 2010, p. 1).

To this end, policy advocated a need for meaningful professional learning programs and for teachers to achieve competence in educational uses of ICT.

The policy goals were underpinned by initiatives aimed at increasing access to ICTs: the National Secondary School's Computer Fund (NSSCF); the ICT Innovation Fund, which allocated funds to teachers' professional development; and the development of a new Australian Curriculum that embedded ICT use as one of seven general capabilities developed from Foundation to Year 10 (ACARA, 2012b; DEEWR, 2009b, 2010).

In sum, the *need* for change is an important characteristic of policy implementation. Australian education policy framed this need in terms of economic prosperity that would rely on education-driven human capital investment. For teachers, the implications were that they needed new pedagogical skills to implement ICT-enabled learning associated with quality learning outcomes.

4.5.2 Clarity

Clarity of the change process relates the importance of teachers knowing what they should do differently (Fullan, 2007). Problems affecting clarity of change relate to "diffuse goals", interpreting change in an oversimplified way, not explicating how the change is to be implemented, or what is to happen when the impact of the change is underestimated (Fullan, 2007, p. 89). For Fullan (2007), this characteristic is tied to teachers and their practice. "Educational change depends on what teachers do and think – it is as simple and as complex as that" (p. 129). Therefore, clarity depends on clearly articulated outcomes and means of achieving intended change. For teachers, this requires a clear and detailed vision of what they should do differently, such as how pedagogy should change within the context of technology-rich learning environments and what ICT-related skills and knowledge are to be taught. Two key areas of DER policy implementation were needs associated with students learning ICT skills and a need for teachers to improve outcomes through ICT-supported pedagogies.

Underwriting national education policy were the 2008 Educational Goals for Young Australians, the release of which coincided with DER policy promulgation (MCEETYA, 2008c). The message to educators was that successful learning in their courses depended on students being "creative and productive users of new technology, especially ICT" (MCEETYA, 2008c, p. 8). This established ICT competency as an over-arching, high-level outcome of Australian education systems. For this goal to be realised, these ICT competencies needed to be an explicit component of school curricula.

While the need for changes to education was firmly rooted in needs associated with economic reform, the discourse in policy subtly shifted towards improvements to an education system through enhancement of learning outcomes (AICTEC, 2008). For teachers to incorporate ICT into teaching and learning programmes and teaching methods, they would need to create "flexible learning environments" (AICTEC, 2008). The vision for ICT-enabled learning was made even more explicit in the DER ICT planning framework *Making Change Happen* (MCEETYA, 2008a). This framework was intended to guide schools in their DER planning, self-review and evaluation (DEEWR, 2009a) by providing detailed expectations. Table 19, drawn from this

document, illustrates the Government's vision for, and the extent of the expected change to, teaching and learning.

Table 19: A vision for ICT-enabled classrooms in leading schools articulated through policy at the outset of the DER period (MCEETYA, 2008a)

What teachers will do	What students will do
- Embed ICT across all curriculum areas, pedagogy and assessment. - Use ICT to differentiate the curriculum in order to extend and personalise learning. - Review the learning impact of new and emerging ICTs. - Distribute the responsibility for the creation of learning content between themselves and their students. - Use ICT to reflect on, negotiate and develop dynamic personal learning pathways for individual students. - Use ICT to facilitate increased parent engagement in order for families to contribute to their schools. - Use ICTs to demonstrate connections between the curriculum, personalised learning goals, assessment criteria and learning. - Electronically record student achievement - Collect evidence of student digital literacies from a range of learning contexts. - Regularly set clear targets for improvement of students' use of ICT. - Use evidence of student digital literacies to inform planning, teaching and learning programs. - Use ICT to analyse individual and group learning outcomes. - Search for, select and tailor a range of digital teaching and learning tools. - Create and publish content online in a manner that is ethical and respects copyright. - Share digital curriculum resources with peers.	- Create ICT products as evidence of learning. - Use ICT to collaborate with other students, teachers and external experts on a range of authentic tasks. - Use ICT to question and enquire; collaborate, share and communicate; conceptualise, produce, create and acquire knowledge; solve problems and think critically; and manage information. - Have access to immediate feedback from peers, staff or community members through electronic access to results. - Make links between different learning contexts and apply and further develop their own digital literacies. - Demonstrate high levels of engagement, confidence and skill in using ICT in their learning.

The DER vision highlights the high expectations for teachers' pedagogical knowledge and ICT skills in implementing policy. Subsequent documents continued this theme, albeit with less detail, outlining expected changes to "the way teaching and learning are delivered in Australian secondary schools" (DEEWR, 2009b, p. 6). Bilateral agreements included *outcomes* and *outputs* relating to increased access to ICTs, online delivery of a new curriculum, high-speed broadband, development of online learning content and access for parents (DEEWR, 2009b). One initiative in particular had direct and immediate consequences for teachers, with states and territories committing to a 1:1 ratio of computers to students by December 2011 (DEEWR, 2009b).

Teacher capability became a priority, and the Australian Information and Communications Technology in Education Committee's (AICTEC) established a working group (Teaching for the Digital Age Advisory Group, TDAAG) to advise on pre-service and in-service teacher capability and leadership (AICTEC, 2009c). A Digital Strategy for Teachers and School Leaders was announced, and funds were made available to "universities, higher education providers and businesses" to support implementation (DEEWR, 2010, p. 2).

Coinciding with the announcement of the Digital Strategy for Teachers and School Leaders was a parallel education reform on Improving Teacher Quality. In its implementation, draft National Professional Standards for Teachers were released describing the "knowledge, skills and dispositions required of teachers" (Teaching Australia, 2010, p. 3). For proficient teachers – those who met the 42 "fundamental professional standards of the profession" (p. 7) of 42 standards, ICTs were mentioned 3 times:

> Standard 1.4 (p.9) Proficient teachers know each student's current level of proficiency in the subject/s being taught, and in literacy, numeracy and ICT and the implications of this knowledge for their planning.
>
> Standard 2.7 (p. 11) Proficient teachers know and understand how to select and use quality resources and strategies to support teaching and learning. They know how ICT can be used to construct, demonstrate and expand knowledge.
>
> Standard 5.5 (p. 18) Select and use a range of strategies, including ICT to collect, organise and store data about their students' achievement in ways

that can be accessed by others and address accountability requirements. (Teaching Australia, 2010)

Although the National Standards were important in clarifying knowledge and skills required for the profession, reference to digital technologies was scant when compared to the required knowledge base needed to implement the government's vision for ICTs in schools summarised in Table 19.

Overall, at the national level, there was clarity in a vision for students who were competent ICT users, teaching and learning environments rich with ICT related resources, teachers who were competent in integrating ICTs in all aspects of their practice and for ICT enhanced learning outcomes. However, implementation at the school level in the context of multiple initiatives spanning different timeframes may have appeared fragmented and disconnected due to the timelines and scope of intended changes.

4.5.3 Complexity

Complexity of change refers to the difficulty and extent of change needed (Fullan, 2007). For teachers, complexity depends on their "starting point[s]" with respect to their existing skills and what is required, their beliefs and resources and teaching materials in use (Fullan, 2007, p. 90). Fullan (2007) states that many system wide reform initiatives require a "sophisticated array of activities" (p. 91). These may include diagnostic tools, teaching strategies and changes to philosophical understandings and will require effort (Fullan, 2007). While complexity associated with change may negatively impact successful implementation, it could also be associated with *greater* change because more is being attempted: "ambitious projects were less successful in absolute terms of the percent of project goals achieved, but they typically stimulated more teacher change than projects attempting less" (McLaughlin, 1977, as cited in Fullan, 2007, p. 91).

The DER was a large scale, system wide reform agenda directly impacting teachers' practice and therefore complexity was a characteristic associated with changes required by policy implementation. This was particularly evident in the challenges to

teachers' belief systems and pedagogical skills required for successful ICT-integration. Even ICT education policy preceding the DER acknowledged this. For example, the 2005 *Learning in an online world: Pedagogy Strategy* acknowledged that ICTs alone do not make change happen: "Making technologies available does not of itself result in changed teaching methods or in the level of learning outcomes. Effective use of ICT in education requires appropriate pedagogies" (MCEETYA, 2005b, p. 5). The later DER policy echoed this need for effective use that moved beyond ICT proficiency, and urged teachers to consider longer-term educational change by developing "the pedagogical understanding, confidence and tools to design and deliver programs that effectively enhance student learning outcomes and harness the benefits and resources of the digital revolution" (AICTEC, 2009c, p. 2).

These are evidence of the high expectations relating to beliefs and extensive pedagogical knowledge required for successful DER implementation.

To support the development of this knowledge, the Australian Government's *Digital Strategy for Teachers and School Leaders* committed $40 million over two years for several initiatives, including the Teacher Quality National Partnership, the implementation of a new national curriculum and the implementation of the DER (DEEWR, 2010). Organisations such as universities and businesses were encouraged to bid for funding for services that could contribute improvements in the capabilities of pre-service and in-service teachers and school leadership. This funding was not directed at individual schools.

The *Strategy for Teachers and School Leaders* (DEEWR, 2010) encompassed the ICT-innovation fund that supported four projects aimed at technology take-up and ICT-integration (Dandolopartners Pty Ltd, 2013). Two of the projects targeting in-service teachers were *The ICT in Everyday Learning Teacher Online Toolkit* and the *Anywhere, Anytime Teacher Professional Learning* project. The *Online Toolkit*, comprising 112 teacher-support digital resources, included examples on how teachers can incorporate ICTs into the teaching of English, history, science and mathematics; they were made available through the Australian national digital learning repository, Scootle (https://www.scootle.edu.au/) (Education Services Australia, n.d.). The

Pathways for Learning, Anywhere, Anytime (PLANE) website, developed in late 2011 as a cross-sectoral portal, was designed to facilitate accredited online professional-learning courses, peer mentoring, collaboration tools and multimedia resources for educators (Maher, Sanber, Cameron, Keys, & Vallance, 2013). While resources associated with the *Online Toolkit* were available at the time of this document analysis, the PLANE initiative did not seem to continue beyond 2013.

Comparing these initiatives with the types of professional learning needed reveals the extent of complexity associated with teacher capacity-building for large-scale education reform. The DER's Innovation Fund did not fund professional-learning programs for in-service teachers until after the DER 1:1 laptop program had begun; and then the types of programs funded were based on teachers' accessing the *Online Toolkit* or the *PLANE* network. In 2009, a report commissioned by DEEWR stressed the importance of teachers' ICT-integration capabilities to the success of the DER (Galatis, Williams, Black, & Putland, 2009). The study included a review of the literature and data from case studies, and concluded that a *multi-faceted approach* at the school level across areas of leadership, strategic planning, community engagement, pedagogy and infrastructure, as well as a variety of professional-learning delivery methods, were important for developing ICT-integration capability (Galatis et al., 2009). Further highlighting the complexity at the school level of DER implementation, was the need for "time allocation away from actual teaching to engage in effective professional learning [and the need for schools] to accommodate for increased time…in order to achieve a critical mass in the use of ICT in education" (Galatis et al., 2009, p. 25).

Complexity was further intensified by the fact that the DER was not the only reform initiative targeting teachers at that time. Concurrent reforms included the introduction of national literacy and numeracy testing in 2008. This was followed by the creation of the controversial My School website, which reported schools' results on the National Assessment Program – Literacy and Numeracy (NAPLAN) in 2010 (COAG, 2009a). Schools that made significant gains in literacy and numeracy were to be rewarded (Australian Commonwealth Government, 2007). Additionally, and somewhat controversially, the Government had announced funding that would target

a performance-based pay program "to reward quality teaching" (Australian Commonwealth Government, 2007, p. 11). Also targeting quality teaching, states and territories agreed to establish new professional teaching standards and adopt a national approach to accreditation of teachers under the 2009 Teacher Quality national partnership (COAG, 2009b). Along with these pressures of higher accountability, the National Curriculum Board was working towards implementation of a new national curriculum (National Curriculum Board, 2009). Together these initiatives introduced an array of simultaneous change for teachers. These are summarised in Figure 7.
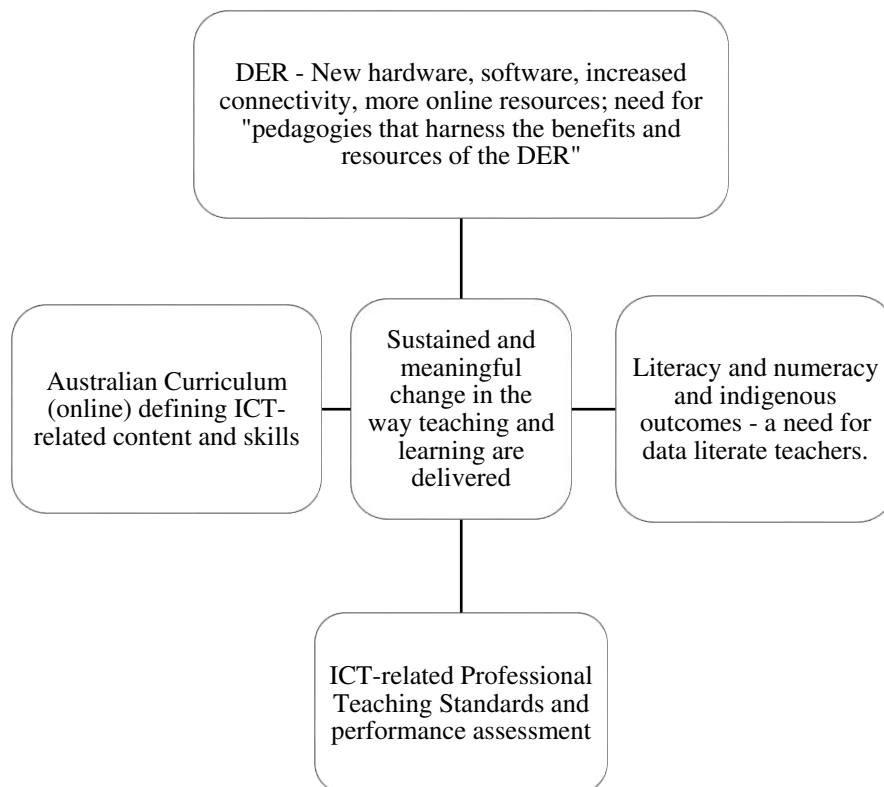
Figure 7: Complexity associated with intended changes of the DER and interconnected initiatives relating to ICT use by teachers.

Those changes specifically relating to ICT included changes to teaching tools such as hardware, software and online resources. The My School website and national testing would have required teachers to have knowledge of *data literacy* to access, manipulate and interpret online achievement NAPLAN results to diagnose and remedy literacy and numeracy skill shortfalls. In addition, as stated previously, new professional teaching standards articulated knowledge required by the profession, including

knowledge related to ICTs. As well, teachers in 2012 would have been preparing for the national curriculum implementation that was defining new ICT-related content and skills.

For teachers, then, education policy field during the 2008-2012 period represented a complex array of changes that encompassed new tools, new practices, big-picture thinking, increased accountability and a new curriculum. These reform directions implied a high level of complexity associated with the large-scale Education Revolution reform. While the DER policy documents allow the directives associated with ICT in schools to be examined in isolation, the reality was that several competing reform agendas would have implications for teachers and their use of ICT in their work.

4.5.4 Quality and practicality

Quality is a term associated with worth or degree of excellence when measured against a standard. Quality educational changes are made on the grounds of real need, are sustainable and are adequately resourced and funded (Fullan, 2007). Quality change can be affected by the unavailability of resources, which, in turn, may negatively affect decision-making (Fullan, 2007). For example, when "adoption is more important than implementation", political processes shift the focus from the development needed for implementation (Fullan, 2007, p. 91). Insufficient development time may result in poor-quality projects. *Practicality* is very closely linked to the *complexity* characteristic discussed earlier because for change to occur in practice it needs to occur along dimensions of adopting new materials (such as technologies), using new teaching approaches and potentially altering belief systems (Fullan, 2007). Successful implementation of large-scale reform is linked to instruction at the local (school) level: "once you dwell on instruction, the whole system can be mobilised to that end" (Fullan, 2011). Therefore, high-quality education reform depends on appropriate professional learning as well as adequate resourcing, especially in terms of time to build capacity required for changes to instructional practice. This final section of the results will discuss factors associated with quality and practicality related to changes advocated in DER policy.

To gauge the quality and practicality of policy implementation, ongoing monitoring and evaluation are essential. The DER was a complex, multifaceted and unprecedented reform agenda that established a national vision for ICT in schools. The Government acknowledged the need for monitoring and evaluation at its outset (AICTEC, 2009b), indicated that an evaluation and monitoring framework was in production (AICTEC, 2009a) and stated that monitoring and evaluation would extend over a five-year period (DEEWR, 2008b). Despite states and territories agreeing to the development of an evaluation process, evidence of a national evaluation framework, specifically for the DER component, did not eventuate until the DER's concluding year (Dandolopartners Pty Ltd, 2013).

In 2011, the Australian National Audit Office (ANAO) reported on DEEWR's administration of the DER. ANAO concluded that the initiative had been effective in increasing the computer-to-student ratio for Years 9 to 12 students; however, oversights were noted, including the absence of intermediate milestones for education authorities to work towards and the lack of key performance indicators to measure program effectiveness. In addition, ANAO stated that: "Evaluating the DER, as a multijurisdictional program focused on changing teaching and learning in schools, is important and inherently difficult" (ANAO, 2011, p. 25).

To this end, DEEWR commissioned a DER mid-program review, released in 2013 (Dandolopartners Pty Ltd, 2013). Data from the NSSCF progress reports and stakeholder consultations were included in the dataset analysed. The review team commented on the limitations of the study: "Decisions about indicators and collection mechanisms were not made until after the DER began. As such, limited benchmark data was captured against which progress could be monitored" (Dandolopartners Pty Ltd, 2013, p. 18).

Apart from this commissioned review and a requirement by state education authorities to report on achieving the target computer-to-student ratios, the national Government did not monitor and review the DER, thus missing the opportunity to more thoroughly evaluate a large-scale, systemic reform agenda aimed at changing education across the nation. This was left to the states and territories.

The practicality and quality of a large-scale, system-wide reform agenda can only be assessed through data collected at the local level. Local factors include the school district, community, principals and teachers (Fullan, 2007). The New South Wales Department of Education & Communities (NSW DEC), what Fullan (2007) would classify as a school district, provided an example of an education jurisdiction that considered evaluation in its NSSCF implementation process. The University of Wollongong was commissioned to evaluate the impact of laptops on teaching and learning over a three-year period (Howard & Carceller, 2010). Howard and her colleagues collected data from stakeholders (students, teachers, principals and parents) associated with Year 9 in 2010, Year 10 in 2011 and Year 11 in 2012 and employed survey and case-study methodologies (Howard & Carceller, 2010; Howard & Mozejko, 2013; Howard, Thurtell, & Gigliotti, 2012). The evaluation considered one-to-one computing and its effect on pedagogy, learning and student outcomes. The substantial nature of this evaluation process has provided a vast and valuable dataset from which to draw conclusions about the effectiveness of one-to-one computing and inform future initiatives relating to ICT in school education.

Practicality can be seen in teachers' changes to their instructional practice and their adoption of new resources (Fullan, 2007). In the case of the DER, changes to practice would include integrating ICTs in their subject area and designing learning sequences using the DER laptops. The NSW DER evaluation reported that teachers' views of the importance of using ICT in their work was highly variable (Howard et al., 2012). Evidence suggests that exposure to the laptops allocated through the DER was improving confidence and familiarity with ICTs; however, in case studies, teachers felt that more "content-specific and focused" training as well as additional time allocations were necessary for effective use (Howard et al., 2012, p. 60). Therefore, the DER may have been a case in point where "adoption [was] more important than implementation" (Fullan, 2007, p. 91). The DER focused on laptop deployment to Year 9 to 12 students (adoption) and less on resource allocation to support planning for the types of change needed for the ICT-enabled learning that the policy envisioned.

In addition to the need for teachers to integrate ICTs, another area of change identified in the DER and previous policy was the need for ICT competence as an outcome of Australian schooling (MCEETYA, 1999, 2000, 2008c; NCB, 2008). ICT competency implies a continuum of ICT understanding and skills that students would develop. The practical implementation of this goal would require cross-disciplinary, ICT learning outcomes to be included in learning sequences. DER policy was directed at instructional practice in the secondary school, and therefore its enactment would be mediated through specialist subject teachers, who would have taught ICT skills in the classroom as new or additional content. The practicality of specialist teachers teaching ICT skills would be affected by the nature of their content, as specialist subject teachers tend to hold particular beliefs about their content and how students learn that content (Grossman & Stodolsky, 1995). Furthermore, enacting policy related to the teaching of ICT content would be a challenge if high-level policy goals associated with ICT competencies are disconnected from course-level outcomes, content and assessment prescribed by state education bodies. While the new Australian Curriculum did include ICT capabilities integrated across subject domains, its implementation began after the commencement of the DER laptop initiatives.

In sum, high-quality educational reform outlined in DER vision statements would require changes to instructional practice, such as the adoption of new technologies, new teaching approaches that integrate ICTs and possible alterations to belief systems associated with new content that specialist subject teachers were expected to teach. Key objectives for the DER relating to sustained and meaningful change in teaching and learning were not associated with indicators or benchmarks aligned to instructional practice at the school level; thus the quality of the system-wide reform agenda's implementation is difficult to gauge. Practicality of ICT-integration would be enhanced through the provision of highly focused teacher training associated with how student learning of subject-specific skills and knowledge could be supported by ICTs. Finally, for DER goals relating to students' ICT competency to be realised, specific ICT skills and knowledge would need to be explicitly included within the curriculum content that specialist subject teachers were expected to teach.

4.6 Discussion

This section discusses the analysis presented as the characteristics of intended changes associated with Australia's Digital Education Revolution. Implications for teachers are synthesised and their characteristics are outlined. A number of limitations are discussed. Finally, recommendations are made for policy-makers and teachers, and for further research.

The Australian reform agenda provides an example of a tri-level approach to whole-system reform where the federal government, state and territory education authorities and schools shared a common vision:

> All Australian school students acquire the knowledge and skills to participate effectively in society and employment in a globalised economy (COAG, 2009a, p. 1).

This common base, foundation or shared objective was a key part of the Australian reform agenda. The Australian government had established national goals for schooling since 1989; however, it was up to the states, and to a larger extent, individual schools to put policy into practice. What changed considerably over that period is the connection between national agendas and funding arrangements through national partnership agreements that provide a direct conduit through to schools and classrooms. The DER was a case in point: a national policy that had a direct impact on teachers' practice via providing ICT to Years 9 to 12.

The increased influence of national government policy on local school practice supports the argument that there is an emerging "national system of schooling" in Australia driven by a "national policy field" that has economised education (Lingard, 2010, p. 131). Fullan (2007) advocates that a good fit between school needs and changes is essential. It is unlikely that a teacher will prioritise national economic needs over the more fundamental learning needs of the students in front of her. For example, research has demonstrated that teachers' decisions to use technology is based on the needs of their students such as future careers or engagement (William, Frank, & Bethann, 2004) and advantages that ICTs bring to learning or teaching (Mac Callum, Jeffrey, & Kinshuk, 2014).

DER policy had very high expectations of teachers and their practice. High-level policy outcomes relating to ICT competencies for learners, student engagement with laptop computers and teachers' implementation of ICT-enabled learning in schools would require advanced, highly specialised and integrated domains of knowledge relating to ICT use, ICT-supported pedagogical practice and the way ICTs affect and enhance student learning. For in-service teachers, it would be difficult to implement the sustained and ongoing professional learning needed.

The most visible element of the DER, the provision of laptop computers to secondary students across the country, has much in common with priorities identified in earlier policy studies (Kearns & Grant, 2002; Meredyth et al., 1999). The NSSCF, not unlike an earlier *rolling-out phase* (Kearns & Grant, 2002), was aimed at improving student-to-computer ratios. This suggests that policy associated with technologies in schools is cyclical and not easily aligned to discrete phases. As technology evolves and educators develop the necessary knowledge and skills to take advantage of those ICTs, it makes sense that rollout phases and mainstreaming phases are revisited as emerging technologies are introduced and become normalised in the context of classroom use.

A great deal of the DER policy process may have contributed to what Fullan (2007) terms *false clarity*. False clarity occurs when change is interpreted in an oversimplified way or an innovation is adopted superficially. Much of the rhetoric of the DER was associated with schools applying for NSSCF funding, logistics associated with infrastructure development and deployment of large numbers of computers. If teachers viewed the DER as an exercise in improving student-to-computer ratios, then a key focus of the policy – to support and improve pedagogy – may have been overlooked.

Examples of false clarity associated with ICT-integration is evident in the literature. A study exploring issues associated with secondary visual arts teachers' ICT-integration found teachers' views varied about the usefulness of ICTs in their subject area (Phelps & Maddison, 2008). Several teachers viewed ICTs as tools "much like a paintbrush, or a pencil or lino tool"; some viewed ICTs as important for future career paths and some as a way to make their subject a more attractive choice for students (Phelps & Maddison, 2008, p. 7). These teacher perceptions fall short of the potential for ICT-

integration to improve and enhance learning. Another example of false clarity can be seen in a study involving observations of a Norwegian secondary history lesson (Blikstad-Balas, 2012). Blikstad-Balas (2012) describes a teacher presenting information via an interactive whiteboard to students arranged in rows, with opened laptop computers. Students were expected to pay attention and take (digital) notes. The researcher observes a number of students who are off-task, not engaging with the presentation and accessing unrelated online content rather than note-taking (Blikstad-Balas, 2012). In this example, ICT-integration is superficial. Student access to laptops provides the appearance of an ICT-integrated classroom, but the instructional activity is not engaging students in their learning of history content or enhancing the instructional activity. The type of change articulated through DER policy is far from superficial. Instead, successful laptop implementation would involve several aspects of classroom practice such as instructional choice of learning activities, classroom management where all students independently access a device, curricular choices involving traditional content and content associated with ICT competencies, as well as the adoption of new ICTs.

Affecting the problem of clarity was the interconnected factor of complexity associated with a system-wide reform agenda with multiple concurrent policy agendas with implications for teachers' practice. The new Australian Curriculum, the introduction of new teaching standards and increased accountability pressures associated with national testing regimes were part of the education policy field; these factors were competing for the school improvement agenda and, ultimately, teachers' time. Coherence between these top-level (national) goals may not have been clear to teachers, particularly DER goals relating to ICT skills that did not coincide with the position of ICT competencies as part of national curriculum reform. Successful implementation would have required sustained and appropriate professional learning time, and in the case of in-service teachers, release from face-to-face teaching to engage with the changes in thinking, practice and adoption of new materials envisioned in DER policy.

Policy is not a specific recipe for classroom instruction; therefore, the practicality of teachers implementing goals articulated through high-level vision statements is

difficult to gauge. In investigating national policy discourse, it is difficult to interpret the way in which policy is promulgated to schools and teachers. Australia has had an ongoing national vision for changes to teaching practice, but it is unclear how intended changes are devolved from national-level vision statements to a school-level plan of action. Likewise, the relationship between high-level policy outcomes associated with ICT competencies and student technology use and syllabus outcomes that guide teaching and learning were elusive. The way policy objectives traverse the three levels of the system is worthy of further investigation and would inform understanding of implementation factors relating to practicality of implementation.

Whether high-quality change takes place and whether changes have a positive impact can only be ascertained if monitoring and evaluation are embedded throughout the policy process. Failure of large-scale reform is over-represented in history. Ignoring lessons from previous reform initiatives is an even greater failure. The quality of educational reform can only be ascertained through systematic and empirical data collection throughout enactment periods that show what the system is doing, what is changing and what is working. The absence of benchmarks, milestones and an evaluation framework is perhaps one of the key failures of the DER administration, and it is difficult to comprehend why part of the multi-billion dollar initiative was not allocated to this part of the policy process.

4.7 Recommendations for policy making

In the context of policy making in Australia's federal system of government, the DER represents a policy process involving collaboration between states, territories and the national government. The 2007 national election that saw one political party in power at both federal and state levels (unusual in Australian politics) may have been the catalyst that promoted a collaborative approach to DER education policy. Large scale education reform is unlikely unless policy making and implementation involves national, state, territory and non-government school systems working towards common goals.

Capacity building at the local school level is an important focus for policy making. The DER included broad-based initiatives aimed at increasing capacity in teaching and

school leadership (DEEWR, 2010); however, this initiative was disconnected from individual schools when funds were directed to universities and businesses. Policy making must acknowledge that while providing increased access to resources such as ICTs are a precursor for changed practice, it does not in itself, result in improved outcomes for students. While working towards national common and agreed goals, it is important that policy implementation target school-level initiatives. These might include, for example, professional learning programs that target ICT use within specialist content areas; release time for in-service teachers to design programs of study and assessment that effectively integrate ICTs as well as prepare non-computing studies teachers to increase student ICT capabilities.

The final recommendation concerns the need to include evaluation frameworks as a component of education policy making. It is acknowledged that the scope of the DER made evaluation challenging but there was a clear need for monitoring to move beyond simply recording of hardware and infrastructure roll out. There is a long history, in Australia, of governments commissioning reports in the context of education (for example Ainley, Fraillon, & Freeman, 2007; Freebody, Muspratt, McRae, & The Le@rning, 2007; Griffin, 2011; Howard & Carceller, 2010; Meredyth et al., 1999). The work commissioned by the NSW Department of Education and Communities involving multiple stakeholders and data collection throughout the implementation period provides an example of an evaluation process to inform future education policy making (Howard & Carceller, 2010; Howard & Mozejko, 2013; Howard et al., 2012).

4.8 Limitations

Policy documents were sourced primarily through Internet searches of websites, as outlined in the methodology section. This part of the research poses challenges for scholars wishing to build on a study such as this. The dynamic nature of Australian politics means that government agencies are in a constant state of flux from one election period to the next. Consequently, websites and documents' uniform resource locators (URLs) current at the outset of the study were often out of date before the research was published. This means that some of the documents drawn on are now difficult to locate.

Creating new policy knowledge will depend on the preservation of digital public assets. In addition to official policy, other documents informing the research included communiqués of government agencies (e.g. COAG meeting communiqué), reviews commissioned by government agencies, HTML pages of government agencies' websites and education authorities' curriculum documents. These types of documents are classified as *grey literature*: documents that are not controlled by commercial publishing or any systematic means of dissemination (Lawrence, 2012; White et al., 2013). This study illustrates the usefulness of grey literature to education research, and social science research more generally, and suggests that work continue (see Lawrence, 2012) into the development of systematic archival systems that indefinitely preserve access to important documents of the state. Only then can catastrophic information losses, such as those described by (White et al., 2013) with the discontinuation of the Education Network Australia (EdNA) initiative, be minimalised.

Another limitation of this study is that the policy focus was at the national level, with some examples drawn from the New South Wales Department of Education context. It was beyond the scope of this study to consider DER policy in detail at the state level or state jurisdictional level (e.g. Australian Independent Schools or Catholic Education Commission) or to examine individual school-based ICT-integration policies. Further studies of state and school-based ICT-integration policies and relationships between national-state-school policies are areas worthy of further investigation.

A final limitation acknowledged is the limited time period on which this study focused. Documents were primarily sourced that were published within a specific time frame (2008-2012) to focus on discourse associated with the DER, and because an aim for the analysis was to provide important contextual information for the wider ICT-integration study, where data were collected from teacher-participants in 2011. The DER provides an example of policy that provided ICTs for a period of time that targeted teachers and students in Years 9 to 12. The DER continued to advocate goals of advancing productivity, improving educational outcomes and developing students' ICT competencies. These goals had their foundations in previous policy, beginning with the 1998 *National Goals for Schooling*, and continued through the subsequent

Learning in an Online World action plan for the information-economy policy suite spanning 2000-2008 (MCEETYA, 1999, 2000) and to contemporary "bring your own device" (BYOD) policies (for example, DETVic, 2015; NSW DEC, 2014; Qld DET, 2013). Despite the discontinuation of DER funding for mobile devices, schools and education authorities have endeavoured to extend the 1:1 environments established by the DER to other levels of schooling through BYOD programs. Objectives relating to improved student learning, ICT skills and ICT-integration continue, and therefore ongoing evaluations of ICT implementation would be valuable contributions to ICT-integration literature.

4.9   Conclusion

An analysis of Australia's Digital Education Revolution policy agenda has been presented. Contents of documents were analysed using a framework based on change characteristics of need, clarity, complexity and quality and practicality (Fullan, 2007). The need for changes to teaching and learning was framed as a component of broader economic reform aimed at economic prosperity. Australia's productivity agenda was linked to a need for human capital, and this was to be achieved through education reform. This reform required a focus on contemporary teaching and learning; therefore, needs relating to teachers' capacity to integrate ICT were identified. For teachers, needs associated with economic prosperity are unlikely to be perceived as a "priority need" (Fullan, 2007, p. 88), because teachers tend to be more concerned with the day-to-day needs of their students.

Need is interrelated to other factors that may not become fully clear until implementation has commenced (Fullan, 2007). This may have been the case for the DER, which saw the rapid deployment of computers to Australian Year 9 to 12 students via the main DER funding component – the National Secondary Schools Computing Fund. Needs associated with contemporary teaching and learning were interconnected with the *clarity* of the changes expected; in other words, how clearly identified were the specific things that teachers were required to do differently during implementation. Students were required to creatively and productively use ICTs within flexible learning environments supported with increased access to digital technologies. Teachers were required to know how to use digital resources, laptop computers and

learning activities to support students' construction and expansion of subject knowledge. While the vision had some clarity, the reality of implementation at the school level was dominated by logistics associated with funding and ICT acquisition, and this may have led to a *false clarity* associated with the presence of laptop computers, rather than real clarity associated with sustained and meaningful change to instructional practice.

Closely related to clarity about what teachers should do differently were factors associated with *complexity*. The DER was a large-scale, system-wide reform agenda; this study highlighted the complexity associated with the array of interconnected policy activities competing for schools' and teachers' time. The type of sustained and meaningful change required by implementation would have required release from face-to-face teaching for in-service teachers for appropriately focused professional learning, and this would have posed challenges for schools that were not directly eligible for funding relating to DER initiatives that targeted teachers and school leadership.

Interconnected with complexity is the requirement for an evaluation framework so that factors associated with *quality and practicality* can be gauged. This is also interconnected with clarity because quality and practicality are closely linked to changes in instructional practice at the school level, and with teachers knowing what they should do differently. For change to occur in practice, it needs to occur along dimensions of adoption of new materials (such as technologies), use of new teaching approaches and possible alterations of belief systems (Fullan, 2007). Therefore, successful policy implementation depends on goals that can be translated to classroom practice associated with instructional strategies and student learning.

CHAPTER 5: INFORMATION AND COMMUNICATIONS TECHNOLOGY INTEGRATION IN SENIOR SECONDARY EDUCATION

Abstract

The effective integration of information and communication technology (ICT) is significant for teachers at all levels of schooling. For senior secondary teachers, teaching and learning involves the use of technology within the context of highly prescribed course content and high-stakes assessments. There is, however, limited research to provide detailed insights into how these teachers approach ICT-integration. This study adopted a phenomenological approach that collected data from 28 Australian teachers through semi-structured interviews. Teachers' technological and pedagogical content knowledge (TPACK) provided a conceptual framework to guide data collection and analysis. The most common pedagogic practices discussed by participants were those aimed at meaning-making. Pedagogic practice routinely involved teacher-led, whole-class discussions supported with engaging and sometimes interactive visualisations using display technologies; and students' creation of digital artefacts through combining and presenting multiple media types using various software applications. This routine use of digital resources offers a range of communicative practices to teachers and their students, with implications for design of learning activities. Also, participants valued students' application, rather than development, of ICT skills, which suggests that there is a need to develop subject-specific ICT skills in junior secondary courses to maximise the benefits of ICT at senior secondary level. The TPACK framework enabled a view of teaching experiences through component teacher knowledge domains (TK, PK, TCK, TPK) that are applied during planning and implementation of quality lessons involving ICT-integration, thereby enabling a connection from theory to practice.

5.1 Introduction

Information and communications technologies (ICTs) are a part of contemporary social, work and educational contexts. In education, ICTs have played increasingly important roles. In the past, the focus for ICTs in school education was on the types of skills needed by future technology workers. These skills were to be developed through specialist computing subjects, and later within the context of different subject areas as ICTs became integrated throughout the curriculum (Markauskaite, 2005). The role of technology continues to evolve and the use of ICTs is now considered a general capability – an essential outcome of Australian schooling (ACARA, 2012b). As well as the need for ICT literacies, educators are concerned with applications to support and enhance learning (Finger, Russell, Jamieson-Proctor, & Russell, 2007; Koehler & Mishra, 2008; Oakley, Pegrum, Faulkner, & Striepe, 2012; Pramanik, 2011).

Governments are a key component of system-level educational changes (Fullan, 2007). As in other nations, these applications of ICTs in Australian schools have been echoed over time in government policy discourse. At the turn of the century, the Australian Government forecast that Australians would need to adapt to live in a world where technological change was transforming the way we lived, worked and learnt (ANTA, 2000). ICT was recognised as an "enabling force", and a "pervasion" of ICT throughout school curricula was called for to prepare future workers with skills for the information economy. Over the following decade, the emphasis shifted from a need for skilled workers to a focus on improved student outcomes through provision of ICT-enabled learning environments and quality teaching (MCEETYA, 2005a, 2005b, 2008a). In 2008, the national *Educational Goals for Young Australians* established ICT capability as a foundation for success across all subject areas, and underwrote multi-billion dollar reform initiatives aimed at increasing computers, online resources and infrastructure in all Australian schools (AICTEC, 2009b; MCEETYA, 2008c).

It is within this period of national reform in Australia, known as the *Digital Education Revolution*, that this research was situated. The Australian Government advocated increased use of ICTs in schools and provided funds to increase access to them to improve students' learning outcomes (DEEWR, 2009b; MCEETYA, 2008a). The national vision required teachers to have knowledge of how learning outcomes are

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improved through the integration and embedding of ICTs in teaching programs, learning activities and assessment. Such changes imply a degree of complexity for teachers, who are required to develop new skills, change existing beliefs, adopt new teaching strategies and develop new teaching resources (Fullan, 2007).

This study specifically explored how teachers integrated ICTs into their teaching practice in the context of senior secondary education during the Digital Education Revolution reform initiatives. The timing of the study was significant, as the senior secondary cohort had been provided with one computer per student (DEEWR, 2008b). In addition, the context contributes to further understandings of how technology integration is enacted in year 11 and 12.

5.2   Teacher knowledge and ICT-integration

Senior secondary curricula are designed to build knowledge and understanding across specific subject areas as measured through internal assessment and final examinations. Proficient senior secondary teachers are experts in their specialist subject areas, and use teaching strategies that help their students link prior knowledge to new concepts, interpret and apply knowledge and become independent learners and problem-solvers (Ayres, Sawyer, & Dinham, 2001; Ayres et al., 2004).

As well as knowledge of content and pedagogy, the increased prominence of technology in senior secondary education means that a third domain of teacher knowledge – technological knowledge – is necessary for effective teaching. This knowledge base, unique to teachers, has been conceptualised in the *Technological and Pedagogical Content Knowledge* (TPACK) framework (Koehler & Mishra, 2009; Mishra & Koehler, 2006).

TPACK is an extension of *Pedagogical Content Knowledge* (PCK), a conceptualisation introduced by Shulman (1986b), to describe specialist knowledge associated with effective ICT-integration (Mishra & Koehler, 2006). Central to the underlying PCK framework is the premise that specialist subject knowledge (content knowledge) underpin the most appropriate instructional practices (pedagogical knowledge) required for effective teaching and learning of that content. In the words

of Shulman (1986b), PCK encompasses knowledge of "the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations - in a word, the ways of representing and formulating the subject that make it comprehensible to others" (p. 9). Shulman (1986b) argued that while knowledge of pedagogical strategies and subject matter content were necessary precursors, expert teachers' enacted pedagogical content knowledge (PCK) when they represented and formulated subject content in a way that was meaningful to learners. In a similar vein, new technologies, argue Mishra and Koehler (2006), have a significant role to play in subject-content representation with the ways in which they can "make it more accessible and comprehensible" to learners (p. 1023).

TPACK conceptualises teachers' knowledge as three interconnected domains:

> "[TPACK] emphasizes the connections, interactions, affordances, and constraints between and among content, pedagogy, and technology. In this model, knowledge about content (C), pedagogy (P), and technology (T) is central for developing good teaching. However, rather than treating these as separate bodies of knowledge, this model additionally emphasizes the complex interplay of these three bodies of knowledge" (Mishra & Koehler, 2006, p. 1025).

The three knowledge domains, technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK); and the inter-related constructs technological content knowledge (TCK), technological pedagogical knowledge (TPK) and technological, pedagogical knowledge (TPACK) are represented diagrammatically in Figure 8.
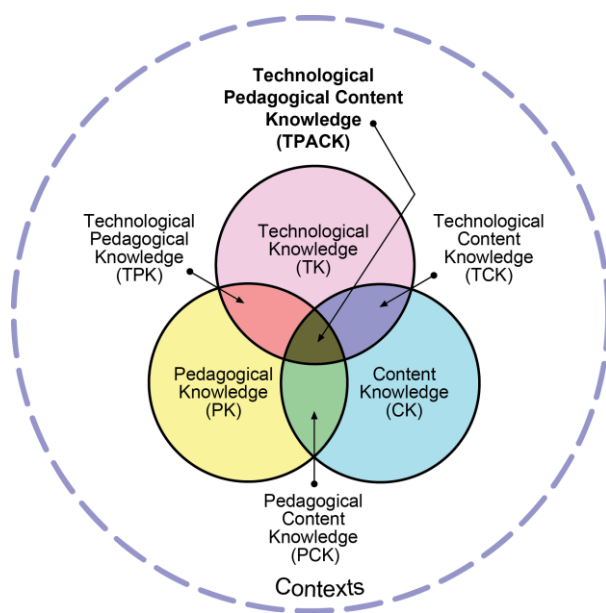
Figure 8: Graphic representation of technological pedagogical content knowledge (TPACK).(Reproduced by permission of the publisher, © 2012 by tpack.org")

In senior secondary schooling, Content knowledge (CK) is the specialist subject knowledge to be taught in a Year 11 or 12 course; pedagogical knowledge (PK), includes knowledge of student learning needs, teaching strategies and sequencing of learning activities; and technological knowledge (TK) is knowledge of affordances and constraints of ICTs that can support and enhance teaching and learning (Cox & Graham, 2009b; Mishra & Koehler, 2006).

TPACK goes beyond discrete knowledge in these three separate domains, suggesting that effective teaching with technology depends on their interaction and interdependencies (Mishra & Koehler, 2006). Technological content knowledge (TCK) is knowledge of how technologies are used to create representations of subject content and technological pedagogical knowledge (TPK) is knowledge of affordances and constraints associated with technologies that are available to support teaching strategies (Cox & Graham, 2009a; Mishra & Koehler, 2006). As well as a conceptual framework, TPACK is one of the seven constructs that make up the framework. The TPACK construct represents knowledge of:

> the representation of concepts using technologies and pedagogical strategies that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students'

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prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones (Mishra & Koehler, 2006, p. 1029).

This conceptualisation of knowledge has informed ICT-integration research in a number of areas including preservice teacher education (Angeli & Valanides, 2009; Jamieson-Proctor, Finger, & Albion, 2010; Niess et al., 2009; Schmidt, Baran, Thompson, Koehler, et al., 2009)   in-service teacher professional development (Graham, Burgoyne, et al., 2009; Harris & Hofer, 2011; Mouza & Wong, 2009; Shin et al., 2009; Swan & Hofer, 2011) and as an analytical lens for instructional planning with ICT (Angeli & Valanides, 2009; Koehler & Mishra, 2005; Koehler, Mishra, & Yahya, 2007).

Despite the volume of fruitful research TPACK has spawned, scholars suggest that further development of the framework is warranted (Angeli & Valanides, 2009; Archambault & Barnett, 2010; Cox & Graham, 2009a; Graham, 2011). This is because the foundational PCK framework has not been sufficiently explicated and this has made it difficult to concisely define constructs within the TPACK framework (Archambault & Barnett, 2010; Graham, 2011). Developing a greater understanding of the framework will help to clarity of definitions of component constructs and their worth to ICT-integration studies (Archambault & Barnett, 2010; Graham, 2011) and using the framework with in-service teachers would be of value in providing examples of TPACK in practice within contexts of different teaching environments (Cox & Graham, 2009a).

In addition to problems associated with clearly defining the knowledge base of teachers, the context for student learning can affect teachers' application of knowledge when implementing ICT-integration lessons their schools. The context of senior secondary schools' prescribed curricula, high-stakes assessment and the high expectations for computers in schools create a potent contextual mix. Somekh (2008), in reflecting on large scale reform agendas in the USA, Norway and Chile, suggested that despite the deep and meaningful positive changes occurring in pedagogies, learning and the roles of teachers and students, concerns about ICT use surfaced in the

context of preparing students for standardised assessment. She concluded that "as pedagogical adoption [of ICT] occurred, a mismatch developed between learning outcomes and the requirements of national tests" (Somekh, 2008, p. 455).

Evidence suggests that Australian teachers at senior secondary level share similar concerns. For example, in a study of the use of web-conferencing technologies in rural NSW schools, teachers noted that the "content driven focus of senior school studies" limited ICT application in those courses, and that assessments were dominated by pen-and-paper-based strategies in line with the "nature of Year 11 and 12 curriculum requirements" (Mitchell, Hunter, & Mockler, 2010, p. 473 & 474). Time constraints were also highlighted, with a senior secondary teacher-researcher noting that time was "very tight in the three terms they have to complete the syllabus", affecting her flexibility and available class time for employing ICT-supported learning activities (Williams, 2009, p. 13). In a larger study, one teacher expressed these concerns succinctly: "the senior syllabi are so prescribed…you're told, you know blow by blow, dot point by dot point what you must cover" (Van Bergen & Freebody, 2008). These studies suggest that while TPACK is an important prerequisite for effective ICT-integration, the context of teaching and learning may override effective application of that knowledge base and the decision to use technologies to support student learning.

5.3 Pedagogy in senior secondary schooling

A study of effective teaching in the senior secondary context observed nearly 50 different teaching strategies in senior secondary classrooms of participating schools (Ayres et al., 2004). A large number of strategies were aimed at developing understanding of subject matter so that students could move beyond factual recall and apply their knowledge through problem-solving and interpretation (Ayres et al., 2004). The teaching strategies used by teacher-participants to build understanding included whole-class questioning and discussion, small-group work, note-making and independent work (Ayres et al., 2004).

As the range and access to ICTs have increased, so to have the means for creating representations of subject matter content (Mishra & Koehler, 2006). For example, technologies enable the creation (or assemblage) of content as text, sound and image

for the screen. This provides multiple possibilities to the designer of those representations and multiple "reading paths" for students when transforming content into knowledge (Kress, 2004, p. 114). Teachers as designers of those representations require skills and knowledge related to constructions of representations using ICTs knowledge of how to maximise meaning-making as students navigate on-screen content.

Examples of using ICT for meaning-making at the secondary level appear in the literature. These include display technologies, such as interactive whiteboards and smart response systems, and the creation of mash-ups from digital learning resources used in senior secondary physics and English courses, which reportedly improved engagement and conceptual understanding (Fillmore & Tuovinen, 2008; Gresham & Gibson-Langford, 2012). Course-management systems, teacher-created learning objects, online lectures, podcasts, images and computer-based simulations have also been used to improve conceptual understandings in senior secondary biology courses (Nichols & Barton, 2008; Williams, 2009). In mathematics, ICTs such as computer algebraic systems, dynamic geometry software and graphics calculators provide opportunities for multiple representations of mathematical concepts, animations of geometric transformations and dynamic interactions between formulae, tables and graphs (Coupland, 2006; Goos et al., 2000; Goos, Galbraith, Renshaw, & Geiger, 2003). These tools have been shown to improve engagement, motivation and conceptual understanding (Heid, 1988; Hollebrands, 2007; Pierce, Stacey, Wander, & Ball, 2011). Such examples provide evidence of successful technology integration in contexts where the right conditions exist.

ICTs can improve motivation and engagement and support students building knowledge and skills in a subject area, but effective teaching depends on teachers' applying their TPACK (Koehler & Mishra, 2009), and on their understanding of digital media and how it can represent and communicate content to develop subject-specific knowledge (Kress, 2004). Therefore, understanding what teachers do in their classrooms and their experiences with ICTs in supporting teaching and learning is important to advance knowledge of ICT-integration and inform policy implementation in school education. The study presented in this paper contributes to this understanding

by providing insights into teachers' experiences of ICT-integration to support teaching and learning in the senior secondary years of schooling.

5.4 Methods

5.4.1 Research question

The study was guided by the research question: *How do NSW senior secondary teachers integrate ICTs to support teaching and learning*? This paper presents a component of a larger study that examined the relationship between Australian Government ICT education policy and its implementation in the NSW senior secondary school curriculum. This component of the research reports on teachers' experiences with ICTs in senior secondary education. In this study, senior secondary schooling refers to the final two years of school (Years 11 and 12). In New South Wales, students typically undertake five or six highly prescribed subjects, one of which must be English. NSW students exit Year 12 with a Higher School Certificate (HSC), providing a record of achievement that may be used to gain employment or admission to tertiary education.

Data collection occurred during the implementation of Australia's Digital Education Revolution (DER), a nationwide program in which students were provided with laptop computers (NSW DET, 2009b). Constitutionally, Australian state and territory governments are responsible for education; however, national goals and initiatives are formulated through intergovernmental agencies. The Australian Government provides funding to states and territories to fund government schools, and is the major provider of funds to non-government schools (Harrington, 2011). The $2.4 billion dollar DER initiative involved all secondary schools in Australia. In New South Wales (NSW), the Department of Education & Communities (formerly NSW Department of Education and Training) is responsible for government schools; most Catholic schools come under the jurisdiction of individual dioceses, and non-government schools may be affiliated with the *NSW Association of Independent Schools* (AIS). In NSW, 66% of full-time students were enrolled in government schools, 22% in Catholic schools and the remainder enrolled in non-government schools (ABS, 2011).

5.4.2 Research approach

The study adopted a phenomenological approach. Phenomenology, literally the study of phenomena, is concerned with the lived world of individuals. This is the world that is immediately experienced by a person "pre-reflectively" (van Manen, 1990, p. 9). The approach moves beyond objective descriptions of reality, and values the subjective experiences of people in describing the phenomenon itself (Sharkey, 2001). This research sits within an interpretive framework that assumes that reality is socially constructed, that multiple constructions of that reality exist and that the researcher and the object influence each other (Lincoln & Guba, 1985).

In adopting a phenomenological approach, this study describes the experience of technology integration. This approach is an appropriate way to capture data from senior secondary teachers, as phenomenology values the perspective of the individual, their personal knowledge and their interpretation of the value of ICTs within the context of their subject area and classroom practice.

5.5 Participants

Participants were sought from government and non-government NSW schools. Permission was granted through the State Education Research Approval Process (SERAP) to contact NSW government schools. A similar approval process was completed prior to contacting Catholic diocesan schools. School principals were contacted by phone and asked if teachers might be available to participate. In addition, teacher professional associations were contacted and asked if any association members who taught senior secondary subjects would participate. In total, 30 schools drawn from metropolitan and rural centres were contacted, of which 14 replied. No Catholic diocesan schools replied to requests to participate; consequently, they were not represented in the dataset.

From the pool of teachers who expressed an interest in participating, criterion sampling (Creswell, 2012b) was used to identify those who were actively using ICT to support teaching and learning in their subject areas. Teachers who exclusively taught computing-studies subjects were excluded, as ICT is explicit in the concepts and skills taught in those courses. This initial information was gathered through email, and

interview times were organised with suitable teachers. Teachers were sent an information kit explaining the purpose of the study and an outline of the interview procedure.

The final participant group included 14 male and 14 female teachers across the government and non-government sectors. Nine teachers came from rural areas and 19 were from metropolitan areas of NSW. Participants were drawn from 14 schools in total: eight were metropolitan schools and six were in rural areas. All rural schools were government schools; three of the metropolitan schools were non-government schools. All participants had five or more years of teaching experience: 11 teachers had between five and 10 years of experience, eight teachers had between 11 and 20 years' experience and nine participants had taught for more than 20 years.

Table 20 provides a summary of participants by subject area and school type.

Table 20: Breakdown of participants by subject area and school type

Subject area	Number of participants (government)	Number of participants (non-government)	Total
Visual Arts	3	0	3
Music	0	2	2
English	1	1	2
Business Studies	1	0	1
Economics	1	0	1
Modern History	0	1	1
Languages	0	2	2
Mathematics	3	3	6
Science	5	1	6
Agriculture	2	0	2
Design and Technology	1	1	2
Totals	17	11	28

5.5.1 Data collection

Teacher-participants were interviewed during Terms 2 and 3 in 2011. Face-to-face interviews lasted approximately 40 minutes. Teachers' experiences were collected through an in-depth semi-structured interview. The purpose of the interview was to obtain first-person descriptions of participants' experiences of teaching and learning

with ICT. The guiding questions (Appendix A) were developed using definitions of the TPACK constructs. The questions were designed to collect data on the following:

- Context, including the type of ICTs available and the demographics and background of students.

- TPACK constructs, with questions designed to elicit data on teachers' content knowledge (CK), pedagogical knowledge (PK) and technological knowledge (TK), as well as their interdependent derivatives (PCK, TCK, TPK and TPCK). The questions and prompts were designed using definitions of the constructs from Cox and Graham (2009b).

- Data specifically relating to Australian government policy initiatives, such as information regarding flexible learning environments, laptop computers and the use of government-funded online resource repositories.

The protocol was piloted with three participants to review the data collected, refine questions and familiarise the interviewer with the protocol. Interviews were audio-recorded and transcribed in full. The transcripts were imported into qualitative data analysis software and coded using the framework described below.

5.5.2 Data analysis

The analytical framework drew on elements from the Australian Government policy document *Digital Education, Making Change Happen* (MCEETYA, 2008a). This document was developed by the ICT in Schools Taskforce to support planning for ICT-integration, and was intended to provide a framework for ICT implementation under the Digital Education Revolution policy (AICTEC, 2009b). The framework describes ICT use across 10 elements of quality schooling. Elements of the framework relevant to teaching and learning in senior secondary education are:

- Element 1: Personalising and extending student learning
- Element 5: Improving student assessment and reporting
- Element 6: Developing, measuring and monitoring digital literacies
- Element 8: Providing, accessing and managing teaching and learning resources.

Element 1 is concerned with personalising and extending student learning; within this element, ICT-integration relating to classroom practices is categorised (MCEETYA, 2008a, p. 7). Definitions for these ICT-use categories were developed specifically for this study and are listed in Table 21.

Table 21: Categories of ICT use related to Element 1 – Personalising and Extending Student Learning

Students use ICT to	Description
Collaborate, share and communicate	Collaboration involves formal and informal learning activities where students work together to achieve a common goal, such as developing understanding of content, acquiring a new skill or completing a group assignment. Sharing involves students accessing shared resources; communicating refers to electronic mail or use of discussion forums.
Conceptualise, produce, create and acquire knowledge	These activities are part of knowledge-acquisition processes. Conceptualisation (to form concepts and ideas) is a part of cognition, where abstractions are used to organise and make sense of new information (Woolfolk & Margetts, 2010). Uses of ICTs in this context includes use of visualisation technologies and students producing and creating artefacts such as presentations, reports and other digital media.
Question and enquire	This category involves students searching for answers to teacher-generated or self-generated questions in research tasks, science and agriculture experiments and major projects associated with HSC practical examinations.
Solve problems and think critically	Activities falling into this category include the application of knowledge, connecting interrelated concepts and students thinking things through, asking their own questions, analysing data and interpreting information rather than reproducing facts (Ayres et al., 2004). Critical thinking is a component of the problem-solving process, along with creative thinking and metacognition (Sale, 2001).
Manage information	This category refers to technologies used to access, acquire, organise, store and distribute learning resources.

These five categories provided the main focus for the analytical framework for categorising the ICT use described by teacher-participants in this study.

Results relating to Elements 6 and 8 are also reported in this study. Element 6, concerning digital literacies, aligned to interview data describing ICT skills. Element 8, concerning accessing and managing teaching and learning resources, aligned to dialogue concerning learning management systems, digital resources and government-created digital resources through The Le@arning Federation. These elements are described in Table 22.

Table 22: Elements relating to students' ICT skills and teaching and learning resources

Element	Description
Element 6: Developing and monitoring digital literacies	Students demonstrate high levels of engagement, confidence and skill in using ICT in their learning.
Element 8: Teaching and learning resources	The use of systems (e.g. content-management systems) that enable creation of digital teaching and learning resources; and the use of nationally developed digital content in the school.

Additionally, data was collected from NSW schools during the DER. This afforded an opportunity to investigate ICT-integration in the context of one-to-one mobile computing in schools. A code was included for dialogue relating to DER laptop computer use and ICT-integration. The complete coding scheme used in this study is described in Table 23.

Table 23: Coding scheme used to analyse ICT-integration

Element	Name	Description
Element 1	Personalise and extend student learning	
	Collaborate, share and communicate	ICTs described in teachers' experiences associated with collaboration, sharing and communication
	Email	
	Intranet	
	Presentation	
	Shared drive	
	Social media	
	Video conference	
	Other	
	Conceptualise, produce, create and acquire knowledge	ICTs described in teachers' experiences associated with conceptualising, producing, creating and acquiring knowledge
	Creating products	
	Maths apps	
	Visualisation	
	VR (virtual experiences)	
	Other	
	Manage information	ICTs used to manage data and information
	Question and enquire	ICTs used for question and inquiry activities
	Solve problems and think critically	ICTs that supported problem-solving
	Improve student assessment and reporting	Use of ICT to support school-based assessment practices
Element 5	Enhance assessment	Use of ICT to support school-based assessment practices
	Streamline with ICT	

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Element 6	Digital literacies	
	Engagement and motivation Planning for DL Skill level and acquisition	Teachers' awareness of digital literacies – need for student skills, improving students' ICT skills
	Teaching and learning resources	
Element 8	Collaboration and networking Digital resources TLF – Scootle – Digital Content	
	Non-use	Specific mention of ICTs not being used
	Laptops	Reference to DER laptop

Thematic coding was undertaken using a "selective or highlighting approach" (van Manen, 1990, p. 93) to deconstruct the data. This involved importing transcripts into a qualitative data analysis database system and electronically tagging sections of dialog that aligned to the analytical framework.

The highlighting and tagging approach revealed that excerpts relating to Elements 1, 6 and 8 produced considerable overlap, and that teacher-participants described digital literacies and teaching and learning resources within the context of uses explicated under Element 1. Therefore results are presented under headings related to Element 1 (as described in Table 21). Results relating to impediments and to one-to-one laptops are also presented. Additionally, results relating to impediments to ICT-integration are included.

In addition to the use of Australian ICT education policy elements to frame the results of this study, TPACK was employed during the data analysis phase in an attempt to "[abstract] out beyond the codes and themes to the larger meaning of the data" (Creswell, 2012b; Kindle Locations 3579-3580). The aim was to better understand the capabilities teachers bring to bear when integrating ICTs in Years 11 and 12. Experiences of teachers' ICT-integration were compared with definitions of the constructs as described in the analysis and refinement of TPACK's described by (Cox & Graham, 2009a, 2009b). Brief definitions of the constructs are presented as an introduction to discussion points so that readers understand how the researcher interpreted their meanings. The use of the framework with in-service teachers' experiences within the context of highly specialised teaching areas provides an

example of TPACK's manifestations in practice. This is of value in the development of understanding the constructs in providing examples of TPACK in practice within contexts of different teaching environments (Cox & Graham, 2009a).

5.6   Results

This section first presents data about participants' access to ICT in their schools, then presents a subset of the data collected; specifically, results relating to the five types of ICT use aligning to the categories described in Table 21. In addition to these five categories, participants' experiences of impediments to ICT-integration were identified as an emergent theme, and results relevant to this theme are presented at the end of this section. Real names have been replaced with pseudonyms when referring to specific participants. The results include data collected about the context of the school environments, as well as the teacher-participants' backgrounds and how they used ICTs to support teaching and learning relating to uses associated with Element 1 (personalising and extending student learning).

5.6.1   Access to ICTs

Twenty-eight participants were drawn from 11 government and three independent schools. Participants reported a high level of ICT infrastructure available to support teaching and learning in their schools (Table 24).

Table 24: Overview of infrastructure and personal access to ICT

Infrastructure and access to ICT	Number of Participants
One-to-one program – each student had access to a notebook or netbook computer during their class	23
Participant had access to a personal school-allocated workstation at their desk or a laptop computer	26
Participant had access to a workstation only in a shared environment	2
Participant had access to an interactive whiteboard for all lessons with their Year 11 and/or Year 12 students	15
Participant had access to a data projector for lessons with their Year 11 and/or 12 students (no IWB)	7
Participant was involved with Connected Classroom (video conferencing) with their senior classes	2
Participant regularly used email	28
Participant had access to a course management system such as Moodle	28
Participant's school had high-speed broadband Internet access	28
Participant's school had workstations that were networked (wired and/or wireless)	28

All schools had high-speed broadband access and access to wired and wireless computers for both staff and students. Twenty-six teachers said their school provided a laptop or netbook computer for their school-related use. Twenty-three participants were teaching Year 11 and/or Year 12 students who were part of a one-to-one laptop or netbook program (i.e. with a 1:1 ratio of computers to students). Year 11 students from all government schools were the first cohort to benefit from a personal laptop computer that had been allocated to them when they were in Year 9 under the NSW Laptops for Learning Program, funded through the DER National Secondary School Computer Fund (NSW DET, 2009b). Year 12 students from government schools were not part of the one-to-one laptop program. Two independent schools did not have one-to-one laptop access in Year 11 or Year 12, and one independent school had a one-to-one program in both Years 11 and 12.

All participating teachers reported that their schools had traditional computer laboratories and libraries with clusters of networked desktop computers. Subject areas such as art, music and languages had specialist ICTs. All three art teachers had access to small clusters of dedicated workstations to support student art-making, both music teachers had access to digital musical instruments and music-composition software

and both language teachers (who were from the same school) had a small language laboratory adjacent to their teaching spaces.

Two of the schools in rural NSW were equipped with the *Connected Classrooms Program* infrastructure, consisting of an interactive whiteboard, video conferencing (VC) and desktop sharing technologies to link to other NSW government schools via high speed broadband. This technology was used for a variety of purposes, but in senior secondary school, it enabled rural students to enrol in subjects not offered at their schools. This is further explained in the following section.

5.6.2   Collaborating, communicating and sharing

This section of the results provides examples of ICTs supporting and extending learning activities involving collaboration, communication and sharing of resources. Collaboration and communication were closely linked, and included the use of tools such as video conferencing and electronic mail (email). Collaboration also involved the use of tools that enabled co-development of artefacts such as wikis, social networking technologies and online discussion forums. Presentation technologies were important in mediating teacher-led classroom presentations. Sharing of electronic resources and information was supported with school-based network drives and Internet-based online technologies.

ICTs were extending learning in rural schools by facilitating teacher-student and student-student communication when students and teachers were in separate physical locations (different schools). The Connected Classroom Program (CCP), provided by the NSW Department of Education and Training, includes video conferencing (VC) facilities, PCs with internet connectivity and lesson-creation software (Groundwater-Smith, 2010). In NSW schools, students study English and five or six other courses they select to make up their senior secondary program of study. Garry, a Year 12 business studies teacher, who also held a leadership position in his school, explained how the CCP was extending the curriculum:

> [Our] schooling district is a partnership of [five secondary schools]. We work together to get subjects up and running through the use of video conferencing if we don't have enough students doing a subject. So we might

have three kids [wanting to study] drama…and two kids from [another high school wanting to study drama] so we will VC that and choose one teacher from the [host] school to take that. Those subjects wouldn't run without [this technology. Students] would have to rechoose their subjects. It is a good initiative and has been happening now for the past four to five years.

Although this example does not characterise a specific instance of ICT-integration, it is important because it demonstrates one way ICTs are extending student learning: through broadening the curriculum available to rural students (those who live outside a metropolitan area).

In another example involving rural schools, Marley, a Year 11 physics teacher, was trialling a new virtual-classroom technology supplied by the NSW Department of Education called *Adobe Connect*. The software included shared interactive whiteboard sessions and video conferencing for audio and video communication. The example illustrates how these ICTs were a routine part of her lesson:

> A typical lesson involves me getting in before the students arrive, and I set-up a [digital] whiteboard on the first page and some questions to answer on a notepad pod. I can see [the students] on my attendance list [when they log in]. We make sure audio is set up…and they can use their microphones. I then say hi and ask them how their weekend was…because you need to develop that rapport with the students. When they have a question they can put their [virtual] hand up…. They can answer verbally [or they can] talk me through an answer to a question on the whiteboard (Marley, Year 11 physics teacher).

The example illustrates how many traditional components of a classroom can be facilitated in online learning environments. ICTs create virtual whiteboards, facilitate note-taking and question-answer style interactions. Additionally, in this classroom, they enabled the less formal communication typical of most classrooms, which helped establish a working relationship between the teacher and her students.

A more specific example of ICTs supporting collaboration was provided by the same physics teacher, where her students were not physically located in the same school. Wikis were integral to supporting an activity where students individually researched and created shared notes on a topic area concerning the origin and evolution of the

universe (Cosmic Engines). The teacher explained how she facilitated this collaborative activity with ICTs:

> I will set up a wiki activity and I will [enter] in specifically what I want each of the students to do. I colour code each student so Jade will be green, Nick will be blue etc. and I will say *Jade, can you please research this aspect of the life cycle of a star,* [for example a] nebula…*Nick, can you research and find out some information about Blue Giants*…. I start off with my wikis with just sort of definitions like this…*Jordan, find out what is a white dwarf.* They do that little bit of research and put that information in there for me in their own colour. Then I can tell who has done what. Then I go through it with them. So at the start of the week I will give them the wiki and at the end of the week we go through the wiki together and we look at each other's responses and talk about them together, and later on we will do a more in-depth wiki and they will have to do a bit more research (Marley, Year 11 physics teacher)

The technologies enabled students' co-constructing of physics content knowledge and provided a means for the teacher to monitor progress and provide feedback.

A similar example was provided by an art teacher who used the education social networking platform *Edmodo* to support a Year 11 visual art lesson. Edmodo supported students in jointly developing understanding of artists and their work through use of forums and blogging tools for writing and text-based discussions. The art teacher explained: "I posted a link on Edmodo to a site that had an art review [for the students] to read. I set out some questions and asked them to respond to the article in a particular way…" (Leroy, Year 11 art teacher). The art teacher valued Edmodo's ability to track his students' written contributions and enabled students to see and respond to other class members' responses to his questions through the platform's blogging feature. Used in this way, Edmodo facilitated communication as well as collaboration.

Two participants used discussion forums to provide alternative means of communication between students and teachers. In the case of art, the social networking platform Edmodo was used, and in the case of biology, a learning management system (LMS) forum was used:

> [Edmodo] provides an opportunity for students who wouldn't normally speak in class, perhaps they are a bit too shy to say something out loud

because they want to carefully consider [their] words (Leroy, Year 11 art teacher)

The [Moodle Forum] works great for those kids who are struggling and not getting it as well as others and they might think, *If I put my hand up and say I don't quite get this, someone else might have a go at me*. It gives them that forum where they can actually go online and they know they are not going to get that negative feedback (Linda, Year 12 biology teacher)

A common pedagogical practice discussed by participants was teacher-led whole-class discussions, or a combination of presentation and question-answer techniques in which the teacher provides instructional cues and stimuli that guide the learning of subject content. In some cases, collaborative interactions were evident, with students and teachers co-creating meaning. In others, the focus was on teachers communicating the essential features of content to be learnt. These examples, which were described by 27 participants, were supported in a variety of ways through the use of presentation ICTs including Microsoft PowerPoint, data projectors and interactive whiteboards. For example, in art:

We use [the IWB] like a blackboard. We show images, we use [Microsoft] OneNote to annotate. If I am analysing an artwork I will have it up and then I get the kids to annotate around it by writing on it. I save it. I email it to them and they can print that off and put it in their books. (Sarah, Year 11 art teacher).

In this example, the participant's use of the word "we" (the art teacher and her students) demonstrates her view of this teaching strategy as a collaborative activity. The pedagogy was supported by an interactive whiteboard in combination with Microsoft OneNote; email was then used to assist students in their organisation of their note-taking. The interactive whiteboard and the digital annotations provided a focus for interactions and dialogue between students and teachers.

Teacher-led, whole-class instruction was the most common pedagogical practice described by participants. In almost all cases, teacher-student and student-student interactions were supported by display technologies such as the ones described by participants in the above examples.

A connected theme that was related specifically to teachers' instructional planning emerged from participants' talk about this type of pedagogy. Five participants spoke about their use of presentation software such as Microsoft PowerPoint or interactive whiteboard software as a mechanism to support their planning for a learning activity and for sequencing content to be delivered.

> My PowerPoints, I try not to read them. They are just discussion points to keep me on track. I will read it, get them to copy something and get them to talk about it…. The PowerPoints I produce are almost lesson plans. I have little notes to myself and stuff like that (Rachel, Year 11 chemistry teacher).

These teachers' instructional planning was very closely linked to the ICTs they intended to use to deliver and sequence subject content.

Email was also a popular communication tool, with 14 participants providing examples of email use to interact with their students. Students exchanged emails with teachers when submitting assignments or homework and to ask questions. Additionally, teachers used email as a tool to share resources when files such as worksheets, presentations, interactive whiteboard notes, feedback (marked-up documents) and links to online resources with students.

The final category of ICT use in this section is sharing. The most common example was teachers sharing resources with students, which was discussed by 14 participants. Sharing resources was supported by three main types of ICTs: email (discussed previously), shared network drives within the school and online tools such as learning management systems (LMSs) or social networking tools. Shared network drives were used by teacher-participants to save electronic resources including worksheets, notes, sample tests and solutions. More often, these types of resources were shared in online spaces such as Wikis, LMSs such as Moodle or posts to Edmodo. For example, two biology teachers posted shared resources such as worksheets, digital images and links through Edmodo. Sharing technologies enabled students to engage with course content outside school hours and helped manage flexible (on-demand) access to it.

Connected to a broader use of the term sharing was a theme related to specialist subject teachers' professional networking. Three examples of ICT-integration were discussed in the context of sharing information or resources with other teachers and connecting with teachers in their subject area. Three teachers provided examples that involved LMSs as a sharing platform for faculty members. For example a biology teacher explained that teaching and learning resources were uploaded to their LMS: "we share those resources between the different teachers. We are quite an open faculty and I quite enjoy that sharing experience" (Tom, Year 11 and 12 biology teacher). In another example, two teachers used an LMS established at the regional level. These teachers (maths and English) accessed resources for their subjects that had been created by others and that were aligned to their syllabus area. The third example, described by six participants, involved email-lists or discussion groups established in subject areas as a method of sharing information relevant to particular subject areas. These groups were established by teachers' professional associations or the Department of Education, and involved teachers logging into online discussions or communicating via email lists. An agriculture teacher explained his use of Yammer maintained by the NSW Department of Education:

> it is basically like a bulletin board [that was] set up with different focus groups…they describe it as Facebook for work.... People post a question [such as] "does anybody have things or resources for…." There's one [Yammer] there for iPads and ag[riculture]...I was using Yammer to keep in touch with what's happening at the moment.

This suggests that ICTs are important for specialist teachers to connect and share information with other teachers in their subject area outside of their schools.

In summary, participants described a range of ICTs that supported pedagogies involving collaboration, communication and sharing. These three were often not separate activities. When collaborative activities were described, they usually included elements of communication and document-sharing. ICTs were important in extending the types of collaborative activities available – for example, they facilitated students co-creating notes and the ability to respond and ask questions in online environments. The most common pedagogical activity described by participants was teacher-led, whole-class discussions. Display technologies such as interactive whiteboards, data

projectors and presentation software mediated teacher and student interactions and dialogue. ICTs including email were routinely used not only as a communication tool, but also as a mechanism for teachers to share and distribute electronic resources. Teacher-participants also used internal network drives and internet-based online tools to distribute electronic materials to students.

5.6.3 Conceptualising, producing, creating and acquiring knowledge

ICT uses classified under this category were concerned with knowledge-acquisition processes. Knowledge acquisition is a process that involves students developing meaning and understanding of the content and skills embedded in senior secondary course outcomes. Meaning-making involved teachers representing content in various ways using tools that aided visualisation, and students engaging with content through creating artefacts. Uses of ICTs in this context included use of visualisation technologies and students producing and creating presentations, reports and other digital media.

Digital media and ICTs that aided visualisation were routinely used to support pedagogical practices such as whole-class discussions, demonstrations, questioning and note-taking. Twenty-three participants described the value of ICT for engaging and motivating students, supporting class discussions and improving understanding of concepts, particularly when combined with display technologies such as data projectors or interactive whiteboards. In Section 5.6.2, display technologies were seen as communicative tools that supported interactions and dialogue between teachers. In the examples in this section, the focus is on meaning-making through visual representation. Images, diagrams, video clips, interactive media and animations were important elements in these descriptions of use.

In the following example, an English teacher, Julie, is describing her teaching in a classroom fitted with a data projector connected to a networked personal computer. The school subscribes to ClickView, a digital video library. Julie explains:

> The dance-scene excerpt from [the film] Chicago…is very colourful, really bright and has lots of symbolism, costuming and sets. I might have an image I label with visual techniques that they have to write about in essays. I would label only half of the techniques and then we would look at the image and I will [ask students] to tell me what the others are. [In another lesson] I can show a ClickView movie and because you can pause it. I can then ask

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the kids to identify different camera angles and shot types and positioning, and it is a useful tool. Years ago you would have to try and find pictures, still pictures, and deconstruct it that way. This is much easier and better (Julie, Year 11 English teacher).

In this example, the teacher-led instructional activity used a projected annotated digital image as the focus for a lesson and modelled or scaffolded the way students were required to deconstruct this type of content in writing about its meaning. Digital video's ease of use and its usefulness as a visual cue in supporting the pedagogical practice of classroom questioning is demonstrated.

Three-dimensional (3D) animations helped students develop a conceptual understanding of scientific processes. For example, animations in biology illustrated complex cellular processes:

> …some of the animations that show it in three dimensions are quite striking and hopefully communicate it. I think I do a decent job in terms of my verbalisation of it, but to put that animation in front of them certainly contributes to their understanding (Tony, Year 11 biology teacher).

Three participants used video clips of other experts to reinforce concepts. For example, an agriculture teacher explained how he had shown his Year 11 students a video clip of a particularly engaging presenter demonstrating the technique of fruit tree grafting: "it's like having an expert visit for five minutes without the organisation" (Douglass, Year 11 agriculture teacher). The *Australian Maths Online* website provided another example in which videos of experts demonstrated solutions to mathematical problems. One teacher explained how this use of video reinforced what was taught in class: "the value is that [the students] can listen to it five times if they want to" (Jonathan, Year 11 general mathematics teacher).

The ease with which these digital resources could be sourced, extracted and incorporated into lesson sequences was evident in participants' descriptions. For example, a science teacher exemplified this:

> [The interactive whiteboard is] made for visual experiences…I can take a five-minute excerpt out of a large presentation and link that to any object on the [interactive] board. As you are discussing things, you can say, "Let's

look at a small video on that," and bang, up comes the video on the board....
[Y]ou can link to Internet sites…. You can use animations – I've begged,
borrowed and stolen animations from everywhere – you put an animation in
and the student immediately gets it…and it's short; not an hour where they
go to sleep – two minutes – to reinforce what you've been saying – it puts a
whole new spin on teaching (Murray, Year 11 and 12 chemistry teacher).

Specialist software was mentioned by all six mathematics teachers interviewed. Three
types of applications were given as examples: spreadsheets, dynamic geometry
software (DGS) and computer algebraic systems (CAS). Participants saw the dynamic
nature of these applications as effective in developing understanding of mathematical
concepts. They spoke about the value of the interactivity that is characteristic of DGS
and CAS applications in teaching functions, geometry, modelling and data analysis.
These applications enabled students to visualise patterns, relationships between
functions and graphs, geometry and 3D volumes. Teachers used these applications to
help students build understanding of complex mathematical concepts without the need
for numerous low-level mechanical calculations or the hand-drawing of multiple
graphs or shapes. For example, one participant used interactive 3D visualisations to
assist his advanced mathematics (called Extension 2 maths in NSW) students'
conceptualisation. In combination with an interactive whiteboard, he explained its
value:

[For volumes] you have to slice it up into tiny thin bits and the more slices
there are the more accurate it becomes and you sum them to get the
volumes. It is impossible to draw on the two dimensional surface. But there
is a program called Mathematica which is…very good for these
demonstrations.... When I was a kid you could never see these things, but
now it's easy to see…. It's not just a picture. You can change [the
parameters] and it will change the curve or number of slices. There are
sliders everywhere…. It adds to the concrete understanding.... You can
really see better what's going on (Samuel, mathematics teacher).

Creating and producing artefacts provided opportunities for learners to engage with
and recombine topic content to develop meaning or improve skills in a subject area.
Seven participants provided examples of activities from English, science and art in
which students created digital artefacts such as presentations, reports, images and film
and audio clips to support learning and knowledge acquisition. For example, oral
presentations involved students creating presentation graphics in art and English. An

English teacher explained that presentation graphics gave her students more confidence and helped them to organise their thoughts when preparing a speech that compared and contrasted text types: "the kids that are not as confident generally had a [Microsoft] PowerPoint, which then allowed them to get up and give their speeches. [PowerPoint] gave them more confidence and allowed them to organise their thoughts and not have the kids' eyes on them" (Diane, Year 11 English teacher)

Podcasts were used in one example described by a music teacher. Students developed skills in the critical evaluation of music by recombining digital resources to produce a radio broadcast that included excerpts of music and students' own voice recordings discussing technical aspects of a composition:

> [Students] put a radio broadcast together analysing the song…like something you might hear on SBS or Classic FM. [They were required to] discuss the piece with little excerpts of music and talk about how the composer has used the melody in this bit. [The students] use whatever the school has available. Last time I used Moviemaker, where they chopped the pieces up, but there are lots of programs you could use for podcasting. Audacity is another one we could easily use, and that's usually straightforward, they usually just need a microphone and headphones to get going. They have to do the research in their own time to work out what they are going to bring out of the song that they are analysing (Norman, Year 11 music teacher).

The example illustrates a range of ICTs students used to create artefacts. The podcasting process involved students researching and analysing the audio track to build understanding of the musical elements and how they were used by the artist.

The creation and production of major projects are a focus in the creative arts subjects. Three art and two music teachers spoke about the importance of digital technologies for creating and producing art, musical compositions and performances – mandated components of final practical examinations in these subject areas. In Year 12, the major project (practical exam) is a summative assessment that demonstrates students' understanding of art-making, music composition and performances. Participating art and music teachers' students relied on digital technologies to support product creation; in some cases, the digital artefacts themselves were the products being submitted for examination. In these cases, it was difficult to distinguish between assessment tasks

and classwork, as pedagogical practices designed to develop more specialist ICT-related skills such as image editing, video production, audio sequencing and composition had become part of the senior visual art and music subject content. An art teacher described how students' ICT skills are developed in preparation for senior secondary school:

> We have state of the art computers…[desktop] Macs with the big screens for making films. On [the desktops] we have [Adobe] Photoshop and [Adobe] Premier which [are] professional standard software packages…. In junior years they learn about cameras and editing, and then they also have to learn about the program itself, which is really complex. Usually by the time they get to Year 11 and 12 they are very confident.

> (Katrina, Year 11 art teacher).

Conceptualising, producing, creating and acquiring knowledge is a significant area of ICT-integration, as many pedagogical practices discussed by participants were aimed at meaning-making, developing knowledge and building skills in different aspects of their senior secondary subject area. The main types of ICT use included in this category supported whole-class pedagogies such as exposition, class discussion and questioning. This type of teaching and learning was supported by almost ubiquitous access to interactive whiteboards and/or data projectors, broadband internet access to online resources and ICTs that easily combined and recombined digital media from different sources. The second type of ICT-integration described by participants was students' interaction with course content through their creation of digital artefacts. Once more, increased student access to ICTs meant that these types of learning activities were commonplace in participants' classrooms.

5.6.4   Questioning and enquiring

The types of ICT use categorised as questioning and enquiring related to learning activities that involved searching for answers through research-based tasks, case studies or practical inquiry tasks (such as laboratory work undertaken in the science and agriculture subject areas). These tasks were almost exclusively undertaken by students on their own laptop computers, either during class time or set as a homework activity.

Nineteen participants related experiences of research-based learning activities. These tasks relied on students gathering information from online resources in all subject areas included in the study with the exception of mathematics. The use of search engines to support case-study research was reported by five participants across agriculture, economics, business studies and visual arts. Ready access to current information to support student inquiry was the common characteristic across these examples. Examples of data sources students accessed included company prospectuses in business studies, and soil and climatic data in agriculture. As well as search engines, Google Books was valued by a Year 11 history teacher to support research tasks:

> Google Books provided a lot of books; far more than the library and the level is above the school library…. [Google Books] is searchable…they have such a variety of [topics] – no library is going to have all the hard-copy resources to support that. (Barbara, Year 11 history teacher).

The online resources routinely used by students in art included artists' profiles and work, performance-art pieces and virtual collections. These were important for student investigations of artists and their art-making. Online art and product-making demonstrations or tutorials were accessed by students of two art participants and one design and technology participant. In these subject areas, art and design teachers are not necessarily experts in every practical aspect of their subject area, and participants described their students' use of these tutorials to self-direct learning of practical skills for their major projects. For example, in senior art:

> I don't do night lighting. One of my kids is doing an installation and he is inspired by the works of Banksy and graffiti art…. [The student] has made all these posters…and he is lighting up using whiskers and night lights…. He just got onto Deviant Art – other art students or other artists telling you about their ideas and how you do stuff. So technique-wise…he learnt that [himself] (Sarah, Year 11 and 12 art teacher).

Inquiry-based practical tasks in the sciences were supported with spreadsheets, data loggers and Internet searching. For example, a chemistry teacher described how her students researched the quality of a nearby water system and undertook fieldwork using data loggers to sample levels of chemicals in the water on a regular basis. An agriculture teacher spoke about specialist technologies for collecting soil data: "it is a

portable piece of electronic equipment with attachments and fittings and reagents…. [Students] use [it] to sample a number of paddocks [as part of a soil analysis]" (Gary, Year 11 agriculture teacher). Typically, the data collected with data loggers or from online sources was then tabulated and charted with spreadsheet software in preparation for data analysis.

Questioning and inquiry learning activities in the form of independent research and scientific investigations were valued by participants. These activities were supported with ready access to portable computers, access to high-speed Internet connections, availability of authentic and current data sets and, in the case of science, access to specialist ICTs such as data loggers.

5.6.5   Problem-solving and critical thinking

Problem-solving activities place an emphasis on interpretation, analysis and application of knowledge. Critical thinking is often a component of the problem-solving process. ICTs to support problem-solving and critical thinking included recording devices used in creative arts for self-reflection, ICTs that reduced the need for low-level mechanical calculations in mathematics and science and ICTs that produced graphical representations of numerical data in science and agriculture.

Three mathematics teachers who participated in the study provided examples of ICTs supporting mathematical problem-solving. One described an unusual application of ICTs for which her students used laptops in her class to search online for solutions to maths problems. Students would compare and contrast their solutions with those found online. Another participant described his students' use of Microsoft Maths for a similar purpose. Rather than students checking results with him throughout the lesson, they quickly found solutions by entering the equation into the software. He felt this de-emphasised the importance of the final answer and emphasised the importance of the steps involved in the problem-solving process. This method was called "guess-check-refine" by a third participant, whose students used spreadsheets to substitute values to check results using the formula-calculation features of the software.

Two senior chemistry and two agriculture teachers also provided examples of spreadsheets being used to analyse data, specifically to eliminate lengthy or repetitive calculations and for working with large data sets. Students could then ask questions or solve problems using inferences from tabulated or graphed data.

For music students, part of the learning process associated with performance is thinking critically about their work. A music teacher explained his use of digital cameras for creating recordings of students' performances and works in progress as part of a self-reflective process. He explained that the recordings enabled his students to "look at themselves and learn a lot.... They can see their body language as well as listening to how their performances are going" (Mario, Year 11 music teacher).

In history, critical evaluation of sources is important. A history teacher explained the importance of students' ability to evaluate sources of information accessed on the Internet: "One of the things we do is evaluate sources…[students] get off the Internet. [They] need to find appropriate sources. In Year 11 and 12 we are looking at more academic sources to support whatever they are claiming" (Barbara, Year 11 history teacher).

Examples involving problem-solving and critical thinking were provided by 20 participants. They emphasised students working through problems, rather than simply presenting a solution. Critically thinking about performances was a feature in music classrooms. In these examples, digital recordings enabled self-assessment and skill refinement in preparation for practical examinations. As expected, tabulation of data to identify trends in datasets was important in the sciences, and these processes were supported through spreadsheet software.

5.6.6 Managing information

Information management is important for senior secondary students, as it concerns the way they organise, store, access and submit electronic work. Teacher-participants related examples in which their students used ICTs to organise their work, access online resources related to their course and submit their work for marking.

Electronic notebooks, such as Microsoft OneNote, were used by five teachers to help students manage information relating to coursework. Students used OneNote on their laptops to create and store notes in various formats such as handwritten notes (with a touch-screen and stylus), typed notes, images, animation, video and audio. In one particular example, Year 11 art students accessed and downloaded a file with their laptops at the beginning of the Year 11 Visual Arts course:

> I have made them a OneNote file with the course on it. We have a resources drive on the network and they can access the files. It's a fairly large file because it contains all the PowerPoints, all the notes, all the assessment tasks for the year on there. Some of the students choose to use [OneNote to write notes]; some like to write it down; some students don't, some just listen, some students will do a bit of both (Leroy, Year 11 and 12 art teacher).

By contrast, difficulties with digital note-making in mathematics were described by one teacher. Netbooks and laptop computers in schools typically used a keyboard and trackpad as input devices, making it difficult to enter mathematical notation and scientific formulae:

> …we are trying to get classes to use OneNote but in mathematics it is a bit limited. … You can use [OneNote] to put some generalised notes in there, incorporate some material from their PDF text book in there; but they can't answer the questions because they can't write [mathematical notation] on the computer screen. (Julian, Year 12 mathematics teacher).

A teacher of the classics (Latin), created notes for her students and these were provided as books at the outset of the course:

> I actually write all my own books. So that's one of the Year 12 texts [produces a ring-bound book]… There is general information, there's the text which we translate, usually together, there is some grammar, there is some grammar analysis where they have to explain various things in it. Then this is their assignment vocab they have to learn. So everything is contained there (Elise, Year 11 and 12 Latin teacher).

In this way notes were managed for students by containing and organising course content within a teacher-created resource.

Documenting major project work, important in Year 12 creative arts and design courses, was supported with desktop-publishing and word-processing applications

such as Adobe InDesign, Microsoft Publisher and Microsoft Word. This documentation, called design or composition portfolios, or process diaries in visual arts, recorded processes undertaken during the preparation or production of major art projects, design projects and music performances. In one example, visual arts students had access to a class set of Apple iPod Touches – small portable devices capable of recording images, audio and video. Her students created digital portfolios using Adobe Acrobat: "We use the video part of [the iPods] to document the process of their art-making…and then that goes as an electronic copy into their diary" (Sarah, Year 11 and 12 art teacher).

Similarly, two science teachers and an agriculture teacher sanctioned the use of personal smart phones in their classes to support documentation of science experiments, field work and excursions. In Year 11 agriculture, for example, "When we have an excursion, there is a range of kids and a range of note-taking [techniques. A student] took all her notes and photographs on her mobile phone. Smart phones – they are the perfect excursion device" (Douglass, Year 11 agriculture teacher).

Online systems enabling 24/7 access were important in storing and distributing course-related resources, providing spaces for course announcements, and in some cases, a means for electronic assignment submission. Participants described their use of the *Moodle* course-management system (eight participants), *Wikispaces* (one participant) and personal websites (one participant). In these examples, teachers provided access to course notes, past exams and revision material. For example, a Year 11 economics teacher established a website that provided access to topic-by-topic course notes, digital worksheets, PowerPoint presentations, OneNote files and a blog he wrote on "economic concerns and issues" (Matthew, Year 11 and 12 economics teacher).

For students, these information-management systems extended learning opportunities and access to resources beyond the classroom and school day, and provided support during independent learning. For example:

> I have broken up the HSC [course] by topic and focus point and … [created] quizzes…. Once we finish a focus point in class, the expectation is that they will go online and do the quizzes by focus point. That then allows me to track them – are they are doing the homework, are they using the ICT, how

are they progressing with their understanding (Tom, Year 11 and 12 biology teacher).

Increased access to ICTs was enabling participating teachers' students to take advantage of digital information management processes and systems. These included students taking electronic notes during class and field work and teachers providing access to course materials through a range of online systems.

5.6.7   Impediments to ICT-integration

Despite participants self-identifying as teachers who used ICT, five impediments to ICT-integration in the senior years were identified in the data. Barriers to ICT-integration were related to time constraints, the prescribed nature of the Higher School Certificate curriculum, a perception that ICTs were unnecessary to teach Year 11 and 12 content, student access to ICTs, and a lack of knowledge about ICTs. One specific example of non-use related to a lack of uptake of online digital content provided to schools by Australian states and territories through *The Le@rning Federation* (TLF) is discussed here.

Time constraints and the prescribed nature of senior secondary courses
Time influenced ICT-integration for 12 participants. For some, the time required to repurpose existing materials into digital formats prevented them from fully realising the potential of the course-management systems that their schools had deployed.

Teachers were also concerned about the amount of content that needed to be covered prior to HSC examinations and the relevance of ICTs in the context of written examinations. In particular, some participants spoke of the pressure to cover the mandated syllabus in time for HSC final examinations. In these cases, participants felt that time to integrate ICTs meant less time was available to complete course material:

> With the amount of content…how do you fit ICT in there? You just have to tuck it round the edges and show them a bit when you can and that's what I sort of do as best as possible (Gary, Year 11 business studies teacher).

Participants also related concerns about the time required to teach students specialist ICT skills. This meant that some technologies were used as class demonstrations rather than students using the ICTs themselves. Two mathematics teachers described how specialist software was used as a demonstration because they felt there was insufficient time within the constraints of the HSC course to teach students those subject-specific ICT skills: "in a perfect world if there were less topics [then students would] have more discovery learning [time] using Geometers Sketchpad or FX Graph. That would be really great. The chances of that happening are pretty slim" (Joanne, Year 12 mathematics teacher). A similar example was described by an art teacher who felt there was insufficient time to teach students the skills they needed to develop electronic portfolios. A biology teacher, when speaking about the need for her students to evaluate and cite "reliable" sources of scientific information from the Internet, felt that those skills should have been developed by the time they were in Year 11: "[the skills are] not coming through from anywhere. I don't know whose responsibility…. I would have thought that it was something you might have learnt in Year 6 in primary school" [Sally, Year 11 biology teacher].

ICTs perceived as unnecessary

In three examples, teachers described some areas of their course where they felt that ICTs were detrimental to students' learning in a particular content area. For example, a history teacher spoke about presentation software and her students' oral presentations:

> I don't want the kids [to] get caught up in using amazing technological presentations and lose the focus on history. And often when I see that sort of work, it has lots of pop-ups and colours and sounds and you look at the history and it's pretty poor. I don't want them to get so involved with the technology that they lose sight of the main thrust of what we are doing (Barbara, Year 11 history teacher).

In contrast, five teachers spoke about their faculties purposefully developing ICT skills in junior secondary (Years 7 to 10) so that students would be prepared for higher-level applications of ICTs in senior secondary classes. In art, an example included the development of ICT skills in image and video editing applications in Year 10; in music, a teacher described his inclusion of instruction in music composition software in his Year 7 classes: "I like to run Sibelius through the junior program so they would

work with little, simple tasks in 7, 8, 9 and 10; and so hopefully, by Year 11 they are fairly skilled with the program…. I like to have a progression through the years" (Norman, Year 11 music teacher). Similar examples were given by two mathematics teachers who explained how their faculties included explicit teaching of spreadsheet skills to junior students and explicit instruction in the use of mathematics software that had been included on the NSW Department of Education DER laptops issued to students from Year 9.

Thirteen teacher-participants gave examples of situations for which they could not see a need to use ICTs in a particular aspect of their work. The reasons were varied. Some participants felt that as they had adequate teaching resources or successful past HSC results, change was not needed:

> …the feedback that I have back on my pedagogy has been overwhelmingly positive and so with that it's hard to think why I should change things away from something that's clearly working and has delivered results over the years (Barbara Year 11 and 12 history teacher).

Another example was related to graphics calculators in Year 11 and 12 mathematics. In one case, a participant felt they were useful for the general mathematics course, but "…the 2 Unit and Extension [students] can't use them on the exam so we don't use the…calculators" (Jim, Year 11 and 12 mathematics teacher). In other cases, teachers could not see a need to use particular ICTs with senior secondary students even though their school had provided them. This was particularly the case with interactive whiteboard technologies, where participants commented that while they understood their place in primary schools, their use in the senior classroom was limited.

Access to ICTs

Despite most participants reporting that their schools were "one-to-one", student access to computers was still an impediment to the integration of ICTs in senior classrooms. In 10 examples, some students did not have access to their own device because:

- They were Year 12 students and the one-to-one program had not been deployed for that cohort.
- Students were reluctant to bring their devices to school.

- Devices were in for repairs.

In these cases, teachers reported booking computer laboratories or library time, planning for alternative lesson activities, or resorting to demonstrations.

Lack of knowledge of Le@rning Federation online content

The final example of impediments to ICT-integration relates to teachers' lack of uptake of the digital curriculum content initiative known as *The Le@rning Federation* (TLF). This initiative, established in 2001 by Australia's Ministerial Council of Education, Employment, Training and Youth Affairs (MCEETYA), was aimed at promoting greater use of curriculum resources in the form of digital content, and, by 2009, had cost $120 million (Long, Burke, & North, 2009). The TLF was established to address a need relating to digital, online curriculum content that was accessible to Australian and New Zealand educators as interactive, multimedia-rich learning objects and digital resources such as images, audio and video (Freebody, 2007). The TLF initiative continued through to the DER strategy, was associated with the supply of digital content linked to state and national curricula (DEEWR, 2008e; The Le@rning Federation, 2008). In 2008, a web interface or portal was established, known as Scootle (www.scootle.edu.au), which provided more direct access to TLF resources for Australian educators (Long et al., 2009).

Given the emphasis on teachers' use of digital content in the DER agenda and the substantial investment of public funds, it was appropriate that the study develop an understanding of how these resources were used in the context of ICT-integrated teaching and learning. Surprisingly, this was not possible because no participants interviewed for this study had used these resources. The interview question included references to TLF and Scootle: *Have you used digital resources developed by The Le@rning Federation and made available through Scootle?* Four participants had "looked at them" and deemed them unsuitable. Three participants confused TLF with other online repositories, and 19 participants had no knowledge of the repository, and follow-up questions were thus not appropriate. Reasons relating to unsuitability were that TLF content was not relevant to the senior secondary context or that there was already "a huge amount of resources out there" (Oscar, Year 11 and 12 mathematics teacher).

Overall, participants generally spoke positively about ICT-integration in their classrooms; however, there were factors that influenced teachers' decisions to use ICTs for particular lessons. Impediments to ICT-integration were related to perceived time constraints on the delivery of HSC course content, teachers not seeing a compelling need to include ICTs, and students not having ready access to ICTs in the classroom. Another factor affecting teachers' integration of ICT was students' lack of ICT skills in specific areas and a lack of time to include ICT skill development at HSC level. Despite education jurisdictions providing online digital content, TLF resources represented an area of non-use, as no participants used this content to support ICT-integrated learning and teaching in their subject areas.

5.6.8 One-to-one laptops

This final section of the results reports on laptop use in Year 11 or 12. This theme was included because the timing of the study coincided with the DER implementation of laptop computers (DEEWR, 2008b). According to policy, the DER was a "once-in-a-generation opportunity" in which the major funding component targeted increased access to computers in Years 9 to 12 (DEEWR, 2008e, p. 3). This was implemented in various ways in NSW; however, all government schools deployed laptops to all students in these years, beginning with Year 9 students in 2008 (NSW DET, 2009b):

> The NSW implementation strategy of the NSSCF [National Secondary Schools Computer Fund] is based on the provision by June 2012 of a wirelessly enabled specialist educational laptop, connected within the school via managed wireless infrastructure, to every student in Years 9 to 12. This will establish a 1:1 ratio where the student effectively has sole use of the laptop and therefore becomes accountable for it (Objectives section, para 3).

Therefore, the Year 11 students of participants in NSW government schools were issued with the device. The DER implementation for Year 11 and 12 students in the non-government schools in this study varied, but involved one-to-one laptop computer access in all but two of these schools. The results in this section describe the capabilities and challenges related to one-to-one mobile computing in schools and ICT-integration.

Positive experiences relating to laptop computers in classrooms were reported by 14 participants. For example:

> Our kids love [their laptops]. They are quite addicted to them. Actually, when they don't have them, which is now, because they are being re-cased, [the students] are at a bit of a loss. They have to pick up a pen again (Belinda, Year 11 design and technology teacher).

The multimedia capabilities of the laptops were valued. For example, an agriculture teacher pointed out that the laptops' ability to accept removable storage cards (e.g. SD cards) commonly used with digital cameras meant that images taken on a digital camera during field work were easily shared amongst students for use with their field reports. In the creative arts, image and audio editing software installed on the devices meant that students could "experiment at home and [learn]…how to use these programs" (Norman, Year 11 music teacher).

For some participants, student laptop use was becoming *normalised.* This is a concept that describes the stage when "a technological innovation becomes embedded in everyday practice" (Bax, 2003). For example: "I just take it for granted. It's a part of the classroom now. I will just say, 'Get your laptops out, guys'.... I always presume they have them on them (Katrina, Year 11 arts teacher). Other examples exemplifying this included teachers' expectations that students could access online resources such as prepared notes, and students' ability to research tasks in class for the topic at hand. A design and technology, art and English teacher provided examples of students using their laptop computers to access online tutorials to teach themselves specific skills required for their project work. For example, a student who had taught himself how to use blogs had negotiated with his English teacher to submit his journal work through this medium. In some cases (five participants), laptop use was at the discretion of the students themselves, especially with note-taking activities. For example: "I had originally planned for [students] to take their notes on their computer, and in the end, I gave them the option and I don't care if they take notes by computer or in a book (Rachel, Year 11 chemistry teacher).

> Negative experiences or limitations associated with laptops in classrooms were described by 15 participants. The most common negative experience associated with laptops was that students did not always bring them to class.

Reasons for this were breakages (both deliberate and accidental), forgetfulness, uncharged batteries, and, in one case, a teacher explained that "the Year 11s don't bring [laptops] because they say not many of their teachers are using them" (Rachel, Year 11 chemistry teacher). Other limitations described included the small screen size, which prevented some programs from running properly, the lack of a stylus for writing mathematical notation and the inability for students to install additional software.

In two cases, teachers had decided to avoid using the laptops in their class; however, negative experiences were not necessarily associated with non-use. In most cases, teachers planned for students not bringing devices. For example, a teacher explained his planning for some of his students not having equipment:

[I have] a backup…. I have a good relationship with the librarian and I can send them down with notice to work down there…. The other option is to have the printed worksheet and give it to them as an alternative. But they still would have to catch up on the work that they missed out online (Gary, Year 12 business studies teacher).

The year level taught (Year 11 or Year 12) affected teachers' planning; generally, teachers of Year 11 seemed to have greater flexibility because they did not need to plan to relocate to a computer laboratory and could easily incorporate laptop use at any time during a lesson. For example:

My Year 12 class don't have the laptops. It has been a little bit more challenging and our computer labs are generally more utilised by the junior students. So the current year 12s are more of a chalk and talk (Jim, Year 12 mathematics teacher).

In Year 9 to Year 11, [with] all the kids having a laptop, most of your resources have to be available electronically. So Year 9, 10 and 11 have access to Moodle… (Linda, Year 12 chemistry teacher).

If they had their own laptops, then they could access [the online simulation] themselves, but because this group doesn't, it is a demonstration (Linda, Year 12 chemistry teacher).

I haven't [used our LMS] but I think I will when the kids have their tablets [next year]…well, that's my intention anyway (Barbara, Year 11 history teacher).

These examples suggest that teachers are changing their practice with the introduction of laptop technologies.

Results relating to the DER laptop initiative were generally positive. They suggest a more flexible environment for ICT-integration, with teachers valuing the greater

access to ICTs in their classrooms. They provided the ability for students to easily access shared resources, access Internet search engines at any time, create a range of artefacts with software installed on their devices and continue working on computers outside of school. Teachers' comments about their Year 12 classes who did not have access to computers suggest that they were changing their practice (or intending to) with the introduction of laptop computers. Evidence suggests that the early stages of the New South Wales laptop program (the first cohort of Year 11 students) had some challenges around the reliability of devices and teachers' management of students bringing equipment to class.

5.7 Discussion

The results of this study provide a snapshot of technology use to support teaching and learning in the context of highly prescribed senior secondary education in NSW. An additional contextual characteristic was that NSW schools were implementing the Australian Government's DER agenda (DEEWR, 2009b). An aim for this study was to describe actual use of technologies by teacher-participants in their integration of ICTs into teaching and learning in their specialist subject areas. TPACK is a conceptual framework that considers teachers' knowledge domains that are invoked when designing and implementing learning activities integrating ICT (Mishra & Koehler, 2006). This knowledge base of expert teachers involves interactions between technological knowledge (ICTs), pedagogical knowledge (PK) and subject-content knowledge (CK). This discussion is framed in terms of TPACK's conceptualisation to illustrate the capabilities teachers bring to bear when integrating ICTs.

Technological knowledge (TK) and content knowledge (CK) interactions – technological content knowledge (TCK)

Teachers' knowledge of contemporary and emerging technologies and their use is represented as TK, and knowledge of how technologies are used to create representations of subject content is represented as the TCK boundary construct (Cox & Graham, 2009a; Mishra & Koehler, 2006).

An important observation in this study relating to TK is that the technologies employed by Year 11 and 12 teachers were more likely to be non-subject-specific technologies.

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Generic, readily available technologies were the most common ICTs described by participants. They are generic in the sense that they are not necessarily restricted to learning in one particular subject area. These included Microsoft Office applications such as Word, Excel and PowerPoint, as well as Adobe Photoshop and Premiere, interactive whiteboards and associated software, search engines, email, image and video editing applications (the Adobe Creative Suite), video repositories, elearning systems such as Moodle and Edmodo and (particularly in rural schools) video conferencing and virtual classroom technologies.

These generic ICTs, as well as some specialist ICTs, were used by teacher-participants to represent a range of subject content. In mathematics, specialist applications enriched the visualisation of geometry and algebraic expressions. English and science teachers valued the capabilities offered by ICTs, such as presentation graphics and flip-chart software (associated with interactive whiteboards), that enabled the recombining and sequencing of content from a variety of sources. Videos of other experts presenting content in mathematics and in agriculture provided senior students with access to detailed and alternative explanations of subject-specific skills. Participants valued specialist texts available through Google Books and digitised literature in a teacher-created textbook as a way for their students to interact with history and Latin subject content. In biology, 3D animations provided representations of complex cellular processes that would be difficult to visualise any other way.

These examples align with the TCK definition because they involved the representation of subject content using ICTs. Therefore, effective ICT-integration in senior secondary subjects can be supported by developing teachers' ICT skills (TK) that enable the manipulation of digital resources and interaction with digital resources. For example, teachers in this study described their use of video editors, music-notation editors, learning management systems and presentation software such as PowerPoint or interactive whiteboard software in organising, sequencing, representing and interacting with content. As well as identification of important knowledge for teaching, the TPACK framework guides thinking about how to develop this knowledge. Professional learning activities that are anchored to specific content areas are more effective than developing teachers' generic ICT skills isolated from the content they

teach (Joan, 2005). That is, effective professional learning would target TCK rather than TK in isolation.

There were exceptions to the dominant use of generic ICTs. In music, teachers used composition software, and student skill development in these applications had become a part of senior secondary music courses; science and agriculture teachers used online simulations of experiments as well as data-loggers and, three mathematics teachers in this study used mathematics-specific ICTs as whole-class demonstrations in combination with display technologies. In creative arts, students developed knowledge of video editing, image editing and digital cameras as an integral part of the visual arts course. These examples of use align with an aspect of the TCK construct that posits the idea that technology and content are reciprocally related (Mishra & Koehler, 2006). In the creative arts subjects, in-depth knowledge and skills in these applications were explicitly taught, and had become part of major project work associated with practical examinations. Therefore, these technologies had affected the content and skills included in the curriculum. However, there were also examples where teachers' beliefs associated with their subject content affected decisions to use technology. If teachers felt that ICT skills were not part of their subject content or were not needed to support the teaching of particular content, or that subject-specific ICT skills represented additional content outside their prescribed syllabus, they were less likely to use ICTs to support instruction. Additional TCK to develop to support teachers' ICT-integration would target discipline-specific ICTs and their value to students' learning of specific topics within a subject area.

A final point relating to TCK is twofold. First, several examples in this study illustrated that teachers themselves do not necessarily need to have expert content knowledge (CK) or ICT skills (TK) with a particular technology to integrate ICTs into instructional practice. This was evident when participants encouraged their students to use other experts, available through online sources, to teach them subject-level content that was outside their knowledge domain. Another example of this was seen when an English teacher and an art teacher were confident allowing their students to explore the applications of ICTs in their subject area, even though they themselves did not have those specific ICT skills. In these cases, teachers had knowledge about the

technologies and their place in the curriculum, but not necessarily detailed knowledge of how to use those ICTs. Second, as expected, simply providing technologies such as prepared digital resources (digital representations of content) did not ensure their uptake. This was evident in the provision of *Le@rnng Federation* resources, which, despite their value (Freebody & The Le@rning, 2005; Wallace & The Learning, 2008), were underused by participants in this study. Therefore TCK associated with searching and selecting existing digital resources and their alignment to subject-specific course outcomes would be valuable in supporting teachers' ICT-integration.

Pedagogical knowledge (PK), Technological knowledge and Technological and pedagogical knowledge (TPK)

Pedagogical knowledge includes knowledge of student learning, classroom management, assessment, lesson preparation and instructional activities (pedagogies) (Cox & Graham, 2009a; Mishra & Koehler, 2006). TPK encompasses knowledge of affordances and constraints associated with technologies that are available to support teaching strategies (Mishra & Koehler, 2006).

Participants provided examples of a wide range of teaching strategies, with whole-class discussions, demonstrations and questioning being the most common pedagogical practices discussed (PK). TK and TPK were evident where participants were routinely supporting these types of pedagogies [what practice?] with display technologies such as data projectors and interactive whiteboards. This finding is consistent with previous research on HSC teachers' practices, which found that class discussions were important in promoting thinking and conceptual understanding (Ayres et al., 2004).

Whole-class instruction with display technologies may be perceived as a substitution of new technologies into old teaching practices (Hayes, 2007). Studies that have closely scrutinised teacher-student interactions and dialogue in whole-class instruction supported with display technologies are providing a more sophisticated understanding of how this pedagogical practice can support meaning-making (Goos et al., 2003; Hennessy, 2011; Xu & Moloney, 2011). The benefits of interactive whiteboards in particular are: support of collaborative learning; a point of focus for a large learner

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group; the ability for teachers and students to directly manipulate digital artefacts; the "iterative construction" of digital artefacts; and the ability to save, re-use or build upon existing artefacts (Hennessy, 2011, p. 470). Additionally, Hennessy (2011) suggests that digital artefacts created by experts in the subject area may be useful as scaffolding or as a stimulus to provoke thinking about learners' views on particular issues. These affordances can support and enhance student learning, but this is dependent on the skill of the teacher in guiding inquiry (Hennessy, 2011). In this study, several teachers explained that they did not see advantages of using interactive whiteboards or *Le@rning Federation* digital artefacts in senior secondary education. This represents an area of TPK that requires development at senior secondary level. Teacher education involving interactive whiteboards can clarify the positive impacts related to learning senior secondary subject content when used with appropriate collaborative, questioning and probing techniques. This could be combined with education on the range and types of digital artefacts available to use with interactive whiteboard technologies in the context of senior secondary education, such as those available through *The Le@rning Federation.*

Students' creation of digital artefacts was another common pedagogical practice discussed by participants. These were highly valued learning activities facilitated by the one-to-one laptop environments available in most schools that were part of the study. Year 11, in particular, had ready access to media-creation tools that enabled students to become authors of their own texts. This was made possible in New South Wales (NSW) Department of Education schools, where Digital Education Revolution (DER) laptops came preinstalled with the Adobe Creative Suite (image and video editing applications); Microsoft Office productivity applications including Word, Excel, Access, PowerPoint and Publisher; Microsoft OneNote; and mathematics software such as GeoGebra and Microsoft Math. Examples of these types of learning activities in this study were student-created reports, essays, presentations, blogs, wikis, podcasts, videos, digital artwork and digital music. Important for ICT-integration, therefore, would be TCK associated with the ICTs to which students have access, and with the ways these ICTs help students engage and interact with subject content. Professional learning targeting this area of teacher knowledge must move beyond ICT skills in, for example, multimedia capabilities of laptop devices, towards a learning-

design approach that emphasises processes associated with ICT-integration. Learning design has gained momentum as a field of educational research because it has the potential to capture processes associated with effective ICT-integration and elearning in education (Bennett, Agostinho, & Lockyer, 2005; Cameron, 2009; Kearney, 2011). Although the DER laptops are no longer issued to senior secondary students, this type of TPK development is still relevant as schools and jurisdictions transition to a "bring your own device" (BYOD) deployment where students have access to a wealth of media-creation tools (NSW DEC, 2014; Reid & Ostashewski, 2011; Stavert, 2013).

Another TPK area identified in this study related to classroom management. This study highlighted examples where teachers could not rely on students to bring devices to class. ICT-integration requires teachers to have strategies to deal with students' reluctance to bring equipment to class and keeping devices charged, and to address the increased potential for independent online work (Reid & Ostashewski, 2011).

In sum, communicative practices available to teachers and students have increased, and the results indicate that digital resources, multimedia and display technologies have become routine components of senior secondary classroom teaching. The implications are that senior secondary teachers' knowledge bases include an awareness of how meanings are conveyed through particular media. As Kress (2000) explains, "The different semiotic modes demand and produce differential engagement with the world. The forms of engagement lead to distinct forms of cognition" (p. 406). Teachers, therefore, must purposefully design for learning activities in which students can make choices about what information to use and how to transform that information into new representations that provide opportunities for meaning-making (Kress & Selander, 2012).

Technological pedagogical content knowledge (TPACK)
As well as a conceptual framework, TPACK is one of the seven constructs that make up the framework. The TPACK construct represents knowledge of:

> the representation of concepts using technologies and pedagogical strategies that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students'

prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones (Mishra & Koehler, 2006, p. 1029).

Participants provided experiences in teaching with technology, and two examples are discussed here to illustrate the application of TPACK in senior secondary education.

Specialist mathematics technologies, dynamic geometry software (DGS) and computer algebraic systems (CAS) were mentioned previously as useful for representing mathematical content. Teachers' knowledge of the dynamic and interactive features of these technologies, in the immediate visualisation of mathematics concepts for students, was an important part of class discussions, demonstrations and modelling, when teaching algebra and geometry at senior level.

Another example in which TPACK was evident was described by a physics teacher (Marley) from a rural school whose students were in different geographic locations. Her pedagogical knowledge combines with technological knowledge when she uses ICTs as the communicative medium through which she fosters positive relationships with her students and a supportive learning environment. TPACK's application is inferred in Marley's pedagogical decisions in implementation of a learning activity where students are using web-based collaboration tools (wikis) in the co-creation of notes (note-making) associated with a specific topic-area of the Year 11 Physics course. She uses the technology to create a scaffold specific to each student that structures his or her research and note-making contribution. At the same time, the technology enables Marely to monitor each students' progress and possibly intervene when student misconceptions surface.

These examples demonstrate TPACK's manifestation because they describe the application of integrated knowledge domains relating to technology, pedagogy and content in ways that transform subject content into representations that students engage with in order to develop understanding and skills as they work towards achieving course outcomes.

Marley's descriptions highlighted her knowledge of the importance of developing and encouraging peer interactions to promote student co-construction of knowledge. Even though students lived in geographically isolated areas, this teacher developed her skills and knowledge of video conferencing and virtual-classroom technologies and integrated these applications seamlessly in her instructional practice. TPACK was evident in her use of these ICTs that bridged the distance gap by developing rapport amongst students and enabling the co-authoring of artefacts through group work. These pedagogies and technologies were integral to her students' learning specific physics content.

What these manifestations of TPACK had in common were their quality of ICT use – what TPACK scholars would describe as skilled teaching with technology (Koehler & Mishra, 2009). The teachers' technological knowledge of specific ICTs was evident, and these were discussed in the context of specific pedagogical processes in the teaching of specific topic areas of their subjects. Furthermore, the teachers conveyed an understanding of how those technologies and pedagogies supported their students' learning.

 Identifying examples such as these is important in illuminating effective ICT-integration. Learning-design researchers are turning their attention to accurate representations of learning sequences (see for example Agostinho, 2011; Philip & Cameron, 2008). Experiences such as these serve as exemplars of experienced teachers' processes associated with integrating ICTs in specific subject areas and when teaching specific content. Precise descriptions at specific levels of schooling would enable the design of professional learning opportunities that highlight effective ICT-integration processes that enhance student learning.

Context

Despite the teachers in this study identifying themselves as ICT users in their senior subject areas, contextual factors, such as limited time relating to the prescribed nature of the HSC curriculum, a written examination focus of most HSC courses and a lack of student access to ICTs, were seen to be constraints on ICT-integration. For some teachers, it was evident that ICT-integration posed a "contradiction" in that they

viewed ICT-integration as an extra activity to be squeezed into an overcrowded curriculum. This was particularly evident in the mathematics classroom, where dynamic graphics were prepared by the teacher rather than created by students because participants felt there was not enough time to teach skills necessary for students to create the graphics themselves. These results demonstrate that "applying [TPACK] is a complex task, often riddled with contradictions and tensions" (Mishra & Koehler, 2006, p. 1040).

The contradiction arises because the ICT skills and knowledge of specialists such as mathematicians, historians or scientists is not explicitly included in senior secondary prescribed syllabi, and not deemed a requirement to teach. Another factor affecting pedagogical decisions is related to external high-stakes exit examinations at the conclusion of senior secondary study in NSW. For these teachers, there was a lack of connection between content examined, the format of the examination (pen and paper), the need to teach ICT-related skills and knowledge in their subject area. New South Wales syllabus development is, necessarily, a long process involving the establishment of a committee, reviews, the development of briefs and extensive consultation with stakeholders (BOSTES, 2014). The current Year 11 and 12 curriculum and system of external examination was last extensively reviewed and reformed in 1999 (NSW Government, 1999). Technology has significantly changed all subject disciplines since that time, but existing NSW syllabus frameworks do not contain the flexibility for inclusion of new ICT-related content as it becomes normalised in that discipline outside of school.

The implications here are twofold. First, curriculum reform can carefully consider exit outcomes related to ICT skills and knowledge in the senior secondary specialist subject areas. There is a need to design senior curricula that maintain the rigour expected at this level of schooling, but at the same time include a degree of flexibility that enables the incorporation of emerging technological content knowledge. If working mathematicians use dynamic geometry systems and computer algebraic applications in their work, for example, then senior mathematics syllabi should reflect their value in the content taught to senior students, and have the scope to incorporate new mathematics technologies as they become mainstreamed in the work of those in the

field. The second implication is that if desired ICT-related skills and competencies are explicitly included in senior secondary syllabi, the relevance of ICTs to teaching and learning of particular subject areas becomes obvious. There is less risk, then, of this type of knowledge being viewed as "extra" or superfluous to success in exit examinations.

Access to ICTs was seen as problematic for two reasons. First, there was a difference in access to ICTs between Year 12 and Year 11 classes at the time of the study. In the context of Australia's Digital Education Revolution, the Year 11 cohort was the first to benefit from the National Secondary Schools Computer Fund, especially for government schools, where these students had one-to-one access to laptop computers. The Government initiative seemed to set a "base level" of access that teachers could expect when planning and implementing learning activities that integrated ICT. In contrast, experiences of ICT-integration in Year 12 were described less, and ICT-integration here often relied on booking laboratories, limiting spontaneity when accessing online resources or using particular applications. Second, in government schools, some participants indicated that students did not always bring their laptops, which meant they could not rely on access to ICTs. In these cases, teachers often planned backup lessons, or the students simply did the task without the use of ICTs. These experiences may be indicative of the fact that this was the first cohort under the initiative, and "teething problems" were to be expected. Alternatively, it may indicate that the type of device chosen as part of the DER roll-out may not have been appropriate. Further research in areas concerning the suitability of mobile devices in school education could include comparisons of schools that have deployed different devices. Areas of investigation might include school-related policies, classroom management and student /teacher perceptions of different devices.

The results also highlighted that in some cases, although ICTs such as interactive whiteboards, learning management systems and The Le@rning Federation digital resources had been provided, they were not necessarily used. It may be that these teachers required explicit training in how to use the technologies in the context of teaching their senior classes. For HSC teachers to value these technologies and the

benefits they afford, ICT training needs to be contextual, topic-specific and relevant to senior secondary educators.

It is important to acknowledge the limitations of this study. The data collected represent a "snapshot in time", as technologies are constantly changing and offering new capabilities in supporting learning across the curriculum. This is a small-scale study situated in the specific context of New South Wales, and the participants are not a representative sample of senior secondary school teachers. For these reasons, the results may not reflect the experiences of teachers in other states, jurisdictions or international education systems. While this study was able to comment on the types of uses, the level of use (frequency) was not considered, and further research is recommended to ascertain levels of technology use in senior secondary education. Though not generalisable, results from phenomenological studies can suggest experiential patterns that may be relevant to other teaching and learning contexts (Pollio, Henley, & Thompson, 1997).

The findings suggest avenues for further research. For example, research is needed to determine whether the ICT-integration described here is representative of ICT-integration more generally by senior secondary teachers in the context of highly prescribed curricula. This study was conducted with a small sample from some, but not all, of the subject areas, and therefore further research across all subject areas is warranted. In addition, the present study does not assess ICTs' contribution to student attainment at senior secondary level. Further research is needed to ascertain whether technologies discussed in this paper have a measurable effect on student learning.

5.8   Implications

This study provides an example of what Selwyn (2010) may call a "social scientific [account] of the often compromised and constrained realities of education technology use" (p. 65). The context of educational technology use reported in this study is shaped by content-laden prescribed syllabi, high-stakes assessment, unprecedented student access to one-to-one laptop computers and heightened expectations for ICT-integrated teaching and learning. It suggests that routine ICT-integration in the senior secondary years supports every-day pedagogical practices such as collaborative group work,

whole class discussion, students' creation of artefacts as well as processes such as distribution and organisation of electronic resources. Context-rich accounts of the ways that technology is actually used by teachers and students across a range of subject areas and levels of schooling contributes knowledge of how and why ICT-integration is enacted. ICT-integration scholarship, Selwyn (2010) argues, that adopts a more critical approach should consider organisational, political, economic and cultural factors that affect end-uses of technology. Further ICT-integration research that analyses actual use as opposed to interventionist, positive or model uses of ICTs in supporting teaching and learning would contribute knowledge of the realities of ICT-integration within the constraints and characteristics of educational contexts.

Contention in TPACK literature is described around difficulties with distinguishing boundary constructs (Angeli & Valanides, 2009; Archambault & Crippen, 2009; Graham, 2011). This study provides examples of TPACK constructs in action in senior secondary education. When introducing the TPACK framework, Koehler and Mishra (2008) argued that "integration efforts should always be custom-designed for particular subject matter … and contexts" (p. 10). The examples described here are of benefit to scholars wanting to explore teacher knowledge requirements within this context. ICT-integration studies in other contexts that deconstruct lesson activities would enable illustrations of practice to be aligned with the TPACK constructs and further contribute to more precise descriptions of knowledge that teachers bring to bear when integrating ICTs.

This study highlights the importance of teaching teachers ICT skills within the context of their subject area and level of schooling. For example, technologies such as web-conferencing and co-authoring environments such as online whiteboards, wikis, Google Suite and Office 365; can support collaborative pedagogies, content representations and the creation of artefacts (for evidence of learning) by students. Unless the technology use is embedded deeply within specific topic content to be learnt and appropriate pedagogical approaches that maximise meaning-making for students; then only an incomplete understanding of effective ICT-integration will be gained. The challenge for teacher educators is to design teacher learning experiences that provide

examples of the ways in which specific topics can be represented using ICTs during a sequence of learning activities.

5.9   Conclusion

This phenomenological study developed an understanding of ICT-integration at a particular level of schooling (senior secondary) through an examination of 28 teachers' experiences with ICT-integration across 11 subject specialisations. The study asked teachers about how they integrate ICTs to support teaching and learning in their subject discipline. TPACK (technological, pedagogical content knowledge) provided a conceptual framework that guided data collection and analysis. At the senior secondary level of schooling, teachers employed a range of pedagogical practices aimed at meaning-making and developing conceptual understanding of subject-specific content. This aligns with the purpose of senior secondary curricula, which are designed to develop knowledge, skills, understanding and attitudes in specialist areas of study in preparation for everyday life, work and further education.

Actual types of technology use by teachers when integrating ICTs were most often associated with generic technologies. The minimum level of ICT provision for teachers was access to an Internet-connected personal computer with software such as word-processors, spreadsheets, presentation software and display technologies including data projectors and/or interactive whiteboards. In addition to generic technologies, specialist mathematics ICTs and music ICTs were used by mathematics and music teacher-participants. ICTs were integrated to represent, visualise and interact with subject content. Skills associated with sourcing, editing and representing digital content were important for teachers, as was an understanding of how these digital representations and interactions supported student learning. Additionally, participants routinely used whole-class instructional strategies supported by display technologies. This suggests that skills associated with student note-taking, questioning techniques and promotion of collaborative classroom talk to diagnose and develop student understanding are important pedagogical skills at senior secondary level.

Effective ICT-integration also depends on the knowledge teachers have of benefits and constraints associated with the technologies to which students have regular access. In

this study, students' creating digital artefacts were highly valued learning activities. In many cases, teacher-participants relied on student one-to-one access to laptop computers. This enabled students to routinely access online resources during the course of a lesson or continue work on digital projects in and outside the classroom. The prevalence of student-owned and student-managed devices in classrooms seems to be increasing, with continued interest in bring-your-own-device (BYOD) programs in schools. Pedagogical processes associated with classroom management of students and their devices are important strategies for teachers of all school levels to develop.

ICT-integration was affected by contextual factors such as time constraints associated with delivery of prescribed curricula within the timeframes allocated to course delivery. Additionally, pedagogical beliefs posed a contradiction for some teachers who viewed ICT-integration, or the teaching of ICT skills to senior secondary students, additional activities, unwarranted in the context of written high-stakes exit examinations. Important considerations for teacher educators are the need to challenge beliefs associated with teaching specialist, high-level subject content and the development of higher-order reasoning and thinking skills (valuable for success at high-stakes assessment) through learning activities enhanced by ICT-integration.

CHAPTER 6: ICT-INTEGRATION IN SENIOR SECONDARY HIGH-STAKES ASSESSMENT

Abstract

Learning environments continue to evolve with increased access and mobilisation of information and communications technologies (ICTs). In senior secondary education, ICTs have implications for subject content and pedagogical practices related to teaching, learning and assessment in the context of highly prescribed courses and high-stakes assessment in Years 11 and 12 (the senior secondary education years). This research explored senior secondary teachers' use of ICT in supporting school-based assessment programs during a national reform agenda aimed at increasing access to digital technologies in the secondary years. The study adopted a phenomenological approach and collected data from 28 Australian teachers through semi-structured interviews. Technological pedagogical and content knowledge (TPACK) provided a conceptual framework for data analysis. As expected, assessment strategies reported by teachers across subject domains varied, as did the types of ICTs and the extent to which they were used. However, traditional, pen and paper examination style assessments or assessments that included exam style questions with a hand-written component, were tasks favoured by teacher-participants, and in some cases were used exclusively through the assessment program. For these teachers school based summative assessment was used as preparation for final external exit examinations. The implications are that the validity of senior secondary school-based assessment may be undermined if evidence of achievement of course outcomes is measured through a limited range of assessment activities. In addition, a lack of ICT-integration in assessment may de-emphasise the importance of ICT skills as an outcome of school education. Pedagogical knowledge relating to assessment types, their alignment to course outcomes and role of technology in assessment processes may be underdeveloped in the context of senior secondary education.

6.1 Introduction

Assessment is a pedagogical tool that provides evidence of students' progress towards one or more course outcomes. It affects all teaching and learning because it influences what teachers and their students most value in the curriculum (McGaw, 2006). This is heightened in the case of senior secondary school education, where high-stakes assessments are linked to university entrance and employment (McGaw, 1997, 2006).

As well as achievement in subject-matter content, education systems are also concerned with what Spady (1994a) refers to as higher-order outcomes: essential skills and knowledge relating to life-roles students will assume post-secondary schooling. Continuing advances in technology and its importance for industry as well as for living and working in a digital world have seen exit outcomes relating to skills in using information and communications technologies (ICTs) included in curricula around the world (Commission of the European Communities, 2008; Department for Education, 2011; MCEETYA, 2008c; U.S. Department of Education, 2010).

Senior secondary education represents the final years of schooling, when young people are making important decisions about their futures, and schools are transitioning students to further education, training and employment. For senior secondary educators the challenge is that higher-order, less explicit outcomes relating to ICTs are expected to be integrated into subject-specific teaching and assessment programs aimed at covering prescribed and often mandated content. This study provided an opportunity to examine this potent contextual mix by exploring ICT-integration in senior secondary education. The broader study has examined ICT-integration by senior secondary teachers. The component of the research reported on in this paper focused on senior secondary teachers' experiences with ICTs in supporting school-based summative assessment.

6.2 Background

New South Wales (NSW) provides one example where high-stakes, school-based assessment practices have collided with government initiatives aimed at increasing ICTs in senior secondary classrooms. Within this policy climate, the study provided an opportunity to explore ICT-integration in senior secondary education. . This paper

reports a subset of a broader study of ICT-integration in senior secondary education focusing on uses associated with school-based summative assessment practices.

Assessment is the process of collecting evidence of students' learning and their development of knowledge throughout a program of study (Harlen, 2007). The reasons why assessment systems exist are threefold: to improve teaching and learning (formative assessment), to summarise student achievement at a point in time (summative assessment), and to evaluate and monitor school or system performance (Brown, 2003; Harlen, 2007). Characteristics of quality assessment are assessment processes that are valid, reliable and fair (Harlen, 2007; Killen, 2005). Quality summative assessment is needed so that achievement and progress in learning can be reported to parents, students themselves and other teachers; and for tracking progress towards certification (Harlen, 2009).

6.2.1 ICT use in assessment

Digital technologies provide opportunities for teachers to design varied assessments that are "active and situative" (Clarke-Midura & Dede, 2010, p. 311). These types of uses include assessment through online examination systems, ICTs providing different modes for assessment artefacts to be created, and ICTs used in supporting the processes of assessment, such as data collection and analysis.

Computer-assisted assessment (CAA) is a term used in the context of computerised examinations where multiple-choice and short-answer questions with automated marking are characteristic (Gipps, 2005). Modern test-authoring tools can combine text, digital images, video and animation, enabling the construction of dynamic and interactive items not available on paper (Whetton & Sainsbury, 2007). In addition, these tools can capture data about students' responses and provide feedback. Examples in the context of summative assessment include the Electronic Reading Assessment in the 2009 Programme for International Student Assessment (PISA) (Searle, Lumley, & Juliette, 2009) and the piloting of online examinations in the United States' National Assessment of Educational Progress examinations (Bennett, Braswell, Oranje, & Sandene, 2008). In Scotland, a large-scale project explored the problem of awarding partial credit in computer-based assessment and the effect of changing the medium from paper to computer for test delivery (Ashton et al., 2005, 2006). In New South

Wales, the scientific knowledge, skills and attitudes of Year 8 students are tested through the online *Essential Secondary Science Assessment*. Until 2011, NSW Year 10 students completed the Computing Skills Test online, and there have been pilot programs with online English-literacy testing (NSW Board of Studies, 2010).

ICTs provide opportunities for students to demonstrate their learning through the creation of digital artefacts or through interactions with digital tools. For example, multimedia products can be created with digital cameras and video-editing tools to provide evidence of learning (Lincoln, 2009). Wikis offer alternative methods of constructing reports and reporting on research (Al-Smadi, Hoefler, Wesiak, & Guetl, 2012; Muwanga-Zake, Frank, Dickins, & Lovelock, 2010). Digital-animation products have enabled students to demonstrate learning of cultural contexts and science knowledge and to produce digital stories (Hoban & Nielsen, 2012; McKnight, Hoban, & Nielsen, 2011). Research is emerging in the area of immersive technologies, where digital environments are used to assess authentic scientific inquiry through simulated experiments and interaction with digital objects (Clarke-Midura & Dede, 2010). In the context of high-stakes assessment, a US study explored the use of astronomy learning activities that were designed for use with a virtual observatory (Taasoobshirazi et al., 2006). The research demonstrated that development of scientific reasoning skills and gains in high-stakes criterion-referenced tests, typically used in school accountability measures, could be aligned.

In the context of senior secondary education, a Western Australian study investigated the use of digital technologies to support assessment in engineering studies, applied information technology, Italian and physical education (PES) (Newhouse, 2008, 2010, 2011; Newhouse & Njiru, 2009). The purpose of the study was to ascertain the potential of digital technologies to capture performance on practical tasks in the context of summative, high-stakes assessment. The study demonstrated the use of digital technologies across a number of subjects and assessment types, such as: creating artefacts under exam conditions (applied information technology and engineering), creation of digital artefacts that were part of a digital portfolio (applied information technology and Italian) and the video and/or audio recording of performances for the purposes of student reflections and evaluation (physical

education and Italian) (Newhouse, 2010). Positive attitudes by students and their teachers towards the use of ICT-supported summative assessment were reported, and the researchers concluded that benefits of e-assessment outweighed the constraints.

6.2.2 Impact of high-stakes assessment

Despite the uses of ICT supporting assessment that were reviewed, examples located in the literature included exemplar cases or exploratory studies suggesting that the use of ICT in the context of summative high-stakes assessment is not common or is under-reported. This may be due to the *washback* effect associated with high-stakes assessments, where teachers are under pressure from their schools and parents to produce results in external examinations, and thus the test influences the teaching (Alderson & Wall, 1993; Cheng, 2000). Washback and backwash are terms more often associated with linguistic and language teaching.

Harlen (2007) argues that teaching inevitably focuses on what is assessed, and that the impacts of summative assessment can be both positive and negative. The impact can be positive if "assessment covers the full range of intended goals" of the summative assessment system, and negative if learning experiences are restricted or narrowed; for example, when teachers coach how to pass the tests, resulting in shallow learning (Harlen, 2007, p. 24).

6.2.3 Construct validity

The impact of summative assessment has been situated within a broader framework of construct validity of assessment (Harlen, 2009; Koch & DeLuca, 2012). Assessment theorists contend that construct validity is highly dependent on the purposes of assessment within an assessment system. Construct validity is high when there is a high correlation between what is assessed and the *intended purpose* of the assessment (Harlen, 2007). Good summative assessment should summarise learning so that achievements can be tracked and reported, and so that accreditation and selection procedures can be undertaken (Harlen, 2009). In school-based summative assessment, validity is likely to be greater when the full range of learning goals is included through evidence collected from a range of regular activities (Harlen, 2007).

Assessment of learning is used for a range of purposes (Harlen, 2007). As well as summative processes associated with exit credentials, state-wide testing programs can take on an evaluative role, with results being used to compare teachers and their schools (Harlen, 2007). Furthermore, high-stakes standardised testing is increasingly linked to policy-making processes aimed at education reform (Goertz & Duffy, 2003; Lingard, 2010; Rizvi & Lingard, 2010). Good decision-making about school improvement, students' exit credentials and the broader context of education reform depends on the quality of the achievement data collected.

6.2.4 Teacher knowledge

The quality of achievement data depends on teachers' knowledge of summative assessment purposes and processes. Stiggins (1991) proposes a notion of *assessment literacy* that includes:

- knowledge of high-quality assessment
- knowledge of assessment methods that align with well-defined learning goals
- understanding of the importance of fully sampling assessment performance
- an awareness of "extraneous factors" and their implications.

This might be seen as a form of pedagogical knowledge. Together with knowledge of course content, outcomes and the appropriateness of assessment task types to outcomes to be assessed, NSW, senior secondary teachers require specific knowledge about the weightings and components specified in official subject syllabus documents, how to devise marking criteria that describe the type of response needed to achieve each mark and how to provide constructive feedback to students on making improvements (NSW Board of Studies, 2011). In addition, the effective use of ICTs to enhance and streamline student assessment requires knowledge of ICTs; specifically, their capabilities and constraints with respect to a range of assessment task types.

This complex interaction of teachers' knowledge domains has been conceptualised as TPACK - Technological Pedagogical Content Knowledge (Koehler & Mishra, 2009; Mishra & Koehler, 2006). TPACK extended Shulman's (1986b, 1987) notion of pedagogical content knowledge (PCK), that gained traction within a climate of renewed interest in the knowledge base of teachers and the professionalisation of the

work of teachers (Segall, 2004b). Pedagogical content knowledge, unique to the work of teachers, is knowledge of appropriate instructional practices (pedagogical knowledge) required for effective teaching and learning of specific subject matter (content knowledge) (Shulman, 1986b, 1987). Shulman (1986b) argued that while knowledge of pedagogical strategies and subject matter content were necessary precursors, expert teachers' enacted pedagogical content knowledge (PCK) when they represented and formulated subject content in a way that was meaningful to learners. In a similar vein, new technologies, argue Mishra and Koehler (2006), have a significant role to play in subject-content representation with the ways in which they can "make it more accessible and comprehensible" to learners (p. 1023).

TPACK considers technology integration as a teacher's application of three interrelated knowledge domains – content (CK), pedagogical (PK) and technological (TK) knowledge – within their particular subject areas and circumstances (Koehler & Mishra, 2009). As a theoretical lens for ICT-integration studies, TPACK has several challenges. The framework builds upon PCK constructs (Shulman, 1986b, 1987) in which the distinct nature of pedagogical knowledge (PK) and content knowledge (CK) domains are questioned (Gess-Newsome, 1999a; McEwan & Bull, 1991; Segall, 2004b). Scholars contend that this has contributed to a lack of clarity in definitions of TPACK's seven constructs which has hampered the framework's theoretical growth (Archambault & Barnett, 2010; Graham, 2011) and has posed challenges for the development of instruments aimed at quantifying TPACK (Angeli & Valanides, 2009; Archambault & Crippen, 2009). Adding a third domain, technological knowledge, increased PCK's three constructs to a seven construct framework increasing the complexity for researchers using TPACK as a theoretical lens to explain the phenomenon under investigation (Graham, 2011).

This study acknowledges that further theoretical development is warranted and contributes to this end through an investigation of ICT-integration in the context of high-stakes internal summative assessment in senior secondary school education. This paper is a component of a broader qualitative study that considers ICT-integration in senior secondary education generally. Quantification of teachers' knowledge was outside the scope of this study. In this study TPACK was used as a theoretical lens for

conceptualisation of teacher's knowledge associated with student assessment (Mishra & Koehler, 2006). TPACK foregrounds the importance of subject content knowledge (CK) and appropriate instructional strategies (PK) as well as knowledge of technologies and its operation (TK) as interdependent knowledge domains that come to bear with successful ICT-integration. In the context of content-laden senior secondary subjects, effective teachers demonstrate a high degree of mastery of subject matter content knowledge (CK) (Ayres et al., 2004). These teachers also require pedagogical knowledge (PK) of mandated requirements, as well as assessment strategies that are aligned to course outcomes and school and state reporting requirements. Teachers require knowledge of how to use new and existing technologies (TK) to support and enhance assessment practices. TPACK is more than the sum of three knowledge bases. It represents "an understanding that emerges from interactions among content, pedagogy, and technology", providing a foundation for skilled teaching and assessing with ICTs (Koehler & Mishra, 2009, p. 66).

6.3 Context for this study

The context for the study is senior secondary education in NSW, where the final stage of schooling (Stage 6) includes Years 11 and 12. These are also called the Preliminary Higher School Certificate in Year 11 and the Higher School Certificate (HSC) in Year 12. The NSW Board of Studies is a statutory body that develops prescribed syllabus documents for NSW schools from Kindergarten to Year 12 (the NSW Board of Studies was succeeded by the NSW Board of Studies, Teaching and Educational Standards (BOSTES) in 2014).

6.3.1   An overview of the HSC assessment process

To qualify for a Higher School Certificate (HSC), students must complete a Preliminary program of study (Year 11) and a HSC program of study (Year 12). A student typically studies five to six subjects, of which at least one will be English. The HSC program concludes with the Higher School Certificate examinations at the end of Year 12, set by the Board of Studies. Students in each subject sit a common exam, which is marked externally. In Years 11 and 12 (Preliminary and HSC courses), schools develop and deliver an internal assessment program in accordance with syllabus documents. The internal assessment program is school-based and summative.

This means that assessment tasks are designed and administered by subject teachers to measure achievement at points in time within the duration of the course, for the purpose of reporting student progress and ranking. The internal school-based summative assessment program typically includes three to five teacher-designed assessment activities per subject. At the conclusion of the Year 12 program of study, students undertake their (external) HSC examinations in each of their subjects. The final HSC mark is a 50:50 combination of the school-based summative assessment mark in their Year 12 courses and the final HSC external examination mark. Figure 9 provides a visualisation of the way the final marks are generated for NSW exit credentials.
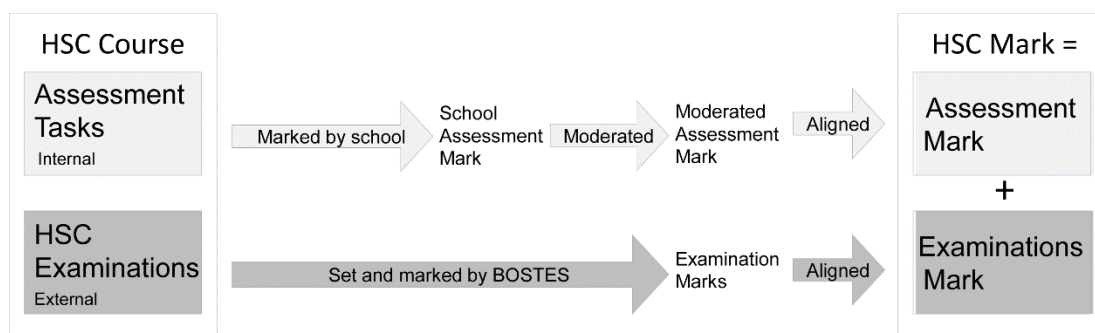
Figure 9: The HSC marking process (Source: BOSTES, 2015).

The contribution of internal school-based summative assessment marks and external examination marks means that all internal school-based summative assessments in the HSC year are part of the high-stakes exit credentials.

A review of the then-new HSC (Masters, 2002) noted concerns about the previous system, including problems associated with school-based assessments that were too often based on methods resembling pen-and-paper examinations. In response, the new HSC examinations were designed to sample syllabus outcomes and be supplemented by school-based internal summative assessments intended to provide evidence about a *broader* range of outcomes than can be assessed through written examination (Masters, 2002).

Harlen's (2007) notions of construct validity and the intent of the new HSC align with the advice to New South Wales (NSW) schools about assessment (NSW Board of

Studies, 2011). The purpose of the internal school-based summative assessment program is explicit. NSW schools are advised that *a major requirement* of the assessment program is to provide summative measures of "a wider range of syllabus outcomes than may be measured by external examination alone" (NSW Board of Studies, 2011, p. 6). The Board also provides advice on assessment tasks:

> Assessment tasks used should be appropriate to the outcomes and component of the course being assessed, for example tasks could include assignments, fieldwork studies and reports, model making, oral reports, research projects, practical tests and open-ended investigations, viva voce, improvisations, arrangements, original compositions, portfolios, and presentations of performance (NSW Board of Studies, 2011, p. 13).

Therefore, it is reasonable to expect that a school-based summative assessment program would include a range of appropriate teacher-developed assessment task types. In addition, the increased availability of ICTs in NSW schools in recent years would afford new opportunities to support a wider range of assessment-task types.

6.3.2 ICT and the HSC

Coinciding with the data collection for this study was Australia's *Digital Education Revolution* initiative (2008-2013). This was a period of accelerated change as upper secondary students across the nation were provided with laptop computers (DEEWR, 2009b; NSW DET, 2009a). The aim was to "contribute sustainable and meaningful change to teaching and learning in Australian schools to prepare students for further education, training, jobs of the future and to live and work in a digital world" (DEEWR, 2009b, p. 2).

In NSW Years 11 and 12, assessment, curriculum and pedagogy are closely linked, as instructional planning is aligned to state-mandated syllabus outcomes and assessment requirements. Integrating ICTs across curriculum, pedagogy and assessment, according to government policy, can personalise and extend student learning (MCEETYA, 2008a). For example, ICTs could be used to demonstrate connections between the curriculum and assessment criteria, and assessment products produced with ICTs may be used as evidence of learning (MCEETYA, 2008a).

It is within this policy climate that data for this study were collected about ICT-integration in the context of senior secondary education. The timing of the study was significant, as the Year 11 cohort in NSW government schools at this time were the first students to be provided with one-to-one computer-to-student access (NSW DET, 2009a). In addition, the study provided an opportunity to explore ICT-integration in the context of senior secondary education more generally.

6.4 Methodology

The study was guided by the research question: *What are the experiences of senior secondary teachers in NSW in using ICTs to support teaching and learning?* This paper presents a component of a broader study that examined the relationship between Australian Government ICT education policy and its implementation in the NSW senior secondary school curriculum. This component focuses on teachers' experiences with integrating ICTs in senior secondary education to facilitate school-based assessment.

The study adopted a phenomenological approach. Phenomenology values the lived world of individuals as they experience it subjectively; these experiences are used to describe the phenomenon under study (van Manen, 1990). This approach enabled the phenomenon of ICT-integration to be examined from the point of view of senior secondary educators. In this way, teachers' knowledge of ICT-integration and their interpretation of the value of ICTs within the context of their classroom practice were considered.

6.4.1 Participants

Criterion sampling (Creswell, 2012b) sought teachers who were actively using ICT to support teaching and learning, and who were currently teaching HSC subjects in the Preliminary or Higher School Certificate programs (Years 11 or 12). Teachers who exclusively taught within computing-studies subjects were excluded, as ICT is explicit in the key concepts and skills taught in those courses. Teachers from government and independent schools in rural and metropolitan NSW were invited to participate. Participants were selected to include a variety of subject areas.

The final participant group included 14 male and 14 female teachers across the government and non-government sectors. Participants were drawn from 14 schools in total: eight were metropolitan schools and six were from rural areas. All rural schools were government schools, and three metropolitan schools were non-government schools. All participants had five or more years of teaching experience: 11 teachers had between five and 10 years of experience, eight teachers had between 11 and 20 years' experience and nine participants had taught for more than 20 years

Table 25: Breakdown of participants by subject area and school type

Subject area	Number of participants (Government)	Number of participants (Non-government)	Total
Visual Arts	3	0	3
Music	0	2	2
English	1	1	2
Business Studies	1	0	1
Economics	1	0	1
Modern History	0	1	1
Languages	0	2	2
Mathematics	3	3	6
Science	5	1	6
Agriculture	2	0	2
Design and Technology	1	1	2
Totals	17	11	28

6.4.2 Data collection

Data were collected by means of semi-structured face-to-face interviews so that first-person descriptions of participants' experiences with ICT-integration could be obtained. The interviews were conducted during Terms 2 and 3 of 2011. Interviews typically lasted for 40 minutes, and were conducted at the participant's school.

The guiding questions for the ICT-integration study were developed using definitions of the TPACK constructs (Cox & Graham, 2009b), and were designed to collect data relating to manifestations of teachers' content knowledge (CK), pedagogical knowledge (PK) and technological knowledge (TK), as well as their interdependent

derivatives (PCK, TCK, TPK and TPCK). In addition, data relating to demographics, school context, and government policy implementation were sought.

This paper focuses on the data collected relating to ICTs' use in school-based summative assessment. During this part of the interview, participants were asked to describe their assessment strategies and if and how ICTs were used to support assessment in their subject areas. If ICTs were used, follow-up questions were asked relating to the types of assessment tasks, the types of ICTs used and how ICTs supported the assessment task. Note that the results reported in this paper are based on dialogue associated with guiding questions in Section 7 of the interview protocol outlined in Appendix C. Interviews were audio-recorded and transcribed. Transcripts were examined for themes relating to ICT use to support student learning and assessment.

6.4.3 Data analysis

Analysis of the dataset was based on a framework that drew on elements of Australian government policy designed to support planning for ICT-integration in implementing the Digital Education Revolution (MCEETYA, 2008a). *Digital Education – making change happen* described ICT use across 10 elements of quality schooling. The focus for this study is Element 5, which describes a vision for ICT use relating to improving student assessment (MCEETYA, 2008a). The document guides schools by describing a continuum of ICT use relating to each element. Element 5 includes a vision in which a leading school:

- routinely uses and regularly reviews a range of ICT infrastructure and systems to enhance assessment and reporting. A range of formative, summative and collaborative assessment tools are evaluated for their suitability and used where appropriate – e.g. running records, digital portfolios, blogs and wikis.

- makes informed decisions about how ICT might be used to demonstrate connections between the curriculum, personalised learning goals, assessment criteria and learning. ICT products may be used as evidence of learning and/or for vocational purposes. (MCEETYA, 2008a, p. 11)

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Therefore, interview transcripts were scrutinised for examples of teachers' use of ICTs to support school-based summative assessment. These excerpts from the interview transcripts were electronically highlighted using qualitative data analysis software. Within this dataset, themes relating to streamlining assessment, traditional assessment and types of use were identified. These results are described in the next section.

6.5 Results

The results are structured in three main sections. The first section presents results about the participants' and their students' access to ICTs. This is followed by results related to the types of assessments and if and how ICTs were used to support these assessment types. Finally, results related to perceived barriers to ICT-integration in assessment are presented.

6.5.1 Access to ICTs

Participants reported a high level of ICT infrastructure available to support teaching and learning in their schools. Year 11 students from all New South Wales (NSW) government schools were the first cohort to benefit from a personal netbook computer. The Digital Education Revolution (DER) was a national reform agenda (2008-2013) of which the major component, the National Secondary Schools Computer Fund (NSSCF), financed laptop computers in NSW schools to students in Years 9 to 12. Students who were in Year 11 and 12 in 2011 were the cohort that was being taught at the time of data collection. In NSW government schools, laptops had been allocated to the 2011 Year 11 students when they were in Year 9 under the NSW Department of Education's Laptop for Learning Program (NSW DET, 2009). Therefore, Year 11 government school students had a standard set of ICT tools that included a Lenovo laptop computer and a software suite that included Microsoft Office (Word, Excel, PowerPoint, Access, OneNote) and the Adobe Creative Suite (image, video and website creation applications) as well as other specialist applications. In 2011, Year 12 students from government schools were not part of the one-to-one laptop program. In the case of Year 12, one government school enabled students to bring their own laptop to school; but generally, Year 12 students accessed computers at school in computer laboratories or in their school libraries. Two independent schools did not have one-to-

one laptop access in Years 11 or 12, and one independent school had a one-to-one program in both Years 11 and 12.

In addition to one-to-one computer access, all teachers in the study reported good levels of Internet (broadband) access and wireless networking infrastructure. Most (26) participants had access to a personal school-allocated workstation or laptop computer, and all participants had access to a course-management system such as Moodle.

6.5.2   Technology-supported assessment

The participants in the study were asked about their assessment tasks and if and how ICT was included. As expected, assessment strategies reported by teachers across subject domains varied, as did the types of ICTs and the extent to which they were used. Assessment strategies reported included writing tasks (such as essays, research and case-study reports), examinations, project work and oral presentations. ICTs used to support assessment by senior secondary teachers included word-processors, spreadsheets, presentation software (PowerPoint), search engines, online collaboration tools and multimedia technologies such as digital cameras.

Examinations

All teachers in the study reported the use of pen-and-paper HSC-style examinations as assessment tasks. These tasks were conducted under conditions similar to those of the final HSC examination, and were not supported with ICTs. This style of assessment was seen as important in providing opportunities for practice for the final examinations, and was usually included as half-yearly (mid-course) assessment tasks or trial HSC exams conducted towards the end of the HSC courses.

Nine of the teachers interviewed explained that traditional pen-and-paper assessments were used often. In mathematics, five out of six teachers explained that *all* of their assessments were conducted under exam conditions. Mathematics teachers commented that exam practice was an important part of assessment. Julian, a Year 12 mathematics teacher, explained that this was because there were no ICTs included in HSC examinations:

They have four assessment tasks through the year to fulfil the Board of Studies requirements…. One of those assessment tasks is their trial [HSC] paper; the other three are ones we make up. They are written – no electronics involved. They are traditional assessment tasks. Not like in Year 10 where they would have their computing-studies test through the computer…they get to Year 11 and it is all written. (Julian, Year 12 mathematics teacher).

In addition to the mathematics teachers, a biology teacher, an economics teacher, a Latin teacher, a French teacher and a history teacher all reported exclusively using HSC-like assessments for the school-based summative assessment tasks.

Writing tasks

In the humanities, nine teacher-participants across English, languages, history, economics, business studies and creative arts reported the use of assessments composed of HSC exam-style questions. These assessment types were intended to improve written responses to extended-response and essay-response questions that were characteristic of these final examination papers. Once again, teacher-participants often spoke about the importance of practising the writing process for HSC examinations. In history, for example: "they [assessment strategies] mainly mimic the HSC. The main thrust is to equip the students with the skills to maximise the potential in the HSC" (Barbara, Year 11 history teacher).

Although seven participants reported word-processor usage to support these assessment types, the process of hand-writing responses was emphasised, because participants felt it was important preparation for the final external examinations. Marcel, an economics teacher, provided a typical example where word-processors were important for the preparation phase of essay-style assessments, but the final task was hand-written:

Some are research tasks where we get them to research – we do one on the Balance of Payments…. When they do all their preparation – kids are using [Microsoft] Word and all those things, but when they actually write it here at school, they use pen and paper (Marcel, Year 11 economics teacher).

In contrast to the traditional approaches to extended-response assessment tasks, Leroy, a senior art teacher, had developed an assessment strategy to improve students' writing responses. His task was supported with an online collaboration tool called Edmodo (www.edmodo.com):

> [A colleague from another school and I] co-wrote an assessment task and … we added our students to the same *Edmodo* group [that enabled students] to complete the task together even though they were from different schools…. [The students' online] conversations help them come up with the response in their assessment…. They then have to think about that and how somebody is going to interpret what they are writing. It helps them to clarify their thinking.... Once they [had] collaborated on their presentation and gathered all that stuff, they then sat down and wrote a personal essay as well. I [then] got them post their responses to that on Edmodo so the other boys could read their final essay.

In this example, a number of ICTs are integrated into pedagogies that are supporting the summative assessment process. Edmodo, which functions as an education social networking platform, facilitates file sharing, discussion forums and the ability for students to view and comment on each other's contributions.

Research and reports

Assessment types supported by online research through search engines were reported by 10 teachers across the history, business studies, agriculture, economics and science subject areas. Research was then reported on in documents produced with word-processors and/or oral presentations supported with software such as Microsoft PowerPoint. An agriculture teacher explained how he was able to assist his students through the process of reporting on fieldwork results with technology:

> [The students] had to write up…a scientific report. I did a fair bit of scaffolding…. Even though they are Year 11 level, some students are really more at Year 9 level; so I gave them more scaffolding for this report so they knew exactly what they had to do for each section…. They wrote up a report on their netbook and put in any photos they had taken and any results (Douglass, Year 11 agriculture teacher).

In this example, the prepared word-processed documents include instructional clues that were shared with students prior to their completing the writing task. The scaffold within the documents supported students in completing the summative assessment task.

Spreadsheets

Five teachers reported their students' use of spreadsheet software to support science, agriculture and mathematics assessment tasks. In the case of agriculture, students accessed external data from the Australian Bureau of Meteorology and performed data analyses that were included in farm case studies. In science, students collected data from first-hand investigations in fieldwork or laboratory experiments and presented and discussed their results as a component of a report. Two science teachers reported that the primary data were collected with data-logging equipment. The teachers explained that spreadsheet software then helped students to process large amounts of data quickly and identify trends in their data through the use of the software's charting function.

One mathematics teacher reported the use of non-exam style HSC assessments. Oscar, the head of mathematics at his school, described his development of a continuum of spreadsheet-based ICT skills that began with his Year 7 students. Each successive year, spreadsheet-related ICT skills increased in complexity until, by the time students reached the senior years, ICT skills were "not an issue. All our assessment tasks in senior years are ICT-based". He went on to provide an example: "[In Year 11] they are modelling employment using the SIN curve and COSINE curve, and draw graphs which are pretty extensive. The questions might be [prefixed with] 'Solve graphically…'" (Oscar, Year 11 and 12 mathematics teacher).

Oscar also emphasised that he had invested time with his staff ensuring they were proficient in the use of spreadsheets and how to apply them in their classrooms. Another mathematics teacher had a different view, explaining that: "…in General Maths…you don't get examined on whether you can use a spreadsheet or not so it is irrelevant to delivering the syllabus" (Julian, Year 12 mathematics teacher). These examples, given by teachers in different schools, teaching the same subject, illustrate that teachers' beliefs about their subject content can affect their pedagogical decision to integrate ICTs in school-based summative assessment.

Multimedia

Five teachers from the creative arts key learning area (visual arts and music) provided examples of multimedia technologies to support assessment tasks. Both music teachers spoke about musical-notation software being essential for HSC students' project work. Their students produced scores using Sibelius, an industry standard score writing and composition tool, and edited audio files using Audacity, a digital audio editing application. In addition, both music teachers valued the process of students self-critiquing their performances (a component of their HSC practical examinations) through the use of digital video and audio recordings.

Kelly, a senior art teacher, designed an authentic style of assessment for a previous cohort of students using multimedia technologies to support the art-making process:

> …they had to work as a collaborative team. They had to create an installation – it had to be site-specific. I didn't have to see it. They could make their installation at the beach, or at the school or in their home. They had to document it using digital photography and they had to research and provide written explanations of the process of what was happening, and they had to work together as a team to put a PowerPoint presentation together. They each had to present it to the class – each table had their own experience. And then we experienced their installation through technology. Because that is how a lot of contemporary artists are working these days.

A science teacher reported her use of the interactive Crocodile Physics online environment as an assessment strategy she found useful for her students, some of whom attended her class remotely using video conferencing technologies. This application enabled the modelling of physical phenomena:

> [The students enter] some data to this [simulated] car – like initial velocity – and they have to calculate the final velocity and acceleration based on the simulation… (Marley, Year 11 physics teacher).

In summary, teacher-participants provided examples of varied ICT uses across a range of assessment task types; however, traditional exam-style assessment practices predominated, especially in mathematics, for school-based summative assessment.

6.5.3   Perceived constraints to ICT in assessment

Teachers spoke of constraints related to ICT-integration in the context of assessment. These constraints related to perceptions of ICTs interfering with the assessment process, irrelevance of ICTs in the context of HSC examinations and the lack of time available to teach students ICT skills.

Three participants felt that ICTs compromised the assessment process for different reasons:

> I don't want them to use it [PowerPoint] in Year 12 because in Year 12 they need to focus on their delivery, diction, content (Julie, Year 12 English teacher).

> [The practical report] was done by hand. I have done it before with the computer, but if you do a search on the Internet, you can actually download that report, so I avoided that. So now they do it in class (Martin, Year 11 and Year 12 chemistry teacher).

> …Their assessments are not [word-processed] because the computer fixes up some of the problems for them... (Marissa, Year 11 French teacher).

Six teachers felt that there was a disconnect between ICT-integration for assessment and the final HSC examinations. Three teachers explained that because HSC examinations were hand-written, students might be disadvantaged if not provided enough opportunities to write during formal assessment tasks. Marcel provided a typical response:

> I try to get them to hand-write things as much as possible considering that's what they have to do for the HSC. So yes. I get them to hand-write quite a bit. If the HSC exam were type-written then that is all we would do (Marcel, Year 11 economics teacher).

An art teacher and a biology teacher expressed concerns about ICT-integration in relation to time needed to train students to use specific ICTs. In art, Sarah was beginning to experiment with the ePortfolio feature of Adobe Acrobat for in school-based assessment project work. She explained:

> I encourage them to use ePortfolios [for the visual diary of their body of work] because they can add images, use text, can annotate…but they are not grasping it, even though it's all there…. I think it takes too long for them to

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do…. We are completely curriculum-driven and we only have so much time to get through the syllabus, and I can't spend hours going through ICT…. I have to meet the requirements and mandatory hours to cover what they have to cover, to meet those external exams. So I just don't have the time to be able to engage in teaching the technology, as much as I would love to (Sarah, Year 11 and Year 12 art teacher).

In another example, a teacher expressed her frustration at her students' lack of skills with their smart phones on a field trip. She had tried to include the use of the phones' GPS (global positioning system) capability as part of an assessment task in Year 11 biology:

We were out there and they had their smart phones and I asked them what is our latitude and longitude? If you are doing a field study...the GPS [can locate] exactly where you are…. They don't use all the facilities on their phones.

This set of results suggest that having access to ICTs does not mean that teachers will necessarily use them, and in some cases, in the context of HSC assessment, teachers felt that ICTs were irrelevant, or even compromised the assessment process.

Overall, a range of ICTs was used to support school-based summative assessment programs. These included word-processors to prepare reports of first-hand investigations and research reports, online collaboration tools to support a writing task and spreadsheets in mathematics to demonstrate problem-solving skills and in science to analyse data. The creative arts were the most likely to incorporate multimedia technologies as part of their school-based assessment as part of the major project work, which is an assessable component of those courses. The most common school-based assessment task types described were those that resembled HSC external examination-type assessments. These where characterised by pen-and-paper tasks that included HSC external examination-style questions. Teachers perceived a number of constraints to the use of ICTs to support school-based summative assessment tasks, including beliefs that ICTs compromised the assessment process because ICT was not required in the final examinations, and therefore was unnecessary in the context of Year 11 and 12 internal assessment; and the feeling that there was no time to teach students new skills they would need to produce particular ICT-created artefacts.

6.6 Discussion

The results suggest that Year 11 and 12 teacher-participants favoured traditional, pen-and-paper examination-style assessments or assessments that included exam-style questions with a hand-written component for school-based summative assessment. Further, in the case of mathematics, exam-style assessments predominated, and were used exclusively by five out of the six mathematics teacher-participants. In addition to examinations, participants provided examples of word-processor use in supporting essays and report writing, search engines in supporting research and spreadsheets in supporting numerical analysis. The creative arts teachers provided examples of varied assessment types where multimedia technologies supported the creation of digital artefacts.

For many participants, the high-stakes nature of the HSC external assessment process influenced the types of tasks selected to assess outcomes in the internal school-based summative assessment programs. This practice contradicts the stated purpose of the NSW Year 11 and 12 internal summative assessment process – a process intended to complement the external assessment by broadening the outcomes assessed and the type of evidence that can be collected (Masters, 2002). Teachers in this study who spoke about the use of examinations suggested that internal summative processes were a means of preparation for the external examinations. If this practice is widespread in NSW schools, this may be compromising the validity of the internal assessment program of the Higher School Certificate.

Where ICTs were used to support assessment, with the exception of creative arts, participant teachers generally provided a traditional and somewhat narrow range of school-based summative assessment types that were supported with a limited range of ICTs. This is surprising, given that these participants identified themselves as ICT users and were selected for inclusion in the study based on this criterion.

This limited repertoire of assessment-related ICT use may be due to time constraints, as some teachers in the study indicated. The high-stakes nature of the assessment process means that syllabus content must be covered within a given time frame –

usually three school terms of approximately 10 weeks for the Preliminary course and just over three school terms before the trial HSC period commences in Year 12. This pressure to complete mandated content means that there is less time for teachers to focus on broadening students' ICT skills as new technologies become available to support the assessment process.

Narrowing the scope of assessment types because of the high-stakes nature of senior secondary courses is evident in teachers' responses. The influence of external examinations was seen in responses about time limitations that prevented the teaching of new ICT skills to Year 11 and 12 students, and in teachers' beliefs that ICT skills were not needed for external exams, and could even be detrimental because of the need for "writing" in the final papers. This devaluation of ICT competencies at the senior level is in direct contradiction to Australia's national goals for schooling calling for young people to be highly skilled in ICT use (MCEETYA, 2008c). There are implications too, for the Australian national curriculum reform that includes ICT capabilities as an essential outcome of Australian schooling (ACARA, 2012b).

The TPACK framework is useful in diagnosing teachers' limited ICT-integration in assessment (Koehler & Mishra, 2008; Mishra & Koehler, 2006). Teachers' beliefs about assessment types, their limited repertoire of assessment types used and the relatively narrow range of ICT use described may be a consequence of underdeveloped TPACK. In Graham's (2011) theoretical consideration of TPACK, he writes: "A theoretical model has value not only in its power to help describe a phenomenon, but also in the way it facilitates one's ability to develop interventions that will predictably influence the phenomenon" (pp. 1958-1959).

Using the constructs as a diagnostic lens for participant teachers' limited ICT-integration in supporting assessment suggests that some participant teachers may require development of knowledge in the following areas:

1. Pedagogical knowledge associated with the purpose of school based summative assessment

2. Pedagogical knowledge associated with prescribed requirements for assessment programs that capture evidence of learning across a broad range of course outcomes – particularly outcomes that cannot be easily assessed by written examinations. In NSW schools, assessment requirements are set out by the Board of Studies (NSW Board of Studies, 2011).

3. Pedagogical content knowledge of varied assessment types and their appropriateness in gathering achievement data across subject specific course outcomes.

Stiggins (1995) argues a need for teacher *assessment literacy* because of the increasingly complex challenges of classroom assessment. He argues that young people are "placed in harm's way" when their achievements are mismeasured (p. 239). Stiggins (1995) proposes four domains of assessment literacy related to purpose, appropriately assessing 'achievement targets', assessment methods that align to 'achievement targets', proper sampling of achievement and controlling for bias and distortion (p. 240). In the NSW senior secondary context, assessment nomenclature is rooted in students demonstrating the *standard* to which they have achieved course specific learning *outcomes* (Killen, 2005). Assessment literacy requires teacher knowledge of the different kinds of outcomes such as content knowledge, reasoning and thinking skills, performance skills and developing quality products (Stiggins, 1995) and the most appropriate assessment methods that enable students to demonstrate the standard to which they have achieved those outcomes (Killen, 2005).

TPACK (Mishra & Koehler, 2006), in the context of assessment literacy, incudes knowledge of emerging technologies and how they can streamline and enhance the school based summative assessment This includes varied assessment types afforded by ICTs (Clarke-Midura & Dede, 2010), computer-assisted assessment (Gipps, 2005; Whetton & Sainsbury, 2007) including online examinations, the varied artefacts that students' can create to demonstrate their learning (for example Hoban & Nielsen, 2012; Lincoln, 2009) and ways in which ICTs can be used to support collection and analysis of assessment data. A deficiency in any one of these areas would limit teachers' ability to design and implement effective school-based assessment programs.

In creative arts, the application of technological pedagogical content knowledge (TPACK) can be observed in the examples given. Kelly, for example, spoke of an authentic assessment task where her students created an installation. Her content knowledge of how artists operate in the real world was applied, as was her knowledge of digital technologies and how they can support the process of collecting evidence of student learning during the assessment process. In another example, Leon's knowledge that his students' learning processes were supported with peer collaboration, and his knowledge of how digital collaboration tools can record evidence of students' learning through online conversations with their peers, was evident in his descriptions of ICT-integration. In these examples, teachers clearly relate their teaching and assessment experiences to their students' learning.

The creative arts subjects are different in another way from other subject domains reported on in this study. In addition to the final written HSC examination, these subjects have a practical HSC examination where an art product or music performance is externally examined. In this sense, ICTs are included in the final external examinations where digital artworks are presented and digital technologies are an integrated component of the performance process. In other words, what is assessed is influencing what is taught. If a digital artefact is presented for external examination, then digital-editing tools become part of the internal school-based summative assessment processes.

6.7   Implications and limitations of the study

In closing this discussion, it is important to acknowledge the limitations of this study and implications for research, practice and policy.

This study drew on a relatively small sample size and it situated in the context of NSW senior secondary education. The trends observed in this sample are not representative of senior secondary education generally In addition, 2011 represented the first year of the DER program in New South Wales senior secondary courses, and one-to-one computing environments may not have reached a level of maturity where teachers were comfortable with ICT-supported assessment tasks. Further research might explore assessment programs in a greater number of schools across more subject areas to build

a more comprehensive profile of school-based assessment practices in senior secondary education.

While TPACK provided a useful theoretical lens in this study, the complexities of the knowledge teachers draw on within a community and context of practice may not be informed by a single theoretical model. For example, in this study, high-stakes assessment, prescribed content and time constraints were factors affecting teachers ICT-integration practice. The implications for researchers are that other theoretical frames would add value in understanding contextual factors affecting assessment and ICT-integration practice. For example, Bernstein's theoretical tools of vertical and horizontal discourses enabled an Australian study to explore social, cultural and contextual factors affecting teachers' understanding of assessment (Willis, Adie, & Klenowski, 2013).

In this study TPACK (Mishra & Koehler, 2006) highlighted a lack of participant teacher knowledge of the purpose of internal summative assessment. In other words, a lack of *pedagogical knowledge* (PK) was evident in responses relating to the use of internal assessment as a means of preparation for external exams, and this affected participants' teaching practice. The implications for teacher education are that a specialist knowledge base must be developed related to the purposes of assessment, aligning assessment to subject outcomes and the use of ICT in supporting the implementation of assessment programs. This resonates with calls by others for explicit teaching of assessment literacy in teacher-education programs (DeLuca & Klinger, 2010; Willis et al., 2013)

Implications for assessment policy in senior secondary education include a need for assessment to be adaptable and inclusive of a broader skill set than is currently examined and assessed. New South Wales is an example of a system where high-stakes external assessment practices have changed little since 2001. Digital literacies are important outcomes of contemporary schooling, as acknowledged by governments internationally. Specialist ICTs are vital to almost every discipline – sciences, mathematics, creative and performing arts, languages and more; however, these skills are not examined in senior secondary curricula in New South Wales and are, therefore,

in danger of being devalued by educators and learners alike. A senior secondary curriculum is needed that can adapt to advances in technologies, and external examination systems must value a broader set of knowledge and skills other than those that can be easily represented in written examinations.

6.8   Conclusion

This paper has examined ICT-integration in school-based summative assessment tasks by senior secondary teachers in NSW schools during an education reform period known as the *Digital Education Revolution*. The results suggest that senior secondary participant teachers favoured traditional, pen-and-paper examination-style assessments or assessments that included exam-style questions with a hand-written component. The effect of external high-stakes examinations on internal assessment processes was evident in teachers' concerns relating to time constraints, the lack of relevance of ICT-related skills in HSC examinations and the need to practise hand-written responses to maximise HSC exam success. The implications are twofold. First, narrowing of the range of task types used for school-based summative assessment narrows the opportunities for students to demonstrate breadth and depth of knowledge, skills and understanding. This threatens the validity of the internal school-based assessment process. Second, if ICT skills and the application of ICTs in assessment tasks are not included in assessment criteria, the underlying message to students is that these skills are neither valued nor necessary. This contradicts the higher-level outcomes of schooling relating to living and working in contemporary society that are part of Australia's national education agreements and national goals for schooling.

CHAPTER 7: TECHNOLOGY IN SCHOOL EDUCATION – ICT-INTEGRATION AND TEACHER KNOWLEDGE

Abstract

The technological pedagogical content knowledge (TPACK) framework has brought together educational technology research. It has framed questions and informed analysis in areas that include teacher education, in-service teacher professional learning and developing understanding of the knowledge needed for successful teaching. Despite the proliferation of literature referencing the construct since its inception, there have been concerns about TPACK's status as a conceptual framework related to lack of clarity of its boundary constructs, differing descriptions of the constructs and lack of theoretical development. In a contribution towards TPACK's theoretical development, definitions of the Technological Content Knowledge (TCK) construct were explored with examples of practice from five senior secondary teachers. An analytical framework was developed that further explicated TCK manifestations in practice, that was then used to deconstruct experiences of ICT use collected through semi-structured interviews. Seven examples of TCK enactment were identified in the literature and in practice as described by participants in this study and these form the basis of recommendations for teacher professional learning related to the development of technological content knowledge. Furthermore, the study provides evidence for the value of the TCK construct to ICT-integration studies: TCK emphasises the importance of discipline-specific knowledge for teaching practice; it enables a deconstruction of enacted knowledge and identifies skills important for effective ICT-integration; and a TCK focus foregrounds important discipline-specific ICT skills that should be explicated in prescribed curricula (a characteristic of senior secondary education) so that their value is clear to specialist subject teachers. Teachers call on an ensemble of knowledge domains and beliefs within widely varying contextual constraints and capacities. This empirical investigation into aspects of teaching using the TPACK model provided a meaningful vocabulary to describe knowledge and its enactment, thereby contributing knowledge on what good teachers need to know in order to teach.

7.1 Introduction

Theory enables researchers to move beyond descriptive reporting towards a deeper understanding of the complexities and nuances of education environments. It provides a vehicle for dialog among scholars and can position micro-level research within a broader context and a larger knowledge base (Anyon, 2008). A framework emerged in 2005 called Technological Pedagogical Content Knowledge – TPACK (originally TPCK) – that has continued to inform research in information and communications technology integration since its first articulation (Koehler, Shin, & Mishra, 2012; Mishra & Koehler, 2006).

TPACK offers researchers a conceptualisation of teacher knowledge (Koehler & Mishra, 2008; Mishra & Koehler, 2006). It extends Shulman's (1986b) Pedagogical Content Knowledge (PCK) framework – born from research that observed changes in teachers' knowledge as they progressed from novice to expert (Shulman, 1986b, 1987). Shulman and Shulman (2004) explained that they wanted a theory "couched in the language of teacher learning" so that they could examine how teachers learned to teach (p. 258). While knowledge of pedagogical strategies and subject matter content were necessary precursors for good teaching, Shulman (1986b) argued expert teachers' enacted pedagogical content knowledge (PCK) when they represented and formulated subject content in a way that was meaningful to learners. In a similar vein, Mishra and Koehler (2006) contend that new technologies have a significant role to play in subject-content representation with the ways in which they can "make it more accessible and comprehensible" to learners (p. 1023).

The answer to the question *What do teachers need to know in order to teach?* continually changes, and the evolution of information and communications technology (ICT) in education environments has been a significant change force. TPACK was a response to the knowledge base required to teach with technology. The conceptualisation evolved from research undertaken with university teachers and the way that technology was becoming increasingly important for their work in developing online courses (Koehler & Mishra, 2005; Koehler, Mishra, Hershey, & Peruski, 2004). The TPACK framework added additional knowledge bases to the PCK model, based on the premise that knowledge of technology and how it worked – technological

knowledge (TK) – could not be thought of as an exclusive body of knowledge and that quality teaching involved an application of three intersecting knowledge bases of content knowledge (CK), pedagogical knowledge (PK) and technological knowledge (TK) (Mishra & Koehler, 2006). These boundary constructs are called technological content knowledge (TCK), technological pedagogical knowledge (TPK) and TPACK (Koehler & Mishra, 2009; Mishra & Koehler, 2006).

TPACK has informed research and practice on a number of fronts. It is shaping the way future teachers are prepared to enter the profession through their teacher-education programs (Angeli & Valanides, 2009; Finger et al., 2013; Lloyd, 2013; Niess et al., 2009). Similarly, in-service teacher professional development associated with ICTs is being developed in a way that promotes the development of the TPACK constructs (Graham, Burgoyne, et al., 2009; Harris & Hofer, 2011; Mouza & Wong, 2009; Shin et al., 2009; Swan & Hofer, 2011). Another line of research considers TPACK in the context of practice in which it provides an analytical lens to examine learning design and instructional planning with ICT (Angeli & Valanides, 2009; Koehler & Mishra, 2005; Koehler et al., 2007).

Despite the proliferation of literature referring to the construct since its inception, there have been concerns about TPACK's status as a conceptual framework. Questions have been raised over whether the constructs represents discrete knowledge domains (Archambault & Barnett, 2010; Archambault & Crippen, 2009), the lack of clarity of the constructs, particularly the boundary constructs of TPK and TCK (Angeli & Valanides, 2009; Cox & Graham, 2009b), differing understandings and descriptions of the constructs (Cox & Graham, 2009b; Niess, 2011; Voogt, Fisser, Pareja Roblin, Tondeur, & van Braak, 2013); the lack of theoretical development of the model (Archambault & Barnett, 2010; Graham, 2011) and the complexity of the framework due to the number of constructs (Brantley-Dias & Ertmer, 2013; Graham, Borup, & Smith, 2012). These concerns over construct clarity and distinctness are related to historical differences inherited from the parent construct (Archambault & Barnett, 2010; Graham, 2011; Niess, 2011).

The purpose of this paper is to offer an example of TPACK's use in guiding research focusing on ICT-integration by senior secondary teachers. We examine some of the quandaries surrounding the construct. TPACK's use in guiding data collection is described, as well as its use as a theoretical lens through which to consider teachers' application of their knowledge to practice. In the context of content-laden senior secondary education, a particular focus on one construct, TCK, has been taken in this paper in an effort to contribute to TPACK's theoretical development.

This paper will begin with an overview of how TPACK theory has developed and how the model is informing educational research.. We contribute to TPACK's theoretical development through an example of its use in a study of ICT-integration. A focus on the technological content knowledge (TCK) boundary construct is afforded by the context of content-laden senior secondary school subjects and a government-policy enactment period where Year 11 and 12 students were provided with increased access to ICTs. TCK's enactment as conceptualised by TPACK scholars is used as an analytical lens through which teachers' experiences with ICT-integration are explored.

7.2   TPACK – an analytical lens for ICT-integration in education

This section revisits TPACK's (Mishra & Koehler, 2006) theoretical roots and provides an overview of its use as a framework for teacher knowledge.

7.2.1   TPACK's parent construct - PCK

A theoretical consideration of Technological Pedagogical Content Knowledge (TPACK) would be incomplete without an understanding of Shulman's (1986b) Pedagogical Content Knowledge (PCK) upon which the TPACK framework was developed (Mishra & Koehler, 2006). PCK was born from Stanford's *Knowledge Growth in a Profession* research project that tracked secondary school teachers who were transitioning from pre-service teacher education to their first full-time year of teaching (Shulman, 1986a; Shulman, 1987; Wilson, Shulman, & Richert, 1987). Shulman (1986b) was critical of teacher preparation programs and evaluation standards that emphasised pedagogical methods that were disconnected from the subject matter to be taught. He urged researchers to consider the importance of subject matter knowledge of teachers and argued that "the absence of focus on subject matter

among the various research paradigms for the study of teaching [was] the missing paradigm" (Shulman, 1986b, p. 6). The questions Shulman (1986b) and his colleagues were asking about the ways in which teachers transform their understanding of subject matter into instruction that their students can comprehend, are as relevant in contemporary times as they were in 1986. For example: "How does the teacher prepare to teach something never previously learned?"; "How do teachers take a piece of text and transform their understanding of it into instruction that their students can comprehend?"; "How does learning for teaching occur?" (Shulman, 1986b, p. 8).

In order to explore questions such as these, a framework was proposed that considered teachers knowledge as two related domains - content knowledge and general pedagogical knowledge (Shulman, 1986b). Initially, thinking focused on one domain of teacher knowledge in particular – content knowledge and the categories within it (Shulman, 1986b). Three subcategories of content knowledge were originally described as subject matter knowledge, pedagogical knowledge and curricular knowledge (Shulman, 1986a), with later refinements including general pedagogical knowledge, subject matter knowledge and pedagogical content knowledge as subcategories of content knowledge (Shulman, 1986b; Wilson et al., 1987). Of special interest was pedagogical content knowledge (PCK) - a specialist knowledge domain involving teachers using pedagogical strategies that are most suited to representing specific subject matter content to maximise student learning. Teachers were positioned as transformers of knowledge and Shulman (1987) proposed the existence of a unique knowledge base of the teaching profession that differed from that of experts in specialist fields. PCK, he argued, was a knowledge of representations of subject matter as well as knowledge of learners, their preconceptions and common misconceptions of topics being taught (Shulman, 1986b). In Shulman's (1986b) words, PCK:

> embodies the aspects of content most germane to its teachability...I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations - in a word, the ways of representing and formulating the subject that make it comprehensible to others… [PCK] also includes an understanding of what makes the learning of specific concepts easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning... (p. 9)

The emergence of pedagogical content knowledge (PCK) spawned a field of educational scholarly dialog that continues (Abell, 2008; Berry, Loughran, & van Driel, 2008; Gess-Newsome, 1999a; Kind, 2009; Park & Oliver, 2008). Over time, the construct, has been interpreted in many different ways (Berry et al., 2008). After initially proposing PCK as a category of content knowledge, Shulman's 1987 refinement listed PCK as one of seven categories of teacher knowledge: subject matter knowledge, general pedagogical knowledge, pedagogical content knowledge, knowledge of other content, curricular knowledge, knowledge of learners and knowledge of educational aims (Shulman, 1987; Wilson et al., 1987). Grossman (1990) added further refinements. She proposed a hierarchy of four constructs – subject matter knowledge, pedagogical knowledge, pedagogical content knowledge and contextual knowledge. She to further delineated each domain into several subcategories. This representation is reproduced in (Figure 10).
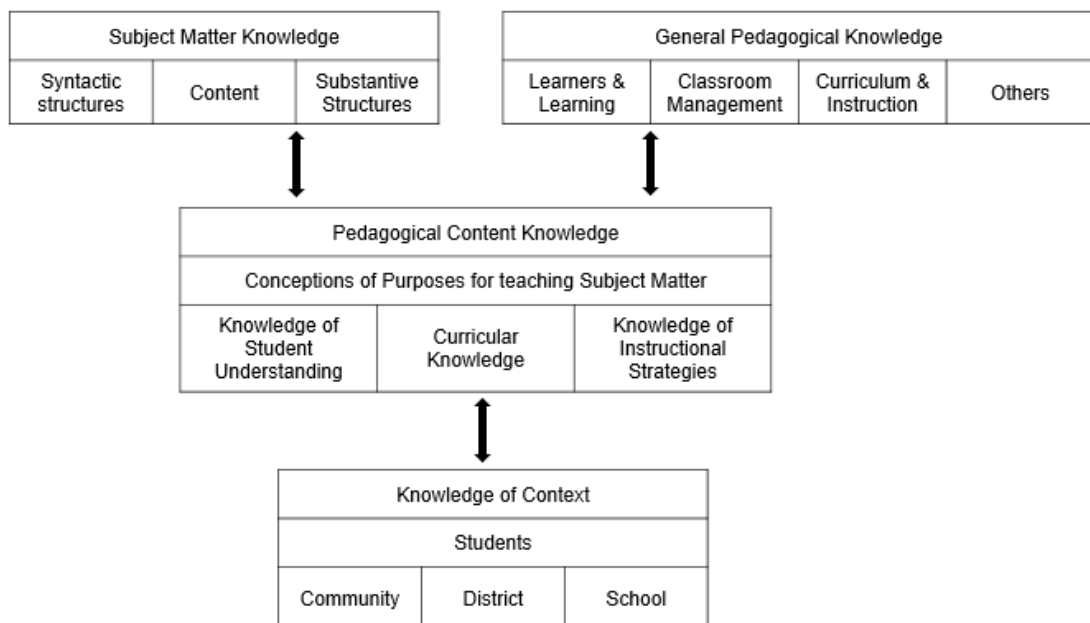
Figure 10: A conceptualisation of pedagogical content knowledge by (Grossman, 1990) that interacts with subject matter, pedagogical and contextual knowledge domains (Source: Grossman, 1990, p. 5).

The representation includes PCK at the centre, seen as a transformation of subject, pedagogical and contextual knowledge (Grossman, 1990).

Adopting an epistemological perspective towards the nature of content knowledge (CK), pedagogical knowledge (PK) and pedagogical content knowledge (PCK), McEwan and Bull, (1991) did not support a distinction between subject matter knowledge and pedagogical content knowledge. They argued that "all content knowledge, whether held by scholars or teachers, has a pedagogical dimension" (McEwan & Bull, 1991, p. 318). The pedagogical content knowing (PCKg) variation, emphasising the importance of knowing learners and the context within which the learning is situated, considered an integrated teacher knowledge domain distinct and different to its component constructs (Cochran, DeRuiter, & King, 1993).

Gess-Newsome (1999a) offered Integrative and Transformative views as a continuum of teacher knowledge. At one end (the integrative model), teachers selectively draw on independent knowledge domains of content and pedagogy in designing and implementing a learning sequence. At the other end of the continuum, PCK is a unique body of knowledge – a synthesis of content, pedagogical and contextual knowledge (Gess-Newsome, 1999a). These views of teacher knowledge are represented in Figure 11.
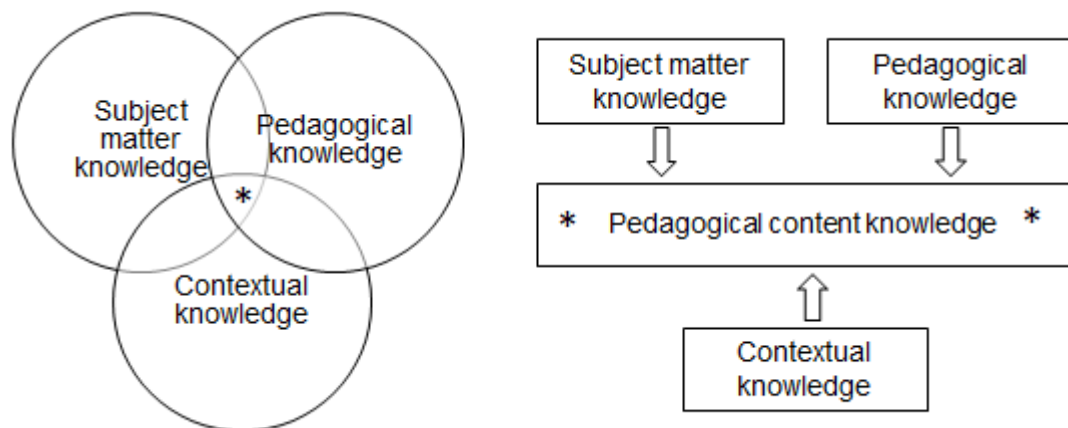
Figure 11: Two models of teacher knowledge proposed by Gess-Newsome – The Integrative PCK model on the left with knowledge needed for classroom teaching represented as an asterisk (*) and the Transformative PCK model on the right (Source: Gess-Newsome, 1999a, p. 12).

Thirteen years after PCK's original proposal, borders between the constructs were still considered "overlapping" and "fuzzy" (Gess-Newsome, 1999a). Gess-Newsome (1999a) noted that "identifying instances of PCK is not an easy task…The PCK construct has fuzzy boundaries, demanding unusual and ephemeral clarity on the part

of the researcher to assign knowledge to PCK or one of its related constructs" (p. 10). Other reviewers, too, have noted the lack of a universally accepted definition of PCK (Hashweh, 2005; Nilsson, 2008; Park & Oliver, 2008). Precise conceptualisation is a precursor to effective measurement and is important in order to assess interventions designed to improve teacher knowledge (Heather, Deborah Loewenberg, & Stephen, 2008). Challenges for researchers assessing PCK in the context of science have included concerns over construct validity of Likert-style instruments (Do items measure what they intend to measure?), the difficulty of crafting questions targeting the (intersecting) PCK construct, and "cumbersome and difficult to replicate" comprehensive qualitative techniques (Baxter & Lederman, 1999a, p. 156).

Despite challenges with the parent construct, the PCK model was expanded to Technological Pedagogical Content Knowledge (TPCK) to include knowledge associated with educational uses of technology (Mishra & Koehler, 2006). Mishra and Koehler argued that since PCK's inception, digital technologies had "come to the forefront of educational discourse" because of greater access and the way digital technologies had altered teaching environments (2006, p. 1023). Just as PCK emphasised the interconnectedness of content knowledge (CK) and pedagogical knowledge (PK), Mishra and Koehler (2006) contended that technological knowledge (TK) should not be developed in isolation from the subject matter or the processes of teaching and learning:

> TPCK is the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones (p. 1029).

TPACK (formerly TPCK; Thompson & Mishra, 2008) was proposed as a theoretical framework for understanding ICT supported teaching and learning (Mishra & Koehler, 2006). It has united scholarship in ICT-integration research related to preservice teacher education, in-service teacher professional learning and in conceptualising the complex knowledge base of teachers (Cox & Graham, 2009a; Graham et al., 2012;

Graham, Burgoyne, et al., 2009; Hofer et al., 2009; Shin et al., 2009). Previous frameworks relating to educational uses of ICT focused on categorisation, such as instructional uses versus lesson preparation or school and classroom administration (Bebell, Russell, & O'Dwyer, 2004), and categorisations relating to ICT skill acquisition, enhancing student learning, curricular reform and whole-system reform (Downes et al., 2001). Also focusing on teachers' use of ICT were measurement instruments aimed at describing and developing good practice, or promoting discussion about technology's impact on schools (Bebell et al., 2004; Trinidad, Newhouse, & Clarkson, 2005). A number of instruments developed continua along which teachers progressed towards ICT-integration implementation (Trinidad et al., 2005)., Trinidad, et al. (2005) described these types of frameworks as adoption-behaviour models of ICT-integration.

TPACK conceptualises ICT-integration in terms of knowledge needed to effectively teach with technologies (Mishra & Koehler, 2006). Like PCK, TPACK is couched in the language of teachers' practice: content, pedagogy and learning technologies (Romeo, Lloyd, & Downes, 2012). It emphasises ICT use in school education in terms of ICT's affordances in representing subject content and supporting pedagogical practice.

7.2.2   Applications of the TPACK framework

TPACK has informed research in a number of areas such as teacher education, in-service teacher professional development and examinations of teachers' use of ICT in practice. An example of TPACK's use in preservice teacher education was the Australian multi-university Teaching Teachers for the Future (TTF) project where the framework provided a schema for ICT use in school curricula (Romeo et al., 2012). Specifically, TPACK informed the development of an online digital resource repository across English, Mathematics, History and Science; informed the development of a national student teacher survey to track changes in TPACK; and informed an audit of teacher-education courses (Romeo et al., 2012). In addition, the researchers explained that TPACK was important in providing a vocabulary to guide teacher educators that emphasised the "intersection and interplay of the three core

elements of knowledge of content, pedagogy and technology" (Romeo et al., 2012, p. 959).

Closely linked to pre-service teacher education are studies aimed at measuring TPACK and its component constructs. This line of research highlighted a number of challenges – especially in research associated with survey instruments designed to quantify teacher knowledge. Measurement is important to teacher educators because it provides a mechanism to assess different methods for developing TPACK (Graham, Cox, et al., 2009). The challenges for researchers relate to the ambiguity of the constructs and the complexity of a model with seven constituent parts (Archambault & Barnett, 2010; Brantley-Dias & Ertmer, 2013; Graham, 2011). The ambiguity is not new to TPACK and is somewhat inherited from the parent construct (Baxter & Lederman, 1999b; Gess-Newsome, 1999a). It refers to a lack of clarity over constituent definitions, particularly overlapping constructs TPK, PCK, TCK and TPACK; and assigning knowledge to one of these areas. The issues are around validity and reliability. For example, in a study using a survey instrument for K-12 online teachers, researchers described the knowledge measurement process as "complicated, muddled, and messy" and found that participants had difficulties in separating out specific issues of content and pedagogy (Archambault & Crippen, 2009, p. 83). In other cases, researchers encountered difficulties developing survey items that statistically differentiated boundary constructs (Archambault & Barnett, 2010; Cox, Graham, Browne, & Richard, 2010a).

Accounts of practice through qualitative explorations enable researchers to use TPACK as a theoretical lens, capture teacher reasoning, and then to 'revisit' the framework in response to observational data (Groth, Spickler, Bergner, & Bardzell, 2009). Examples of this approach include qualitative studies that have collected and analysed interview data, lesson plans, lesson artefacts (student and/or teacher products), classroom observation, video transcripts and journals (Angeli & Valanides, 2009; Graham et al., 2012; Groth et al., 2009; Guzey & Roehrig, 2009; Harris & Hofer, 2011; Swan & Hofer, 2011). For example, in studies of teachers' development of TPACK, Groth, and colleagues (2009) collected multiple qualitative data sources including lesson plans, lesson reviews, transcripts of video lessons and transcripts of

debriefing sessions; while Agyei and Voogt (2011) analysed lesson plan documents, interviews, observations and survey data in exploring how teachers expressed their TPACK relating to spreadsheet use in Mathematics. In these cases, researchers made inferences about teachers' overall TPACK and did not deconstruct data along the lines of component constructs.

Studies have also explored component constructs and their applications in practice. For example, Harris and Hofer (2011) explored the TPACK growth of in-service social-studies teachers by coding datasets that included interviews, unit plans and written reflections. The researchers used PCK, TPK, TCK and TPACK definitions to guide interview protocols and data analysis. Harris and Hofer (2011) reported difficulties in finding examples of participating teachers' TCK. They reported that despite probing for responses that embodied TCK during interviews and providing prompts for the written reflection, they were able to document TPK and TPACK more than TCK. Specifically focusing on the capabilities offered by podcasting technologies, a similar study with economics teachers used the TPACK framework as a lens through which to view instructional planning associated with ICT-integration in senior economics (Swan & Hofer, 2011). The researchers analysed surveys and interview transcripts and reported that teachers successfully integrated podcasting processes and technologies with their curriculum; however, it was difficult for teachers to articulate "content-based rationales" for teaching economic concepts and skills through these technologies (Swan & Hofer, 2011, p. 84).

7.2.3 Development of the framework

Following TPACK's conceptualisation, researchers turned their attention to clarification of its component constructs. Like scholars clarifying PCK (for example, Gess-Newsome, 1999a), Angeli and Valanides (2009) juxtaposed the integrative and transformative views of the TPCK construct. It was suggested that TPCK was a unique body of knowledge (transformative) rather than a type of knowledge that is integrated from its constituent knowledge bases (Angeli & Valanides, 2009). Their conclusion was supported by studies with pre-service teachers with good ICT skills who did not necessarily design good ICT-supported lessons. The implications (Angeli & Valanides, 2009) were that teacher-education programs must explicitly target TPCK

development. Despite this refinement to the TPCK definition, as with PCK, a range of integrative to transformative perspectives is evident in the literature (Gess-Newsome, 1999a; Graham, 2011).

A conceptual analysis of the model led to the development of what were termed "precising" definitions for the boundary constructs: TCK, TPK and TPACK (Cox, 2008; Cox & Graham, 2009a, 2009b). The analysis involved an in-depth review of the literature, as well as interviews with then-current researchers. They offered detailed definitions (Cox & Graham, 2009a) and the following "precising" definitions aimed to distinguish between boundary constructs:

> TCK: a knowledge of the technology-content interaction independent of pedagogy.
>
> TPK: a knowledge of the technology-pedagogy interaction independent of topic-specific representations or content-specific instructional strategies.
>
> TPACK: a knowledge of the technology-pedagogy-content interaction in the context of content-specific instructional strategies (Cox & Graham, 2009b, p. 4043).

A "sliding" definition for TPACK was proposed that involved a difference in the way users perceived technologies (Cox & Graham, 2009a, p. 63). Technological knowledge was further defined as "knowledge of how to use emerging technologies" (Cox & Graham, 2009a, p. 63). The terms *emerging* and *transparent* technologies were introduced to differentiate TPACK and PCK (Cox & Graham, 2009a). Transparent technologies are those technologies that are ubiquitous and people take for granted – such as a chalkboard or overhead projector (Cox & Graham, 2009a). Cox and Graham (2009a) suggest that as emerging technologies become mainstream, the constructs *slide* – TCK slides back to CK and TPK slides back to PK as the emphasis on the technology is no longer needed. Likewise, "as the technologies used in those activities and representations become ubiquitous, TPACK transforms into PCK" (Cox & Graham, 2009a, p. 64).

Research in the area of TPACK and teachers' planning introduced an Activity Type Approach to ICT-integration, provided a connection between theory and practice (Harris & Hofer, 2009; Harris et al., 2009; Hofer et al., 2009). This approach to ICT-

integration is grounded in teacher's processes during instructional planning. Activity types make explicit connections between curriculum goals, the activities students are undertaking and the technologies that are able to support those processes (Harris & Hofer, 2009). Harris and Hofer (2009) have documented taxonomies of subject-specific activity types that can be assembled into lessons, units of work and assessment strategies (also see the Learning Activity Types Wiki: http://activitytypes.wmwikis.net).

Despite the large corpus of fruitful research TPACK has informed, theoretical considerations of the model have concluded that further work is warranted in the following areas:

- The question of the existence of the component constructs in practice (Archambault & Barnett, 2010).
- The value of the theory in providing a common language for productive discussion, which would require further clarification of the vocabulary (Graham, 2011).
- The use of the definitions with practising teachers (Cox & Graham, 2009a).
- Detailed examples of teachers' knowledge in practice (Cox & Graham, 2009a).

The results presented in this paper contribute to these areas through an exploration of the TCK construct with examples of practice provided by in-service teachers. This is in response to doubts surrounding the existence of boundary constructs, the need for clarification of boundary constructs and the need for practising teachers to use definitions (Archambault & Barnett, 2010; Cox & Graham, 2009a, 2009b; Graham, 2011).

7.3   The study design and methodology

In a contribution towards TPACK's theoretical development, definitions of the Technological content knowledge (TCK) construct were explored with examples of practice from senior secondary teachers. The boundary constructs are an aspect of the TPACK model that has presented a number of challenges to researchers because of varied interpretations and lack of precision. The findings presented in this paper are a

component of a broader research project examining education policy and technology integration in senior secondary education. They contribute to theoretical discussions on TPACK and connect theory to practice in school education by drawing on examples from the Australian context and teaching New South Wales Higher School Certificate (Years 11 and 12) courses. The analysis and discussion presented in this paper are guided by the question: *What forms of teacher knowledge are evident in senior secondary teachers' descriptions of their practice?*

Construct value describes the theoretical value for constructs in a model (Graham, 2011). This study adopts the premise that TPACK's boundary constructs are important to studies of ICT-integration as an emphasis on "content specific applications of technology [rather than] technical skills independent of pedagogy or content" are needed for successful ICT-integration (Graham, 2011, p. 1958). Year 11 and 12 course content and high-stakes assessment are contributing contextual factors affecting the way technology is used by senior secondary teachers.

Cox and Graham (2009b) noted that fewer studies had attempted to explore TPK and TCK compared with TPACK. This study provided an opportunity to focus on content and technology interactions because of two complementary contextual factors:

1. Content-laden NSW Higher School Certificate (Years 11 and 12) courses. There is a focus on subject content knowledge in this context because Year 11 and 12 courses are the final stage of schooling in NSW, and teachers are expected to have advanced subject knowledge in their specialisations. These teachers employ a number of strategies aimed at developing understanding, skills and knowledge for subject-specific content in time for external high-stakes assessments (Ayres et al., 2004).

2. Data collection occurred during the enactment of Australia's *Digital Education Revolution* (DER) policy agenda aimed at implementing a 1:1 computer-to-student ratio in Years 9 to 12 (DEEWR, 2008e, 2009b). The overarching goal driving the agenda was "sustainable and meaningful change to teaching and learning in Australian schools to prepare students for further education,

training and to live and work in a digital world" (DEEWR, 2009b, p. 1). The national vision required teachers to have knowledge of how learning outcomes are improved through the integration and embedding of ICTs in teaching programs, learning activities and assessment (DEEWR, 2009b; MCEETYA, 2008a). Changes advocated in policy implied a degree of complexity for teachers who were required to develop new skills, change existing beliefs, adopt new teaching strategies and develop new teaching resources (Fullan, 2007).

This context offered a unique opportunity to examine the relationship between content knowledge and technological knowledge and an opportunity to explore the contribution of the TCK construct and TPACK framework to ICT-integration studies.

7.3.1 Data collection

The data collection and analysis adopted a phenomenological approach that values the subjective experiences of participants to better understand a topic of interest (Sharkey, 2001). The analysis drew on experiences of Year 11 and 12 teachers who were actively using technology in their classrooms. Criterion sampling (Creswell, 2012b) identified 28 participants who were actively using ICT to support teaching and learning in their subject areas.

A semi-structured interview protocol was designed to elicit experiences of teachers' ICT use in senior secondary education. Definitions of the TPACK constructs and their applications in practice were used to construct a protocol to guide a semi-structured interview process aimed at fostering discussion of participants' use of ICT and their interpretation of the value of ICTs within the context of their subject area and classroom practice. The guiding questions relating to the TCK construct are shown in Table 26.

Table 26: Interview protocol – guiding questions and TCK indicators

Guiding Questions	TCK Indicators
- Teaching career - What was your training/majors/minors and subject areas - Number of years teaching - Number of years teaching at this school	Content knowledge (CK)
Personal ICT use How would you rate your own ICT skill level and confidence? (Prompts: fix own hardware or software problems; connecting to wireless network; helping colleagues with their problems)	TK Technological knowledge – how to use different ICTs.
Current and recent topics Can you give me an overview of what you have been doing in [subject] recently? (Prompts: topics; what area of the syllabus does that come from?)	CK Structure of their subject-matter content.
What types of learning activities or teaching strategies do you like to use when covering this content/topic area/ unit of work? (Prompts: learning activities and teaching strategies that work best with your students for this content). Describe a lesson/unit on [that topic area] where you have used ICT. (Prompts: types of hardware, software or online tools; what were the students doing with the ICTs?; How does it help delivery or understanding of that topic?)	TCK (but also TPK and TPACK) Is there evidence of "a way of thinking" about T, P and C and the relationships between them?
Online resources What sort of online resources or activities do you use? Why is it appropriate/useful for that part of the syllabus? How do you use your Intranet/Course management system?	TK and TCK How ICT can create new representations for specific content. Applications of ICT may change the way learners' practice and understand concepts in a specific content area.
ICT literacy What are your students' ICT skills like? Do you need to explicitly include ICT skills in your instruction (e.g. word-processing, spreadsheets, search engines, ethical use of resources)?	TCK Students must learn how to use the technology, particularly technologies that are specific to a given content area. In this case ICT skills and knowledge become part of the content that must be explicitly taught.

This paper reports examples of TCK in practice as described by five participants. All five participants were from non-metropolitan (rural) schools and had more than 10 years' teaching experience. Teaching areas are summarised in Table 27.

Table 27: Participants providing examples of TCK

Participant	Subject area	School type
Martin	Chemistry	Non-government
Mario	Music	Non-government
Samuel	Mathematics	Non-government
Diane	English	Government
Elise	Latin (Classics)	Non-government

Vignettes from these participants were selected for this paper because they represented four key learning areas (subject specialisations). The examples of ICT-integration they described illustrated various aspects of TCK identified in the analytical framework.

Martin

Martin was selected because he is a specialist Year 11 and 12 chemistry teacher with a high degree of content knowledge (a PhD in chemistry), and was particularly comfortable with using a range of technologies to represent chemistry content. He owned his own laptop and the latest mobile phone. He had an interactive whiteboard in his classroom and he was scheduled in the same classroom for all of his lessons. His students did not have personal laptop computers; however, the school had good levels of access to computer laboratories. Martin had 20 years' experience and was teaching in a non-government coeducational school in rural NSW.

Mario

Mario was selected because he was a Year 11 and 12 music teacher with a high level of content knowledge (having taught at tertiary level prior to becoming a school teacher). Mario used specialist, subject-specific ICTs and considered their use by students important for their success in the senior secondary courses. Mario's school had a laptop program where his students brought their own laptops to school. Mario had 10 years' teaching experience and was working in an all-girls non-government boarding school in rural NSW.

Samuel

Samuel was a Year 11 and 12 mathematics teacher. His ICT-integration demonstrates the way specialist mathematics software in combination with display technologies can enhance student learning. Samuel's school did not have a laptop program; however, there was good access to computer laboratories. He had 12 years of teaching experience and was working in a coeducational non-government school in rural NSW.

Diane

Diane was a Year 11 English teacher who was selected because her examples of ICT-integration demonstrate developing TCK. While Diane had taught for 30 years (indicating high levels of CK), she had only recently had access to an interactive whiteboard. Diane taught in a coeducational government school in rural NSW that was part of the NSW DER initiative, in which all students in Year 11 in the year of data collection were issued with a laptop computer.

Elise

Elise was a teacher of the classics. She had over 20 years' experience and taught Year 11 and 12 Latin as well as an extension (advanced) Latin course in her school. Elise was selected because of her high level of content knowledge. Elise's school had a laptop program where her students brought their own laptops to school. Although Elise, herself, used ICTs to create resources for students, she did not value her students using computers in her course. Elise represents a counter-case, where TCK is either lacking or not being applied in this context. Elise's school is a non-government, all-girls school in rural NSW.

7.3.2   Development of an analytical framework for TCK

This paper reports on a dataset selected to explore the TCK construct; an analytical framework that describing TCK manifestations in practice was developed through further scrutiny of the TPACK literature. Examples of TPACK's definitions and applications in practice were sought from the literature that also included definitions and examples of the TCK boundary construct. Studies examining component constructs provided insights into conceptualisation of the constructs. Studies published

between 2006, when the first description of TPCK (Mishra & Koehler, 2006) appeared, and 2011, when the data was collected, were selected. Interpretations of the meaning of TCK and examples of how it was applied in practice are presented in Table 26. This process was important in building an understanding of how different researchers interpret TCK's applications in practice.

Definitions of the component constructs – technological knowledge and content knowledge – are presented so that readers understand how the researcher interpreted their meanings. A framework was developed as a set of sub-themes relating to the technological content knowledge (TCK) boundary construct. This was used as the analytical framework to analyse participants' experiences of ICT-integration.

Technological knowledge (TK)

Further engagement with the literature revealed the TK construct as the most varied amongst authors in terms of definitions; it was shaped by the types of technologies, the sort of knowledge addressed, and its rapid change (Voogt et al., 2013). Angeli and Valanides (2009) narrowed the definition of TK to that associated with ICT knowledge (ICT-TPCK). ICT knowledge was defined as knowledge and skills associated with hardware and software operation and knowledge of troubleshooting ICT-related problems. This is in contrast to the original definition, which included non-digital technologies such as books and chalkboards (Mishra & Koehler, 2006). Graham (2011) encourages researchers to confine TK to those technologies that are *emerging* because it enables transparent or commonplace technologies, which are not the focus of this analysis, to be contained within the PCK construct.

In this paper, the term "information and communications technology" (ICT) is used instead of the more generic "technology" because this is consistent with terminology adopted in Australian as well as New South Wales curriculum documents. These definitions are connected to student *learning*. In the context of students' ICT capabilities, it is noted that skills in this domain are "not fixed, but are responsive to ongoing technological developments" (ACARA, 2012b, p. 41); this would extend to teachers' ICT skills as well. Therefore, TK encompasses ICT skills in the use of both contemporary as well as emerging digital technologies that are used for accessing,

creating and communicating ideas, solving problems and working collaboratively (ACARA, 2012b). Furthermore, digital technologies are more specifically defined as "any technology controlled using digital logic, including computer hardware and software, digital media and media devices, digital toys and accessories and contemporary and emerging communication technologies" (ACARA, 2013, p. 100). This is a slight departure from the definition put forward by other scholars (for example, Graham, 2011), as *contemporary* as well as *emerging* digital technologies are of value for school ICT-integration studies.

Content knowledge (CK)

TPACK scholars adopt relatively consistent definitions of CK that align with Mishra and Koehler's conceptualisation, which was, in turn, based on Shulman's (1986b) original discussions of pedagogical content knowledge (PCK). CK is knowledge about the subject matter that is being taught. For example, a senior chemistry teacher's content knowledge would include the central facts, concepts, theories, knowledge and understanding of chemistry.

Senior secondary teachers require flexible and efficient access to highly structured conceptual understanding of their discipline (Gess-Newsome, 1999b; Mishra & Koehler, 2006; Shulman, 1987). This enables teachers to draw on a wide variety of content representations when linking teacher-held understanding to students' knowledge being constructed (Gess-Newsome, 1999b). The characteristics of teachers with good content knowledge include a strong repertoire of content representations and classroom instruction that moves beyond the textbook (Gess-Newsome, 1999b).

Technological content knowledge (TCK)

TCK is described as the relationship and interactions between technological (TK) and content knowledge (CK), independent of pedagogical knowledge. After initial coding of interview transcripts, TCK-encoded data seemed to more closely align to the TPACK construct than to the expected TCK. It was difficult to identify interactions that were exclusively TK-CK in teacher's descriptions of their practice. This blurring of constructs is at the heart of criticisms of the framework (Angeli & Valanides, 2009; Archambault & Barnett, 2010; Cox, 2008; Graham, 2011). TCK is the hardest

construct to identify examples of practice (Cox, 2008; Harris & Hofer, 2011; Hofer & Harris, 2012).

A conceptual analysis of the TPACK and its component constructs included a literature review and interviews with TPACK scholars and provides following "expansive" definition of TCK:

> a knowledge of appropriate technologies that may be utilized in a given discipline and how the use of those technologies transforms the content of that discipline through representation or the generation of new content or how the content of that discipline transforms or influences technology. The essential features of TCK are (a) the use of appropriate technology (b) in a particular content area (c) to investigate, represent, or transform that content *or* (a) the selection or transformation of technology (b) based on the imperatives of a particular content (Cox, 2008, p. 60)

Additionally Cox (2008) offers a precising definition of TCK to 'facilitate the classification of examples of teacher knowledge' focusing on three major knowledge areas of (a) how technology represents content, (b) how technology generates new content, and (c) how content transforms technology (p. 66).

As examples of teachers' practice were scrutinised, they were compared to both definitions in order to identify examples of TCK.

In a similar vein to Cox's (2008) technical use analysis, further exploration of CK and TCK's definitions and examples in practice were sought. Sub-themes relating to TCK and its manifestation were identified. They included representation of content knowledge, the reciprocal relationship between technological and content knowledge, manipulation and interaction with content knowledge, subject-specific ICTs, curation (selection and organisation) of content and subject-specific ICT skills. These sub-themes and their explanations are presented in Table 28.

Table 28: Sub-codes developed for thematic analysis relating to the TCK construct

TCK sub-code	Meaning	Examples of how it may look in practice	Literature referring to this type of use in the context of TCK
TCK-REP	Use of ICT to represent content for a specific topic or subject; create new representations of content.	Represent content in a discipline in a unique way. Observe things that would otherwise be difficult to observe (e.g. animations of protein synthesis).	(Archambault & Crippen, 2009; Bowers & Stephens, 2011; Burgoyne et al., 2010; Cox & Graham, 2009a; Cox et al., 2010a; Graham, Burgoyne, et al., 2009; Koehler & Mishra, 2008; Mishra & Koehler, 2006; Schmidt, Baran, Thompson, Mishra, et al., 2009).
TCK-AUTH	Use of ICTs, usually web-based, that enable teachers to author content, organise content or deliver subject-matter in an online environment.	First-hand accounts of current events via blogs. Implement district curriculum in an online environment. Use various courseware programs to deliver instruction (e.g., Blackboard, Central).	(Archambault & Crippen, 2009; Cox & Graham, 2009a)
TCK-CUR	Curation of content. Use of ICT to source, organise and sequence content.	Pre-selection of websites for students to use.	(Cox, Graham, Browne, & Richard, 2010b; Hofer & Swan, 2008)
TCK-REC	Reciprocal nature of ICT and content. ICT affects or changes content.	Simulations (e.g. in physics and mathematics).	(Koehler & Mishra, 2008; Mishra & Koehler, 2006)
TCK-MAN	ICTs used to manipulate, interact with or navigate subject matter. Navigating used here includes representations that slow down, speed up or identify trends or patterns in data. ICTs that change the way learners practice and understand content.	Physics or mathematics simulations. Using ICT to understand a concept. Speed up or slow down the representation of natural events. Create and manipulate models of scientific phenomena. Organise and see patterns in data that would otherwise be hard to see. Represent and manipulate phenomena using ICTs to mediate (mathematical) dialog – Geometers, Sketchpad and other DGSes	(Bowers & Stephens, 2011; Burgoyne et al., 2010; Cox & Graham, 2009a; Graham, Burgoyne, et al., 2009; Koehler & Mishra, 2008; Mishra & Koehler, 2006; Schmidt, Baran, Thompson, Mishra, et al., 2009)
TCK-ICT	Subject-specific ICTs.	Understanding specific technologies and their suitability for addressing subject-matter learning.	(Cox et al., 2010a; Koehler & Mishra, 2008; Mishra & Koehler, 2006)
TCK-ICTSKILLS	Subject-specific ICT skills (overlap with TCK-REP).	Instruction in the navigation of cumbersome search features in some of the digital archives for history.	(Hofer & Swan, 2008)

Following data collection from 28 participants, transcripts were created and organised into a database using QSR's NVivo qualitative data analysis software. A process of analysis was used to identify applications of teachers' knowledge. Thematic analysis was driven by this study's theoretical interest (Braun & Clarke, 2006) in the TPACK construct, and began by identifying broad themes relating to each of TPACK's seven constructs as described by Mishra and Koehler (2006). Examples of five participant teachers' practice were sought from the data that aligned with definitions of TK, CK, PK, TPK, TCK, PCK and TPACK. Elements of transcripts relating to TK, CK and TCK were re-analysed using the codes described in Table 28. The results are presented as vignettes that capture elements of the TCK construct enacted.

7.4   Results

The results are presented as five vignettes that introduce the context of the teacher and the subjects taught. Each description is then followed by an interpretation of the TCK evident in practice. Five senior secondary subject areas are represented: mathematics, chemistry, English, classical languages (Latin) and music.

7.4.1   Martin

Martin was an experienced Year 11 and 12 chemistry teacher. He had a PhD in chemistry and had begun his teaching career with undergraduates at university level. He is head of the science department at his school. Martin explained that he was a very confident technology user. He had exclusive access to a desktop computer at school and had purchased a laptop at his own expense that he used for personal as well as schoolwork. He was timetabled for all his classes in one teaching space (a science lab), which had an interactive whiteboard. He had loaded the interactive-whiteboard software onto each of the computers he used for his work. Martin made extensive use of visuals that were downloaded and organised into presentations for his senior classes.

Martin provided a good example of what this study calls *teachers as content curators*. The ideas captured by the concept of content curation, a buzzword (Bhargava, 2009) associated with organising content using Web 2.0 and social networking tools, very

much align with how participating teachers are organising content for their students in an online era.

The following vignette is an excerpt from the interview where Martin is talking about preparing work for his Year 12 Chemistry class. Specifically, they were completing a unit of work on acids and esters. Just like traditional curators, Martin sourced, selected, organised and displayed content for particular students:

> It's like a doodle – I tend to grab what I need to teach from that lesson, which comes from your program, then I go to the interactive whiteboard [software] and then search for images related [to that content]. I have a big bank of video files...and you look at the video file and say, "That small snippet there is useful." Then I cut that out and save it to a resource folder. I am constantly making resource folders for each interactive whiteboard activity. Then I throw everything on the page and start thinking about how I want to present it. I start thinking about being in class and how I am going to say this, and then I start working through logically what I am going to do in class. I then start using the transitions for the whiteboard and I pull the video in for different [content] or reveal certain phrases at appropriate times. It has many levels and the levels are all hidden – you click on one word and it releases another level. You can annotate it. Then you click it and it disappears again and you are back to where you were. Once I have done the whiteboard activity, then I go back to the word-processed document and work out what the kids need to know. And maybe I would write sentences with them to fill in blanks or [prepare] a writing activity [in which] they might summarise key words, and they put it together in their own text…. There are definitely three parts: gathering the resource for yourself, and then playing with the [interactive whiteboard software] to try to get it the way you want it, and then there is the…worksheet that accompanies it.

Shortly after, Martin explained how and why he edits video resources and the benefits associated with integrating video content with his interactive whiteboard:

> The interactive whiteboard is absolutely made for visual experiences. I have learnt that with [Microsoft] Movie Maker, I can take a five-minute excerpt out of a large [video] presentation and link that to any object on the board. So as you're discussing things, you can say, "Let's look at a small video on that," and bang, up comes the video on the board. You're not changing programs and moving out of things, it's all there, you can [hyper]link it to Internet sites; you can use animations…. You put an animation in and the student immediately gets it…and it's short; not an hour where they go to sleep – two minutes – to reinforce what you've been saying – it puts a whole new spin on teaching.

In this dialog, Martin's technological knowledge (TK) comes through in his descriptions of editing digital video, combining digital resources using the interactive whiteboard software, and using Internet search tools to locate resources. As Martin discusses his use of technology within his context of senior chemistry, subject domain of Chemistry Technological content knowledge (TCK) is being applied as he assesses what content areas are specified by the topics in the chemistry syllabus, his critical analysis of various online resources in relation to content he has to teach and the use of technologies to edit and recombine content into a meaningful sequence for instruction (TCK-REP, TCK-CUR). His judgements about the worth of online resources and their subsequent recombination into new, more streamlined resources for his students' meaning-making processes suggests a high level of conceptual understanding of chemistry in addition to his well-developed ICT skills (TK).

This example is indicative of the difficulty in distinguishing TCK from TPACK. This may be because the technology that Martin is using to represent content is an Interactive Whiteboard (IWB) – a combination of hardware and software whose pedagogical intent - classroom demonstration - is at the core if its design. Martin does not distinguish between his curation of chemistry content using ICTs and the presentation of that content to students. As others have suggested (McEwan & Bull, 1991; Segall, 2004a), his content knowledge is inherently pedagogical in nature. However, analytically, the worth of the TCK construct is that we can identify foundational knowledge structures that Martin requires in order to successfully implement his esters and acids ICT-integrated unit of work:

- Knowledge of the specific Year 12 curriculum content related to esters and acids (CK).
- Knowledge of online repositories of digital video and animations specific to Year 12 chemistry as well as how to access and download or embed (TCK).
- Knowledge of file management, organisation and storage of digital assets relating to areas of content to be taught (TCK).
- Editing and sequencing of video clips to create a precise and meaningful representation of chemistry content (TCK)
- Knowledge of how IWB software and hardware can combine representations of content from a variety of sources into new representations of chemistry

content through precise sequencing aimed at maximising student conceptual understanding (TCK).

Further investigations on how Martin uses these representations within a learning activity sequence would reveal the full picture of his TPACK application. For example, IWB representations created could be used as part of a whole-class discussion, to guide a practical demonstration or to present a lecture where students are creating notes.

7.4.2 Mario

Mario taught Year 11 and 12 music. He had a master's degree in music, had taught at the tertiary level early in his career and was the Head of Music in his school. The music department was well resourced with desktop computers, interactive whiteboards and MIDI instruments. He provided examples of music-specific ICTs that he used to prepare lessons, such as music-notation and editing software (Sibelius, Finale and Cubase) highly likely to involve TCK and reported that he was "quite proficient" with word-processing and spreadsheets. His students used their own laptops in class. In response to follow-up questions regarding subject-specific ICTs he referred to. Mario said:

> [The students] have to produce a notated score to submit to the [Board of Studies] in Music 2. They tend to know nothing about the Sibelius program and recording technology…. There is a lot of education that has to go in to create the kind of [Sibelius] skills you need by the end of the senior course. The girls use [Sibelius] when we have tasks to do with composition. They create something and they put it into the software and they get to hear it back. You can use it with harmony. The girls can create their own chords underneath a melody. So yes, Sibelius is definitely a student-focused tool.

Mario emphasised that students needed to develop competency with the Sibelius software in order to complete the senior music courses and that at his school they began teaching it from Year 7 (TCK-REC). Mario linked use of these ICTs to how they helped his students learn music (harmonies), explaining Sibelius's features such as immediate playback with "a full orchestral score [that] is immediately audible" (TCK-ICT).

Mario's example was selected to illustrate how subject content has changed as a result of technology and how developing subject-specific ICT skills (TCK-REC, TCK-ICTSKILLS) has become important for music students.

The content being taught in this dialogue is the act of composition. It is a skill to be learnt (content), and it is taught using music-specific ICTs (TCK-ICT). Additionally, the software afforded a means for students to engage with individual elements of a sequence of music (TCK-REP) – both a skill to be learned (content) and a way to gain understanding of individual elements that make up a sequence of music (TCK-REP). This illustrates an example of Mario's application of knowledge about specific technologies changing the way learners practise and understand concepts in Music. This is an interesting example because it highlights how the content of a discipline has changed as a result of ICTs, and how ICT skills are now an important part of the content that teachers have to teach (TCK-REC).

7.4.3   Samuel

Samuel is an experienced Year 11 and 12 mathematics teacher. At the time of data collection, he was teaching advanced Year 12 courses (Extension 1 and Extension 2 Mathematics). Samuel explained that having access to an interactive whiteboard for all his lessons was important in his TK development, and spoke about the close alignment between the content he was planning to teach and the technologies that were at his disposal in his teaching environment. He explained that he used a textbook less "when you are imagining what you are going to do for a lesson" because everything was easily accessible through the interactive whiteboard.

In conjunction with an interactive whiteboard, Samuel used dynamic geometry software (DGS) to represent mathematical concepts. In Year 12, Samuel was teaching content associated with volumes of a revolution and harmonic and projectile motion. He spoke about the discipline-specific software programs Mathematica and GeoGebra, and how these ICTs were able to create interactive, dynamic representations that let his students "see in three dimensions" and "make things move". In addition, Samuel used mathematics "applets" – small, web-based applications:

In Extension 1, I am just starting the applications of calculus, which is things like physical applications – simple harmonic motion and projectiles and heating and cooling and things like that. Again, that's all graphs. I've got a good little demonstration of simple harmonics connecting the circle – circular motion – with the simple harmonic, and the sine curve as well. That moves as well so you can see the motion. In Extension 1, the projectiles don't have any air resistance, but in Extension 2 [they do]. I've got [an applet where]…you can shoot a grand piano or a golf ball…. With Extension 1, they all follow the same path; it doesn't matter how heavy something is, but then you can add air resistance for Extension 2 and then different things will go different distances. I just Googled projectiles, I didn't even prepare that. It just came up. It was really good. We spent around half an hour playing with it. It just takes 30 seconds to see what is there.

Samuel explained that he used mathematics software such as GeoGebra to create graphics or interactive demonstrations to use during lessons with the interactive whiteboard. He explained that there was a time factor involved in learning these applications "before you get to the mathematics". Although Samuel valued these ICTs for mathematics teaching, he felt he was not yet ready to devote course time teaching his Year 12 students how to use the software.

There is a few hours there of a hurdle to get over before you get to the mathematics… Some of [the demonstrations] took ages to work out what [to] mov[e] where and make it look nice, which is fun for me but is not really a good use of time for [the students]. But then at the same time, using geometry packages is something they should learn how to do, particularly at this level. We have only had it put on the computers this term and I will get around to it. I need to plan out what I really want them to do. I haven't really got that clear yet.

Therefore, Samuel predominantly used the specialist mathematics software in combination with an interactive whiteboard to support direct instruction and whole-class discussions.

Samuel's TCK is evident in his discussion of specific technologies that enable the representation and manipulation of data relating to concepts of 3D volumes and simulations of projectile motion (TCK-ICT, TCK-REP, TCK-MAN). Samuel discussed the capabilities of technologies in relation to his students' learning: moving between linked mathematical representations; dragging to explore properties and using

ICTs to simplify complicated constructions and interactive online applets to mediate mathematical dialogues of projectile and harmonic motion. Samuel struggled with the idea that creating and manipulating these representations with ICTs are important skills (content) of his subject domain that his students should be taught (TCK-ICTSKILLS). The quandary for Samuel seems to be that he could not justify the class time needed to teach those skills.

7.4.4 Diane

Diane teaches Year 11 English Studies and Year 12 Standard English. Year 11 English Studies was developed to address the needs of students with specific needs (NSW Board of Studies, 2009) relating to a range of issues in their personal lives such as their living arrangements, attendance or family-related problems. While the subject contributes to a student's Higher School Certificate credential, it cannot be counted towards credentials used for university admission. Diane had recently had an interactive whiteboard installed in her classroom. Although Diane's Year 11 students were part of the New South Wales laptop initiative, she said during the interview that they could not be relied on to bring their laptops to school. She spoke with absolute passion and respect for her students and how they helped her set up her computer and interactive whiteboard at the start of the class. Diane has over 20 years' teaching experience across all the HSC English courses, suggesting good levels of English content knowledge (CK).

In contrast to Martin and Samuel, Diane's technological knowledge (TK) with respect to the interactive whiteboard was developing. She indicated that she was reluctant to use it at first, but conceded that she was becoming more familiar "with the different apps and different sites".

At the time of the study, Diane's students were studying a topic called *The Language of Sport*. She referred to online resources that she accessed through a learning management system (the Moodle LMS) developed by the NSW Department of Education and Training. Diane explained:

> This region has put a lot of time into perfecting units. The [LMS] site has lots of different lessons on each of these units. For example we have done [topics called] *The World of Work* and *The Language of Business*. We are [currently] doing *The Language of Sport*. You can virtually access the [interactive white] board and get into that site and into the different areas each time that you have the class…. For example, for *The Language of Sport* we watched a [video] which was called *Australian Rules*. Then I modelled a response and they did that. We accessed interviews with coaches. That's all part of this site. I must admit I was a little bit of a Luddite with the [interactive white] board. I think becoming more familiar with the [LMS] site and accessing the different lessons [has given me confidence]…. It has been a learning curve for me…. As I become more and more conversant with it, I am finding more sites because now I am looking for them. I am realising it is a great tool to inspire the students.

This example was selected because it demonstrates a lack of technological knowledge on Diane's part; however, Diane's experiences enabled us to make inferences about her path towards TPACK development. The LMS resources, created by other teachers, provided a TCK *model* that shaped the way Diane was integrating ICTs in her teaching. First, the types of digital resources selected showed Diane how New South Wales senior secondary prescribed syllabus content can be digitally represented for classroom instruction (TCK-REP). This built Diane's confidence to integrate these ICTs, as well as her interactive whiteboard, in her teaching. Second, the LMS modelled the way digital resources can be sequenced, and the ways in which English content can be represented to students (TCK-REP). Third, easy access to syllabus-aligned digital resources was increasing her confidence in using display technologies to access and present content (TK). In terms of the TCK elements, other teachers, at the regional level, are applying their TCK when they select, organise and create digital resources and provide access to schools via the LMS authoring tools. This would require applications of TK, CK, TCK-CUR, TCK-REP and TCK-AUTH.

7.4.5   Elise

Elise is a classical languages (Year 11 and Year 12 Latin) teacher. She has 22 years' experience as a secondary teacher. Her school has a 1:1 laptop program. Elise had well-developed TK associated with word-processing, but was less confident with other ICTs. Elise did present as a teacher who integrates ICT during the selection process; however, she believed student access to computers was not important for HSC Latin studies. Elise was asked about her students' bringing their laptop to class:

They don't in Latin. They don't need to [use computers] – there is translating…there are set texts so it is translating the set text, it's then doing a grammar analysis – I have grammar questions for them which I prepare and they answer in class or "prep" (study time), and then we do a stylistic analysis. I give them notes for the stylistic analysis and they write additional comments. I have the Latin up on the interactive whiteboard so that I can highlight it or manipulate it in various ways….

In a later part of the interview, Elise further explained her views about ICT-integration and teaching Latin:

Latin is such a set format [in Year 11 and 12], there is not much opportunity…[to use] interactive whiteboards...I don't think for seniors [Year 11 and 12]…. You wouldn't find many teachers of Latin using lots of [ICT] things. I do know one teacher, we were talking about unseens and she said her students just went on the Internet and found translations and handed them in. And I said, "My girls wouldn't think of doing that – what is the point?" I don't think Latin teachers would use computers that much…. I don't think they learn anything using it in Latin that they don't learn in other subjects. I think there is too much of it, to be honest. Every single subject now has ICT embedded in it. But you get to the stage…I see girls in prep [after-school study], they have to do a science project and they just cut and paste vast amounts of information which they don't understand. I can't see the point of it. It's no different from photocopying a book and sticking stuff together.

Elise used Internet resources "for general information", explaining that there was not much published on the web related to her Latin course. She explained that she preferred books – "It's still books, it's from books or my head". Elise used word-processors to create the books for her students. She explained that she sells the books to other schools. They closely align to the syllabus, with texts and their translations, grammar-analysis exercises and vocabulary. Elise went on to explain a method of showing students the structure of Latin using an interactive whiteboard and a word-processor:

Cicero, for example, can write a sentence that is six lines long…so it's got to be broken up into chunks. There are subordinate clauses, and different clauses of all sorts, so I can actually break it up to show them how it is made up of smaller pieces. They will look at a paragraph of Latin and just see words. So I do that just with the computer, the space bar, the interactive whiteboard and a Word document.

Elise exhibited high levels of content knowledge (CK) in her explanation of how students find the structure of the texts difficult. Additionally, she was considered an expert in the field by other Latin teachers who purchased her resources. Elise sourced and organised large amounts of content information when she created her textbooks (TCK-AUTH, TCK-CUR). She also represented content with a word-processor and used the interactive whiteboard, integrating those ICTs when she helped her students to deconstruct texts to examine individual elements (TCK-MAN).

Elise's comments about the need not to use computers for Latin studies and her reluctance to have students engage directly with online texts may represent either a lack of TCK or a lack of its application. Additionally, Elise's comments illustrate her strong beliefs about the nature of the knowledge of her discipline and how her students learn Latin content. She preferred to pre-organise or scaffold the content for her students in books she prepared herself. This suggests adequate TK with using word-processors and organising resources, as well as good knowledge of subject content (CK). However, there was little TK-CK interaction and little or no TCK enactment.

7.5 Discussion

This paper explored the nature of technological content knowledge (TCK) in practice and its implications for ICT-integration studies. A definition that describes TCK exclusively at the domain of technology-content interactions *independent* of pedagogy (Cox & Graham, 2009a) was difficult to identify in the first-level analysis, which coded interview transcripts based on the seven constructs of the TPACK framework. An analytical framework was developed that identified elements of TCK enactment. When examining teachers' dialogue using the framework that focused attention on very specific examples of enacted TCK, it was possible to identify the TCK construct. These enactments included:

- TCK-REP: Using ICT in representing subject content
- TCK-AUTH: Using ICT to author content and deliver subject matter in an online environment
- TCK-REC: ICT affecting or changing subject content – the reciprocal nature of ICT and content

- TCK-MAN: Using ICT to manipulate and interact with subject content
- TCK-CUR: Curating (selecting and organising) digital content
- TCK-ICT: Using subject-specific ICTs and
- TCK-ICTSKILLS: Providing instruction in subject-specific ICT skills.

While it was possible to identify individual elements of TCK, participating teachers did not think about or clearly articulate separate domains of knowledge. In examining interpretations of TCK (Table 28), and TPACK scholars' agreement on essential features of TCK (Cox, 2008), technology use in *representation* and *transformation* of content are recurring themes. Representation and transformation are also inherent in conceptualisations of the parent PCK construct and enacted through processes involved in pedagogical reasoning (Shulman, 1987). The PCK and TPACK models both represent *internal constructs* of knowledge, whereas the model of pedagogic reasoning offers a conceptualisation of teachers drawing on their knowledge as they make choices and actions for teaching (Shulman, 1987). This model views the teaching of a topic as a six-part action cycle - comprehension, transformation, instruction, evaluation, reflection and new comprehension (Shulman, 1987; Wilson et al., 1987). The transformation part of the cycle involves critical interpretation of subject matter, representation, adaptation and tailoring (Wilson et al., 1987). The examples described, suggest that when expert teachers are planning their content delivery, they are thinking about the *experiences* their students will have when they are in the classroom. In the context of senior secondary teaching, the pedagogic reasoning process is initiated by a mandated syllabus that outlines content to be taught. This is followed by teachers' comprehension of the subject matter and then the constructions of representations using a range of ICTs that are then be employed during a sequence of instruction.

TPACK scholars interpret representation and transformation as processes within the TCK construct and this represents a degree of overlap with definitions of PCK. Shulman positioned teachers as transformers of knowledge; the concept of representation was connected to the idea of transformation. Shulman (1987) offered this definition of representation:

> Representation involves thinking through the key ideas in the text or lesson and identifying the alternative ways of representing them to students. What

analogies, metaphors, examples, demonstrations, simulations, and the like can help to build a bridge between the teacher's comprehension and that desired for the students? Multiple forms of representation are desirable. We speak of the importance of a representational repertoire in this activity (p. 16).

This thinking through key ideas in the lesson was articulated by teacher-participants Martin and Samuel: their uses of technologies in sourcing, selecting, recombining and representing knowledge, involved pedagogical reasoning associated with using their representations in a learning sequence involving whole-class discussions and questioning. Cox and Graham (2009a) suggest that as emerging technologies become mainstream, the constructs slide – TCK slides back to CK and TPK slides back to PK as the emphasis on the technology is no longer needed. However, this overlap between TCK and PCK observed in this study suggests that as technologies become mainstream, TCK slides to PCK as representation and transformation are characteristics of the TCK construct.

This observation aligns with the transformative view of the TPACK model that sees the individual TPACK construct "as a unique body of knowledge that is constructed from the interaction of its individual contributing knowledge bases" (Angeli & Valanides, 2009, p. 154). This is an epistemological distinction that sees TPACK move beyond a knowledge base made up of constituent components that are assembled during instruction (the integrative model) and towards a distinct body of knowledge in its own right (Angeli & Valanides, 2009). Other PCK and TPACK scholars acknowledge both integrative and transformative conceptions of teachers' knowledge and place each of these as extremes of a continuum along which teachers' progress (Gess-Newsome, 1999a; Graham, 2011). In her discussion of pedagogical content knowledge (PCK), Gess-Newsome (1999a) writes, "New knowledge gained through preparation programs and teaching experience increases the organization and depth of both PCK and the foundational knowledge domains, though changes in one knowledge base will not necessarily result in changes in the others. PCK" (p. 13).

This idea of foundational knowledge is important. Effective technology integration is not a forgone result of increasing knowledge in constituent components; however, developing foundational knowledge is a precursor, and perhaps part of the journey

from novice to expert teacher. TPACK has three foundational knowledge domains CK, PK and TK. By considering constructs TCK and TPK as foundational constructs would focus attention on the types of precursor knowledge required to move teachers towards TPACK enactment that integrates the contributing foundational knowledge. Samuel and Martin's ICT-integration examples illustrate TPACK's enactment as an integration of knowledge domains. TPACK helps to deconstruct their complex thinking patterns associated with teaching specialist content knowledge so that the type of knowledge necessary for effective integration can be more fully understood.

TCK as a type of foundational knowledge for ICT-integration was identified in other examples in this study. Mario's example in the context of senior secondary music highlights foundational knowledge in the form of TCK that is important for ICT-integration in music. First, this example highlighted the importance of students' development of specialist ICT competencies for success in this subject area and that will be of benefit to them beyond school, particularly if they continue into tertiary studies or vocational pathways associated with music. In the music industry, music-notation software is commonly used in music composition and in senior secondary music courses; thus, music ICTs had become an important part of the content that teachers have to teach. This is supported by references in the NSW music syllabus. It should be noted, however, that the syllabus does not mandate notation software and only *encourages* ICT use:

> Teachers are encouraged to use a full range of technologies as available to them, in the classroom and in the wider school context. For example: a variety of computer hardware and software exists which can be used to teach a range of theoretical, aural and compositional skills (NSW Board of Studies, 2009b, p. 27).

Second, this example demonstrates a specific experience of technology in the content area of music and illustrates what TPACK scholars refer to as the reciprocal relationship between and ICT and the content of a subject domain (Koehler & Mishra, 2008). ICT has changed the act of music composition, and that has, in turn, changed the nature of subject content. Teaching music content in senior secondary education in Mario's school, and perhaps many others, includes skills related to digital music composition.

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Diane's case is important because it lends weight to the concept of a continuum of ICT-integration expertise. She is considered an expert teacher. She has strong foundational knowledge associated with her content area and pedagogical knowledge associated with the needs of her learners. The area of her knowledge in need of development is associated with technology. This example shows that development of technological knowledge is highly effective when it is aligned to teaching very specific subject knowledge – that is, when it is developed as TCK. In Diane's account, her reluctance to integrate ICTs was overcome as her awareness of the benefits associated with specific technologies for her personal teaching context increased. This included her growing confidence with interactive whiteboards, digital resources and learning management systems, and their effect on her Year 11 students learning English.

Elise's example also lends support to the importance of foundational knowledge in the development of TPACK required for effective technology integration. Her comments about there being no need for ICT integration for learning Latin may represent either a lack of TCK or a lack of its enactment. Her views on Latin teaching contradicts university teaching of classical languages, where ICT-integration has several benefits. For example, ICTs have the capacity to give meaning to Latin words through imagery and context (Clapp, 2013). Along those lines, the Perseus Digital Library (http://www.perseus.tufts.edu/), a resource for classics scholars, includes collections relating to literature, culture and geography associated with the relevant times in history. As well as providing access to rare or difficult-to-obtain texts, it includes digitised images of objects, places and geographic information. Mahoney (2001) explains a benefit of organising content in this way:

> Students who have not yet read a great deal of Latin or Greek can use these bidirectional links to begin to build a mental picture of classical literature. The connections created by citations in reference works, commentaries, and other texts model the way sophisticated readers experience a classical text (p. 272).

The Perseus Digital Library is a subject-specific ICT (TCK-ICT) that enables new representations for specific topic content (TCK-REP). Additionally, it changes the way learners practise and understand concepts in a specific content area, and affords

flexibility in navigation of different representations. Developing TCK knowledge associated with ICTs such as the Perseus Digital Library would be of benefit to teachers of classical languages and provide foundational knowledge for effective ICT-integration.

This study offers an example of the constructs' analytic use in exploring content-technology interactions and manifestations of teacher's knowledge in practice. Graham (2011) encourages researchers to establish the value of each construct. TCK has worth as a construct in the TPACK model because it offers important analytical insight. The value of the TCK construct to ICT-integration studies is that it highlights the importance of discipline-specific knowledge for teaching practice. Content knowledge is a foundational knowledge that underpins the selection, organisation, evaluation and creation of teaching resources that become the basis for a teaching sequence or unit of work. Without well-developed conceptual, discipline-based content knowledge, reorganisation and representation of subject knowledge for teaching will be limited. Technological knowledge has now become inseparable from this reorganisation process, beginning with content outlined in digital syllabus materials, applications of well-developed internet search skills and skills in multiple ICTs that facilitate recombining knowledge to create multiple representations for students. Therefore TCK is also foundational knowledge, and effective TPACK enactment will depend on teachers' TCK.

Additionally, the TCK construct adds value to the TPACK framework because it enables a deconstruction of enacted knowledge that identifies skills that are important for effective ICT-integration. In developing higher levels of TCK, teacher professional development is recommended in the following areas:

- Expert knowledge of the subject-matter to be taught.
- Translation of mandated curricular goals into knowledge representations for learners (TCK-REP).
- Clarification of the intended learning in a sequence (rather than a focus on the type of teaching or technology).

- Topic-specific representations of content, such as the types of visualisations employed in chemistry and mathematics (TCK-REP).

- Knowledge of the ways topic-specific content can be manipulated (TCK-MAN). *Deconstruction* of content was an important instructional strategy evident in examples reported in this study (for example, identification of musical or Latin-language elements).

- With increasing amounts of ready-made digital content available, the development of strategies for teachers in locating and evaluating learner-appropriate resources that align with topic-specific content (TCK-CUR). Additionally, knowledge of intellectual-property laws associated with repurposing digital assets sourced online is important.

- Skills that enable teachers to customise resources created by others to the needs of their learners, including recombining digital resources into new and varied representations (TCK-AUTH; TCK-REP). This highlights skills such as video editing and expertise in the use of interactive whiteboard software as important.

- Skills in sequencing and representing topic-specific content with tools typical of learning management systems (TCK-AUTH; TCK-REP).

This list specifically uses the term "topic-specific content representations" (Cox & Graham, 2009a). This is because in the context of Year 11 and 12, it is highly likely that different technologies will be important for different topic areas within a particular subject domain.

Part of the theoretical definition less obvious in practice was the notion of the reciprocal nature of technological knowledge and content knowledge. TCK, by definition, includes the idea of a reciprocal relationship between the two. While the content affects what technologies may be most appropriate for representation, subject matter, in turn, can be changed by the application of technology. This is apparent where subject-specific ICTs used in mathematics are providing ways to model and navigate data. This allows more varied representations of mathematical phenomena as well as mediating mathematical dialog (Bowers & Stephens, 2011). Music provided another example where discipline-specific ICT tools, such as music-notation software,

that are part of practising musicians' work are now incorporated across the process of learning music. As the use of ICTs becomes important for the learning of content knowledge, the ICT skill then becomes a component of the content knowledge of that discipline that teachers need, and should teach their students. The following skills can be added to the list as important in TCK for effective ICT-integration:

- The use of topic-specific ICTs and applications within the discipline (TCK-ICT).
- An expansion of teacher content knowledge (CK) to teach students ICT skills and knowledge that are important in the practice of a discipline beyond school (TCK-ICTSKILLS).

The findings of this study also suggest that the curriculum affects content knowledge that teachers deem important to include in their representations. While the music syllabus explicitly referred to technologies and their applications in teaching music, the Latin syllabus had no explicit references to technology. Knowledge and skill in ICT tools in common use by classical-language scholars was not seen as important for senior secondary students learning Latin. Similarly, in mathematics, Samuel valued the representations afforded by specialist mathematics ICTs, but did not consider ICT skills associated with their use as important knowledge to develop in his learners. The implications here are that school curricula must be flexible so that contemporary and emerging technologies used within specialist disciplines can be included in the prescribed content that specialist subject teachers are required to teach.

7.6   Limitations

Isolating one construct means that comparisons cannot be drawn between constructs such as TPK and TCK; further research is needed in this area. A small number of subject areas at one particular level of schooling (senior secondary) were considered, and therefore conclusions about TCK were within this context. Interview data is self-reporting, and teaching practice was not directly observed; however, this data-collection process aligned with the underlying methodology and the overall goal of learning more about the phenomenon of ICT-integration. The difficulty of aligning practice to boundary constructs relies on researcher's interpretations of their meanings.

This limits the potential to properly quantify and assess teachers' knowledge if there are varying interpretations of their definitions and enactment. We have attempted to be as transparent as possible in our characterisation of enacted TCK and in our categorisation of examples. We hope the details in our descriptions may be of use to scholars undertaking similar studies and allow readers to draw their own conclusions.

7.7 Further research

TPACK is a relatively new theory that is unifying research in areas of ICT-integration. This study offers a contribution towards further clarification of TPACK as a theoretical model, particularly in the area of technological content knowledge and its enactment in school education. Further research would contribute to conceptualisations of technology-content knowledge interactions. Conceptualisations would benefit from further knowledge about how different representations assist learners in making meaning from subject-specific content. For example, studies involving observations with secondary teachers who work with students having difficulties grasping a concept or solving a process may reveal what practices and representations are drawn on to improve that understanding. Furthermore, the NSW Higher School Certificate provides an opportunity to study TPACK with teachers using the same curricular materials: state-mandated syllabus documents that detail the content of each course. This would enable studies that examine how different teachers within the same subject discipline create different materials for teaching the same content with different learners, enabling a focus on the strengths and weaknesses of various representations in supporting students' learning.

7.8 Conclusion

TPACK offers a framework that brings together a knowledge base of research in the area of ICT-integration. In a contribution towards TPACK's theoretical development, an analytical framework based on TCK enactment in practice was developed. This enabled an exploration of ICT-integration through a consideration of teachers' knowledge in practice. Teachers represent and manipulate content knowledge with ICTs when they reorganise subject matter to make it more accessible to students. Content curation (the selection, recombination and sequencing of digital resources)

requires teachers to have a repertoire of ICT skills that are important for lesson preparation and implementation. Knowledge of subject-specific ICTs and their use is important for senior secondary teachers' practice, as is their impact on the changing nature of discipline-specific content knowledge and subject matter that students need to learn.

This study supports the existence of a specialist knowledge base for teachers that describes interactions between technological knowledge and content knowledge – TCK. The analytic act of considering this particular construct in in-service teachers provided insights into how teachers practise their craft and the types of skills and knowledge that are important. Teachers call on an ensemble of knowledge domains and beliefs within widely varying contexts. Empirical investigations into aspects of teaching using the TPACK model provide a meaningful vocabulary to describe knowledge and its enactment, thereby contributing knowledge on what good teachers need to know in order to teach.

CHAPTER 8: CONCLUSION

8.1   Introduction

This chapter summarises conclusions that emerge from the findings of the study. It includes responses to the three questions that guided the research, which focus on an ICT education policy analysis, ICT-integration in senior secondary education and teacher knowledge. Responses to the questions are a consolidation of the key findings of the study. An overview of how each question was investigated is presented, followed by a synopsis of the results, their implications and contributions to knowledge on education policy and ICT-integration. Finally, recommendations are made for policy-makers and teachers, and areas for further research are proposed.

8.2   Summary of the study

The purpose of this research was to investigate teachers' integration of ICT to support teaching and learning within a context of increased access to information and communications technologies (ICTs) and heightened expectations for ICT use in schools. The study focused on ICT-integration in senior secondary education during a period of rapid change associated with Australia's Digital Education Revolution (DER). The research was undertaken as a two-phase qualitative study. The first phase analysed Government policy associated with the DER, and the second phase investigated the range and types of ICTs used in in senior secondary education and how they supported teaching and learning.

Governments are key drivers of system-level educational change (Fullan, 2007). In the current study, the Australian Government promulgated an ambitious policy suite, Australia's DER, that directly affected teachers' practice through providing one-to-one access to computers for students in Years 9 to 12 (DEEWR, 2009b). The aim for the first part of the study was to gain an understanding of the context in which senior secondary teachers were working at the time. The analysis was framed using Fullan's (2007) characteristics of intended changes relating to ICT in school education so that implications for teachers and their practice could be better understood. It was significant because Australia's DER provided an example of a tri-level approach to school improvement, with the involvement of schools, jurisdictions and the national government.

This period of rapid change was the background against which an investigation of ICT-integration was undertaken in the second part of the study. An aim for the study was to examine how ICT was being integrated to support teaching and learning in senior secondary education – a specific stage of schooling targeted by DER policy. Senior secondary education, the final two years of schooling, is a particular context that has its own set of characteristics and pedagogical requirements. Teachers work within specialised subject domains defined by prescribed course outcomes, syllabus content and assessment programs and high-stakes exit examinations. Contributing to the contextual backdrop was the DER enactment period, which meant that most teachers were working with students who had access to their own device.

Specialist subject teachers draw on knowledge systems associated with the content they teach, pedagogical knowledge and knowledge of technology when they design learning activities that integrate technology. This study explored the knowledge of in-service Year 11 and 12 teachers through the use of an emerging theoretical construct that connects ICT use with knowledge required for good teaching. This knowledge base, unique to teachers, is called technological pedagogical and content knowledge (TPACK) (Koehler & Mishra, 2009; Mishra & Koehler, 2006). A phenomenological approach enabled an understanding of ICT-integration to be grounded in the experiences of practising teachers. This approach shaped the method of data collection, protocols guiding data collected, data analysis and subsequent meaning-making of the phenomenon of ICT-integration. The study relied on qualitative data (interviews) from 28 teachers who were using ICTs to support pedagogies in senior subject areas.

The findings of the study are synthesised under three research questions. The research project was investigated in two phases. The first phase involved the research focusing on education policy relating to ICT-integration; results for the first phase are presented as a response to Research Question 1. Several implications for senior teachers were identified and the project was extended to include an investigation of ICT-integration in senior secondary education; these results are discussed under Research Question 2. Research Question 3 presents a contribution to an understanding of theory associated with teacher knowledge and how knowledge is put into practice.

Research Question 1: *What were the key characteristics of intended changes advocated in education policy relating to information and communication technologies (ICTs) in school education?*

This component of the research contributed knowledge about external change forces that affect teachers and their practice. The DER represented a system-wide reform initiative that funded the introduction of ICTs directly into the classrooms of Year 9 to 12 teachers. It was the Year 11 and 12 teachers of this group from whom participants were drawn for this study.

The policy analysis contributes to understanding the context within which teachers were working. According to Fullan (2007), four *factors* affect implementation, and therefore the extent to which teachers and students change their practice – "the more factors supporting implementation, the more change in practice will be accomplished" (p. 86). Factors relating to the characteristics of change – need, clarity, complexity and quality/practicality (Fullan, 2007) – provided a useful analytical framework for developing an understanding of the intended changes as a result of DER implementation.

The *need* for change was framed as two over-arching themes. One need was firmly rooted in wider economic policy concerning the "productive capacity of the economy" (COAG, 2007, p. 1). The second (related) theme concerned the need for technology-enhanced learning environments to support high-quality learning outcomes so that students could productively contribute to society and the economy (DEEWR, 2009b). DER implementation needed "21st century programs and educators capable of using 21st century resources and strategies for learning" (DEEWR, 2010, p. 1). To this end, the Australian National Government funded the introduction of ICTs, mostly as laptop computers, into upper secondary classrooms across the nation.

Clarity about goals and means of achieving those goals relates to what teachers and students were expected to do. The need for 21st-century learning was met, in part, by providing more ICTs in learning environments. It was clear that teachers were to use computers to support and enhance learning. While most policy discourse articulated

relatively *high-level* goals around teaching and learning, the *Making Change Happen* document (MCEETYA, 2008a), an ICT planning framework intended to guide schools in their DER planning, provided detailed examples of how teachers and students would be using ICTs. This offered a degree of clarity about what a DER classroom may have been like in practice. However, the vision required specialised and highly developed pedagogical and technological knowledge, and knowledge of the ways ICTs affect student learning. Research shows that changes to beliefs and practice associated with integrating ICTs is evolutionary, complex, nuanced and gradual (Chen, 2008; Dwyer, Ringstaff, & Sandholtz, 1991; Orlando, 2014; Prestridge, 2008; Shin et al., 2009). What was not clear was how teacher capacity was to be developed.

While the DER rapidly transformed physical environments with deployment of mobile ICTs for Years 9 to 12, meaningful and sustained in-service professional learning would have required a great deal of time if the implementation was to align to the vision portrayed in policy. Policy fell short on details about how schools were going to provision release time for teachers involved with the DER in order to acquire the skills and develop the changes to learning programs needed to achieve the Government's vision for meaningful changes to student outcomes.

Complexity was inherent in the scope of the system-wide DER reform – requiring what Fullan (2007) might see as "a sophisticated array of activities" (p. 91) in preparing school infrastructure, providing laptops and building teacher capacity. Capacity-building for DER implementation was possibly the most complex component, more so than the logistics involved in providing infrastructure. This is because teachers' knowledge and belief systems were challenged and there were implications for school organisational structures as well as curriculum and assessment.

Studies in system-wide reform highlight issues of complexity associated with "sustained and meaningful change" (DEEWR, 2009b, p. 1) to teachers' practice. For example, a scientific-literacy reform agenda in the US targeted the way science was taught (Mitchener & Anderson, 1989). The case study found that there were teachers who struggled with their changing roles (Mitchener & Anderson, 1989). The new curriculum challenged their view of what constituted knowledge in their discipline,

with some teachers considering the new content to be more in the realm of social science than science. Furthermore, teachers perceived the innovation as a departure from content and pedagogies associated with their subject domain because they felt students would be disadvantaged when exposed to traditional testing regimes characteristic of higher-level science courses.

The DER too, was formulated on the assumption of a departure from traditional content and pedagogies associated with prescribed specialist subject domains within the curriculum (see Table 19: A vision for ICT enabled classrooms). In practice, in-service teachers would have required release from face-to-face teaching to undertake the sustained professional learning required to develop advanced ICT-supported teaching practice. Studies undertaken in ICT-integration point to beliefs as a factor affecting teachers' implementation (Ertmer, 2005; Prestridge, 2008). In reviewing literature associated with technology integration, Ertmer (2005) suggests that as well as ICT skills, teachers need engagement in "explicit belief exploration [and] opportunities to examine new practices supported by different beliefs" (p. 33) . Time for professional learning, as well as its quality, therefore, will be will be important for teachers in implementing the high-level ICT uses expected in the DER objectives.

Complexity was further intensified by concurrent performance-focused education-reform agendas competing for teachers' time (Gannon, 2012; Lingard, 2010). The DER coincided with Australia's school-accountability trajectory that came in two guises: National Professional Standards for Teachers and the introduction of the My School website. Professional Standards, Gannon (2012) argues, contributed to the bureaucratisation of teachers' work in its need for greater documentation, ongoing performance reviews and accreditation. My School introduced literacy and numeracy testing that has become high-stakes as the results are reported online in a way that enables comparison of schools' academic performance (Lingard, 2010).

Additionally, along with these pressures of higher accountability, the National Curriculum Board was working towards implementation of Australia's national curriculum, which would change what was to be taught and introduce new

achievement standards and consistent nomenclature associated with reporting achievement (National Curriculum Board, 2009; NCB, 2008) .

The implications for some teachers, particularly for Australian teachers of Year 9 and above, were that they were contending with increased accountability pressures, meeting teacher accreditation requirements and preparing for the national curriculum at the same time as integrating ICT in their subject areas. For teachers, this policy field was another layer on top of the contextual challenges associated with meeting the needs of the diverse group of learners in their charge (Comber & Nixon, 2009). According to Bore and Wright (2009), this is representative of the "wicked problem" typical of contemporary teaching. As well as knowledge and skills associated with content knowledge and pedagogical practice, teachers need capabilities in areas that include complex problem-solving and decision-making in unpredictable situations, self-direction and originality, the ability to act autonomously and the capacity for continuous learning (Bore & Wright, 2009).

Quality and practical reform depends on interactions between need, clarity and complexity (Fullan, 2007), as well as an innovation's worth and the degree to which proposed changes can be put into practice. It also depends on the stakeholder's point of view of the implementation. If quality is judged in terms of access to technology, then experiences reported by teachers in this study suggest that the DER had a levelling effect, with similar levels of access to similar technologies for a cohort of students throughout Australia.

ICT access is a prerequisite for ICT-enhanced learning outcomes, but increased access does not ensure high-quality use. For teachers and school leaders, their idea of quality may be grounded in tangible ICT uses such as those connected with achievement of *required* learning outcomes, supporting authentic, independent, individualistic and collaborative learning approaches in addition to increased access to ICTs.

Quality and practicality are negatively affected by insufficient time devoted to politically driven initiatives (Fullan, 2007). While a policy period spanning 2008 to 2013 may have facilitated structural changes to school environments, it is unlikely that

the same would have been true for the changes required to teachers' knowledge, beliefs and practice. A recent longitudinal study supports this view, finding that change in practice was evident only after teachers had sufficient lead-in time (from the fourth year) to develop knowledge of their own digital literacies, practice and class organisational structures that best supported student learning (Orlando, 2014).

In summary, the policy-analysis phase of the research sought to elucidate the characteristics associated with the implementation of Australia's Digital Education Revolution to develop knowledge of the implications for teachers of a nationwide education-reform agenda.

Fullan (2007) asserts that "the more factors supporting implementation, the more change in practice will be accomplished" (p. 86). Implementation of the DER might be loosely defined as teachers integrating ICTs when working towards high-quality learning outcomes. Teachers, however, are unlikely to change their practice with educational technologies unless needs are grounded in benefits for their students and in the usefulness of the technology for teaching and learning (Mac Callum et al., 2014; William et al., 2004). Therefore, factors associated with *need for change* framed in terms of usefulness to teaching and learning processes and the needs of students are more likely to gain teachers' support than needs related to broader economic objectives. Factors associated with *clarity of the change process* were met in part through providing ICTs to schools. While technology itself provided the foundation for DER implementation, there was less clarity over how the highly specialised pedagogical and technological knowledge would be developed; this may have hindered implementation associated with effective ICT-integration. Factors affecting implementation associated with *complexity of the change process* were the mismatch between the timing of the Year 9-12 laptop deployments and the fact that funding for teacher training did not precede deployment and was not directly accessible by schools. Additionally, concurrent reform agendas would have competed for teachers' time, and this, too, would have been a non-supportive factor in DER implementation. Finally, factors associated with *quality and practicality* hindering the change process may include the lack of time available for teachers to develop knowledge and belief

systems in addition to digital literacies required for a project aimed at sustained and meaningful changes to learning.

Research Question 2: *How do NSW senior secondary teachers integrate ICTS to support teaching and learning?*

This study contributed knowledge on ICT-integration within a context dominated by prescribed syllabi and high-stakes assessment. The discussion focuses on the main areas of ICT use by senior secondary teachers to support teaching and learning in the context of content-laden senior secondary courses.

The findings in this part of the study relate to ICT access, the use of visualisation and display technologies, the ways teachers create and use resources to support teaching and learning, the changing nature of senior secondary content and reluctance to use ICTs to support school-based summative assessment practice.

The lack of use of ICT in supporting high-stakes summative assessment suggested that teachers continued to favour traditional pen-and-paper style tasks; the implications of this are discussed.

Participants consistently reported good levels of access to ICTs. This was shown by
- The access teachers themselves had to a computer – most often reported as a laptop computer allocated by their schools.
- Connectivity – computers were networked and teachers routinely reported good access to internet and intranet services.
- The access to projection technologies (data projectors and interactive whiteboards), which was routinely reported by teachers.
- Teachers who reported their Year 11 students having access to their own laptop computers.

An exception to this was Year 12 teachers. In 2011, the Year 11 students at the time were the part of the first cohort with one-to-one access to laptop computers under the DER implementation. Teachers in these schools tended to focus their discussion on

their Year 11 classes, and saw lack of access to be an impediment to using ICTs with the Year 12 classes.

This aligns with research that found that computer availably and access to ICT resources positively affects ICT use (Inan & Lowther, 2009; Jones, 2004; Kitchen, 2007). Jones (2004) highlights that the issue of access is complex. As well as a lack of quantity of reliable computers, access issues can also relate to a lack of appropriate software, scheduling constraints limiting access to laboratory-based computers or hardware that is obsolete. Teachers in this study generally reported using technology less with their Year 12 students, who did not have the same level of access as their Year 11 students who were part of the DER rollout. Additionally, the universal access in Year 11 to Internet-capable (networked) laptop computers facilitated routine and spontaneous ICT uses. This suggests that barriers associated with a lack of access to ICTs were reduced.

As expected, the types of ICTs used by senior secondary teachers in this study aligned with the predominant types of pedagogies they employed and the content that they taught. The most common pedagogic practices discussed by participants were those aimed at meaning-making. They routinely involved teacher-led, whole-class discussions supported with engaging and sometimes interactive visualisations using display technologies. In this study, these pedagogical practices, often reported as whole-class discussion and teacher-led questioning, were dominant in the reported experiences of participants. These examples are consistent with previous research into pedagogies of successful senior secondary teachers that highlights key characteristics typical of this level of schooling (Ayres, Dinham, & Sawyer, 1999; Ayres et al., 2001, 2004). One characteristic was that classroom interaction and in-class, face-to-face time were "a central learning element" of senior secondary education environments (Ayres et al., 1999, p. 8). This was further deconstructed into pedagogies such as whole-class questioning, specific-student questioning, probing questions and patterns of question/answer/explain (Ayres et al., 2004). The point of differentiation in this study was that these types of pedagogies were supported and *enriched* by a range of visualisation technologies such as data projectors, interactive whiteboards and digital media including images, video excerpts and animations. Teachers spoke of routinely

incorporating digital resources into learning sequences and using them to mediate discussions aimed at building understanding. This was facilitated by the display technologies in participants' classrooms providing easy access to digital content and the tools to manipulate that content.

The teacher-centric pedagogies described by participants in this study could be interpreted as teachers using new technologies in ways that are consistent with preferred teaching methods (Cuban et al., 2001; Hayes, Schuck, Segal, Dwyer, & McEwen, 2001). An alternative interpretation is that this pedagogical practice is effective in the context of content-laden specialist subjects and working with adolescent students (16 to 18 years of age) – contextual factors characteristic of senior secondary education. Previous studies support this view. For example, a longitudinal study of graphics calculators and projection panels provides an example of how ICTs enrich this type of pedagogy (Goos et al., 2000, 2003). The sociocultural perspective that had been adopted highlighted teacher-student and student-student interactions *mediated* by ICTs in Year 11 and 12 classes. The researchers observed:

> instances of knowledge production and repair where partial solutions were shared and completed with whole class input; in other cases, previously unnoticed errors in the student presenter's work were identified and corrected by peers (Goos et al., 2000, p. 310).

The study by Goos and her colleagues supports the argument that teacher-directed discussion and questioning combined with whole-class input can be highly effective in students' knowledge-construction processes. Likewise, descriptions of practice in the context of language learning (Xu & Moloney, 2011) and earth science (Chang, 2004) illustrate the usefulness of multimedia technologies with visual display devices in supporting interactive, whole-class teaching at the senior secondary level of schooling. Together these studies suggest that ICTs affording visual displays together with carefully crafted learning activities that are visually stimulating, active and highly collaborative are effective for senior secondary students' meaning-making.

Researchers have continued this line of inquiry that looks closely at how meaning-making processes are supported by ICTs that make interpretations visible, observable and transparent (e.g. Furberg, Kluge, & Ludvigsen, 2013; Jornet & Roth, 2015;

Karlsson, 2010). These studies necessarily focus on the interactions with the ICTs and their capabilities; however, increasingly, there is growing evidence of the critical role of the teacher in providing explanations and directions when using multiple representations of course content (Chang, 2003; Furberg et al., 2013; Karlsson, 2010). For example, in a Taiwanese tenth-grade earth sciences classroom, teacher-directed computer-aided instruction (CAI) involving visual display technologies and whole-class interactive discussions was more effective at supporting learning than student-controlled, self-paced activities using the same software on individual computers (Chang, 2003, 2004). In studies of shared meaning-making in senior science using visual representations such as diagrams and animations, teachers' explicit instruction was important in concept construction and avoiding misinterpretation of scientific phenomena (Furberg et al., 2013; Karlsson, 2010). This suggests that *transformation* of subject matter knowledge, at the heart of TPACK and PCK frameworks, is an ongoing process throughout a learning sequence as teachers adjust explanations that support students' interpretations of digital representations of course content.

The second area of prominent ICT use identified in this study was around resources and planning, with teachers providing examples of teacher-developed resources. For example, a Latin teacher described developing her own textbooks; several teachers *curated* content and made it available online through learning management systems; and examples of teachers creating websites and sequencing resources via IWB software have been reported. This pedagogical practice was observed in a previous senior secondary study that described a predominance of teacher-developed resources to supplement textbooks (Ayres et al., 1999). As well, ICTs were used to support communication between teachers and students, including discussion forums, blog posts, video conferencing and online collaborative spaces. These types of routine ICT uses are affecting the teacher knowledge structures that come into play when planning learning sequences, as well as student knowledge structures as they navigate the diversity of modern learning environments. These findings resonate with research around visualisation, display technologies and use of digital resources. Examples in the literature include animations helping biology students to transform digital modalities into their own representations (Karlsson, 2010; van Rooy, 2012), the use of interactive whiteboards enabling the seamless integration of digital resources from a

number of sources in Chinese-language teaching (Xu & Moloney, 2011) and "on-the-fly" access and incorporation of internet-based resources such as Google Maps to support English-language learning (Flanagan & Shoffner, 2013).

These examples of representations demonstrate the "multiplicity of modes" (Kress, 2000, p. 402) employed in Year 11 and 12 classrooms. Thinking about student learning is really thinking about how students make meaning about a concept. Kress (2010) suggests that this happens through modes of representation during interactions in our social environments. In addition to the more traditional face-to-face classroom interactions, this study suggests that Year 11 and 12 students are routinely accessing representations such as learning management systems, teacher-created websites and other online resources that have been disconnected from teacher actions such as speech, emphasis, gesture and board-work. Moreover, the examples of ICT use described such as teacher-authored booklets, websites and a plethora of digital resources suggest that written modes of communication are no longer dominated by professionally designed, printed textbooks. (Kress & Selander, 2012).

ICT uses associated with teachers accessing and creating digital resources could be easily dismissed as simple substitution-type uses. However, representations for making meaning are changing as emergent uses of technologies become normalised in the classroom (Kress, 2010). Different modes offer a range of capabilities for shaping meaning; the increasing range of representations employed in senior secondary education has implications, as well, for what teachers and their students need to know. The design of curriculum materials presents choices related to layout, typeface, colour, use of still and moving images and the use of audio. These choices have different potentials for meaning making (Jewitt, 2005). For example, in an examination of students' misinterpretation of science phenomena represented as on-screen multimedia, (Jewitt, 2005) noted that:

> The students do not ''take up'' the written information offered to them by the writing on the scientific ''frame'' of the CD ROM. Instead, they rely solely on image and colour to ''read'' the transformation [of solid to liquid]...This difficulty appeared to be a consequence of a difference in the principles that students and the application designers used in relation to the use of the modal resources of colour, texture, and shape (p. 328)

In addition, the unfixed and dynamic nature of electronic texts means that readers often construct *customised* views of information (OCED, 2009). This shift from the linear to non-linear, static to interactive media as the dominant form of content representation means that teachers must be purposeful when designing learning sequences in a way that prioritises their learners' meaning-making.

A third area of ICT use in senior secondary education concerned the changing nature of the Year 11 and 12 course content and the notion that "technology and content are reciprocally related" (Mishra & Koehler, 2006, p. 1028) . In this study, this was most prominent in the creative arts; this is not surprising given the way that digital technologies have pervaded art- and music-making. For these teachers, their knowledge included skills associated with art-making technologies, such as digital image and video editing applications, as well as music-notation software. In turn, these skills were explicitly taught to students. In some cases teachers also directed students towards online tutorials when the art-making technique was beyond teachers' repertoire of skills.

While teachers in this study offered many examples of students using generic technologies to create digital artefacts such as reports, essays, presentations, blogs, wikis, podcasts, videos, digital artwork and digital music, the teaching of subject-specific ICT skills in other subject areas was not common. In an account of the use of dynamic geometry software, a mathematics teacher felt it was not time-effective to teach advanced mathematics software applications to his students because of time constraints associated with mandated content. This illustrates the conundrum for some teachers, where their prescribed syllabus content delegitimises the use of ICT by not updating content to include new and emerging ICTs that are advancing a field of study.

These specific examples provided by participants illustrate the changing nature of knowledge associated with specialist subjects in the senior years. What counts as knowledge in a discipline and the way it is taught are in a state of flux. ICTs challenge the very notion of what is important to teach – what part of the domain constitutes the knowledge taught in a school curriculum. This question has been explored by in the context of the UK science curriculum (Osborne & Hennessy, 2003). As with much of

the ICT-integration discourse, the UK review discussed *potentials* of ICT in supporting teaching and learning. In one example, the authors assert that ICTs have the potential to "dissolve" boundaries between science as a discipline and the school science curriculum because of the range of real and authentic online data easily available to schools, including:

> … real-time air pollution measurements, epidemiological statistics, or providing direct links to high quality astronomical telescopes, and providing ready access to a wealth of information about science-in-the-making (Osborne & Hennessy, 2003, p. 19).

The implied ICT-associated skills are accessing, manipulating, representing and interpreting scientific sources of data. These are not generic ICT skills, but science-specific data-processing skills. Subject-specific ICT skillsets must be present in a science continuum of learning if the potential for ICTs integrated into a curriculum is to be realised. This, in turn, implies that instructional methods associated with teaching computer hardware and software knowledge – knowledge traditionally confined to the domain of computing-science-related subjects – is deemed relevant by subject-specific teachers. As learning outcomes related to ICTs are not prescribed in HSC syllabi and cannot be assessed in written examinations, teachers seem reluctant to devote time to their explicit instruction. This, in turn, limits the potential for ICTs' use in higher-level problem-solving scenarios common to senior subject curricula.

The final major finding concerns summative school-based assessment. Data collected in this study suggests that the high-stakes assessments characteristic of senior secondary education hindered the adoption of ICTs for supporting and enriching school-based summative assessment. As expected, assessment strategies reported by teachers in this study varied across subject domains, as did the types of ICTs and the extent to which they were used. However, traditional, pen-and-paper examination-style assessments and those that included exam-style questions with a hand-written component were favoured by participant teachers, and in some cases were used exclusively through the assessment program. In addition, the range of ICTs and the repertoire of task types used to collect evidence of student achievement were relatively narrow, with research and writing tasks predominating.

The effect of external examinations was seen in responses regarding time limitations that prevented the teaching of new ICT skills to Year 11 and 12 students. Furthermore, teachers' beliefs that ICT skills were not needed for external exams, and could even be detrimental because of the need for hand-writing in the final papers, further affected ICT use for assessment. This devaluation of ICT competencies at the senior level is in direct contradiction to Australia's national goals for schooling calling for young people to be highly skilled in ICT use (MCEETYA, 2008c).

Results presented here suggests that "testwiseness" (Lam, 1995) was perceived to be important for HSC success and a belief that school-based summative assessment was the best way for students to gain those experiences. Broader implications for limiting the repertoire of assessment tasks relate to the impact on student learning. Some participant teachers believed that assessment and instruction were separate practices, and that external examination preparation was an important part of the internal summative assessment process. For these teachers, the use of ICT to support assessment was incompatible in the context of HSC exams that prohibit their use. Official documents and research advocate the need for varied tasks gathering evidence from a range of regular activities (Harlen, 2007; Masters, 2002). A narrow range of tasks limits the inferences teachers can make from assessment marks, and therefore their usefulness in the learning process (Killen, 2005). Other studies, too, point to the conflicting nature of emerging technology-rich contexts and examinations that require students to use pen and paper to document their knowledge (Aagaard & Lund, 2013).

The experiences of senior secondary teachers in NSW in using ICTs to support teaching and learning were diverse. Developing students' conceptual understanding and providing opportunities for their meaning-making were supported by a variety of ICTs. Teachers valued explicit instruction and whole-class discussions supported by interactive visuals and display technologies such as data projectors and interactive whiteboards. These pedagogies often relied on teacher-created resources or those the teachers had assembled through selecting, organising and recombining digital content to use in combination with display technologies. ICTs seemed to be affecting the content teachers are required to teach; for example, in the creative arts, explicit instruction in digital technologies was common. For other teachers in this study, ICT

skills and knowledge were seen as extra content that was unnecessary in the context of state-prescribed content that did not explicitly require ICT knowledge and skills. Finally, teachers in this study frequently aligned school-based summative assessment processes to those of external state-based examinations, where ICTs were not used. In this context, school-based assessment was seen as a means of preparing students for final examinations that were dominated by pen-and-paper style tests.

Research Question 3: *What forms of teacher knowledge are evident in senior secondary teachers' descriptions of their practice?*

Theory enables researchers to move beyond descriptive reporting towards a deeper understanding of the complexities and nuances of education environments. It provides a vehicle for dialog among scholars and can position micro-level research within a broader context and a larger knowledge base (Anyon, 2008).

In this study, the context of content-laden senior secondary education against a backdrop of an ICT policy-enactment period afforded a closer look at the TCK construct. The boundary constructs, TCK and TPK, are an area of the TPACK model that has presented a number of challenges to researchers relating to varied interpretations and lack of precision. In contributing to TPACK's theoretical development, an exploration of the TCK construct was offered in this study. This is in response to doubts surrounding the existence of boundary constructs and the need for their clarification, as well as a need for definitions of TCK that can inform teaching practice (Archambault & Barnett, 2010; Cox & Graham, 2009a, 2009b; Graham, 2011).

In developing an understanding of TCK in relation to this study, literature was carefully scrutinised for TPACK scholars' interpretations of the constructs' applications in practice. TCK indicators were developed, and the data collected for this study were scrutinised for manifestations of the construct. TCK can be seen in the following practices:

- The use of ICTs in representations of subject content

- The use of ICTs to author content and deliver subject matter in an online environment.

- The use of ICTs that affect or change subject content, reflecting the reciprocal nature of ICT and content

- The use of ICTs to manipulate and interact with subject content

- The curation (selection and organisation) of digital content

- The use of subject-specific ICTs and

- Instruction in subject-specific ICT skills.

Each one of these areas of ICT use was allocated a code (TCK sub-codes). The development of a coding scheme further clarifies the TCK construct by offering scholars explicit examples in the ways this knowledge construct manifests in classroom practice.

In this study, this refinement to TCK enabled a deconstruction of specialist subject teachers' description of practice, and provided insights into the way content is organised in teaching and learning. It showed that pedagogical reasoning is always in play as teachers select or create materials that are most appropriate for their learners in the context of a sequence of instruction. In expert teachers' descriptions of practice, it was difficult to distinguish TCK from TPACK.

According to some scholars, all content is pedagogical because it is a communication of ideas by structuring knowledge (Au, 2007; McEwan & Bull, 1991; Segall, 2004b). Knowledge embedded in a curriculum is structured and organised, and therefore the intended form of communication – the pedagogy – is also embedded in that curricular structure (Au, 2007). Pedagogical decisions are shaped subject matter that is being taught (Shulman, 1987). On closer scrutiny of the technology-content interactions in this study, ICTs enabled a number of alternatives for content representation, manipulation and interaction with subject specific content. These representations are then employed as part of the transformation processes that take place as teachers enact TPACK during a sequence of instruction.

While this overlap between TCK and TPACK inherent in teachers' actions may present a *degree of fuzziness* for TPACK scholars, the TCK boundary construct is of value. The value of the TCK construct to ICT-integration studies is that it draws attention to the importance of discipline-specific knowledge for teaching practice. In highly prescribed courses, content knowledge underpins the selection, organisation, evaluation and creation of the teaching resources that become the basis for a teaching sequence or unit of work. Without well-developed conceptual, discipline-based content knowledge, teachers' reorganisation and representation of subject knowledge for teaching will be limited. Technological knowledge is now inseparable from this reorganisation process. For HSC teachers, reorganisation begins with accessing content outlined in (digital) syllabus materials, then applying well-developed online search skills in curating digital resources that align to syllabus dot-points and well-developed ICT-related skills in creating multiple representations for students.

Scholars have argued the importance of a theoretical foundation in educational technology research (Bennett & Oliver, 2011; Johnson, 2015; McDougall & Jones, 2006) and education research generally (Ball, 2006; Lingard, 2015; Wright, 2008). The review of literature for this study (Chapter 2) suggested that educational-technology scholars are not always explicit about their theoretical underpinnings. Additionally, the literature review revealed that the diversity in theory and conceptual frameworks employed by educational-technology scholars reflects the diversity of the education research field itself. In recent years, TPACK has gained acceptance as a construct for educational-technology research; however, some believe that TPACK is an insufficient model to guide educational-technology research (Johnson, 2015), and that further theoretical development is warranted to strengthen educational-technology research (Graham, 2011).

This study contributes to the theoretical development of TPACK as a conceptual framework. The framework offers researchers a "conceptual toolbox" (Wright, 2008, p. 9). In this study, TPACK informed the development of the interview protocol that guided data collection on teachers' experiences of ICT use; acted as a reflexive tool in analysing experiences relating to ICT-integration; provided a way of understanding ICT-integration as an enactment of teacher knowledge; and situated the particulars of

this study within a broader knowledge base of TPACK, and within education research generally. Additionally, this study supports the argument that TCK does exist and can be identified in detailed descriptions of practice (Archambault & Barnett, 2010). In response to a need for the use of TCK definitions with practising teachers (Cox & Graham, 2009a), this study provides examples of the TCK boundary construct's enactment with Year 11 and 12 teachers from NSW schools. The final contribution adds value to the theory in further clarifying the vocabulary used to identify TCK in teachers' practice through further refinement of sub-codes used for thematic analysis that enabled a closer exploration of technology-content manifestations in practice.

In this study, the context of content-laden senior secondary education against a backdrop of an ICT policy enactment period afforded a closer look at the TCK construct. The refinement of TCK enabled a deconstruction of specialist subject teachers' description of practice, and showed that TCK was a component of pedagogical decision-making involved in the preparation and delivery of learning sequences. While this overlap between TCK and pedagogical reasoning inherent in teachers' actions may present a *degree of fuzziness* for TPACK scholars, the TCK boundary construct is of value. The focus on content-technology interactions of teachers' practice enabled a detailed exploration of technology use in relation to content representations and enabled inferences to be made about skill sets that are becoming important for contemporary teachers.

8.3   Implications

8.3.1   Policy-making

While policy timelines are short, change processes in schools are not. Education-policy processes have long-lasting effects, and ongoing evaluation of implementation and intended changes for teachers and students is important. This study noted that monitoring of policy implementation in terms of what teachers and students were doing was not an explicit component of the DER policy agenda. Policy-makers and school leaders cannot know what is working and what is not if they do not know what the system is doing. Evaluation is complex, as policy goals are broad, and an ongoing challenge for policy-makers is to include systematic reviews that can provide

information on successes and challenges associated with intended changes sought by reform agendas.

Ongoing capacity building in education is difficult, but at its foundation is the knowledge base of teachers. This study highlighted the need for specialised and highly developed pedagogical and technological knowledge, along with knowledge of how ICTs affect student learning if the DER were to bring about the type of reform advocated in policy documents. The DER has come and gone; however, ICTs will continue to evolve and schools will continue to adopt emerging technologies even before their educational benefits are fully realised. For example during the DER, Apple released the first generation iPad – a tablet device not designed specifically for the education market. Schools in Australia and internationally were quick to investigate what these light-weight, long-battery life, small-footprint, easy-to-use devices might bring to teaching and learning (for example, DEECD & I & J Management Services, 2011; Goodwin, 2012; Queensland Government, 2011; Reid & Ostashewski, 2011). In the Australian context, these iPad trials evolved into *Bring your own device* (BYOD) programs, where schools and school systems are encouraging students to use personal mobile devices to support learning (for example, DETVic, 2015; NSW DEC, 2014; Qld DET, 2013). This suggests that the 1:1 laptop environment established in the upper secondary years during Australia's DER period is not only continuing, but extending to all levels of schooling. Change brought about by technologies is ongoing, and highly flexible and adaptable teacher knowledge around the integration of emerging technologies in schools will remain an important focus for pre-service and in-service professional learning providers.

In addition to professional learning, another implication identified in this study concerns change for teachers in the context of work environments. In-service teachers, in particular, need clear directions and purpose to develop an understanding of why they need to change and what they have to do to change. This needs to be connected to the realities of their contexts, particularly of what and whom they teach. In addition, teachers need time to engage with and enact those changes, particularly when teachers' belief systems are challenged, as highlighted by this study. Additionally, school organisational structures need to accommodate teachers' release from face-to-face

teaching to undertake the types of sustained professional learning required. Time is hard to find and costly to provide. Policy processes that involve billions of dollars must consider the cost to schools in staff relief and professional learning as well as infrastructure.

Mandated and prescribed curricula shape the pedagogical decision-making process embodied in teaching in senior secondary education, and affect teachers' decisions about ICT use. There is a need to design senior curricula that maintain the rigour expected at this level of schooling, but at the same time include a degree of flexibility that enables the application of technological content knowledge. If working mathematicians use computer algebraic system (CAS) applications in their work, for example, then senior mathematics syllabi should reflect their value in the content taught to senior students. Current curriculum documents need a way to incorporate new technologies as they become mainstreamed in the work of those in the field.

8.3.2   Educational practice

At the heart of school-based reform is the professional capacity of its teachers to engage in new practice (Fullan, 2006, 2009; Galatis et al., 2009). This directly affects in-service teachers and their schools. The DER initiative was an example of ICTs affecting in-service teachers with a short lead-in time, and this seems to be continuing with the introduction of tablet trials and BYOD policies. Additionally, this study highlighted that change in other areas of practice were simultaneously required from concurrent policies such as the Australian Curriculum, the introduction of new teaching standards and increased accountability pressures associated with national testing regimes. Capacity-building in ICT-integration requires an array of supporting structures at the local level. These include strong leadership, strategic planning for ICT-enabled learning as well as infrastructure and a "multi-faceted approach to professional learning" (Galatis et al., 2009, p. 25). Sustained and appropriate models of professional learning will require time away from face-to-face teaching, and this must be factored into ICT-integration planning and implementation processes.

The findings from this study also have implications for students' ICT skills in one-to-one device environments and in learning with online materials.

Professional capacity will involve teachers' knowledge of planning for technology-mediated learning. In the context of tertiary education, *design for learning* is a process where teachers, and others involved in the learning situation, purposefully design for the pedagogic intention at hand; whether that be the design of leaning resources, the learning environment, learning activities, units of work or entire courses (Beetham & Sharpe, 2013). Increasingly, schools are transitioning to blended learning environments, where ICTs are shaping the content to be delivered as well as the interactions within communities of students and their teachers (Barbour et al., 2011) and therefore, principals associated with design for learning are relevant in the k-12 context too. In this study, teachers provided examples where creating electronic texts such as websites, wikis, OneNote documents and, in some cases, learning management systems such as Edmodo and Moodle provided a means for delivering electronic resources. Sound design for learning will require knowledge of the ways in which ICTs can mediate tasks students are engaged as they work towards course-specific outcomes (Beetham, 2013). (Beetham, 2013). In addition, teachers must ensure their students have the necessary skills to traverse the belended learning environments within which they are situated.

Skills at senior secondary level must include subject-specific ICTs. In NSW, there is a disconnect between what is examined in the HSC and valuable skills associated with technology use that are relevant to specialist fields. If more applied and higher-level student ICT skills are valued, then there need to be subject-specific, ICT continua included in the curriculum. Outcomes relating to student ICT competencies must move beyond generic low-level uses towards authentic and discipline-specific applications of ICTs.

Assessment is complex and nuanced. At senior secondary level in NSW, there are conflicting roles for summative assessment connected to measurement for credentialing and assessment as part of a learning process. Once more, teacher knowledge is at the heart of this conundrum. For some schools a reconceptualisation of the purpose and process of assessment is warranted. Teachers need time to engage

with research and official documentation that builds knowledge around the purpose of school-based summative assessment at the senior secondary level. When there is a fundamental understanding that assessment and instruction are interconnected, the benefits of technology-enriched environments in enhancing assessment become apparent.

This study identified a number of specific skills that would be of benefit to specialist teachers integrating ICTs. The TCK focus adopted in this study emphasised specialist subject teachers' pedagogical reasoning that came into play as they thought about the topic knowledge they were teaching and how ICTs supported different ways of representing that content. Teachers use a range of TCK-related ICT skills when designing learning activities; however, this study suggests that in the context of senior secondary courses, these skills were embedded within the content they were representing when preparing learning activities. Professional learning and teacher training focusing on ICT-integration would benefit from teaching ICT skills that are firmly grounded in specific topic areas of specialist subjects to develop teachers' technological content knowledge. Professional learning should also target pedagogical knowledge related to student learning so that teachers understand the ways digital representations of content support meaning-making in their particular subject area, as well as the ways their students interact with and make meaning from digital representations during learning sequences.

8.4 Limitations of the study

8.4.1 Phase 1 – Policy analysis

Policy studies represent a snapshot in time. This study considered documents published up to 2012. Several policy frameworks, new governments and advisory groups and many web sites have succeeded the ones reviewed for this analysis. The rapid growth of technologies has changed learning spaces since this study commenced. Within a broader context, research in policy processes and educational technologies will always have these constraints, as policy cycles are relatively short and ICTs continue to evolve.

Another limitation is that this study did not analyse state or school policies. In Australia, state policies do not apply to all schools – only those schools funded by the state (called government schools). Other bodies, such as church groups and schools themselves, have policies that set goals within their jurisdictions, and these have implications for teachers and practice. Establishing a scope for research within the time and technical constraints of a doctoral study meant that documents promulgated at the national level, pertinent to all Australian schools, were selected.

There are also limitations for researchers wishing to access policy cited in this study. Documents were sourced primarily through Internet searches of websites outlined in the methodology section. This part of the research poses challenges for scholars wishing to build on a study such as this. The dynamic nature of Australian politics means that government agencies are in a constant state of flux from one election period to the next. Consequently, websites and document uniform resource locators (URLs) current at the outset of the study were out of date even before the research was complete. While the major policy documents, such as National Agreements, may be archived by the National Library of Australia, much discourse exists in other forms, including Government websites, ministerial statements and advisory-committee communiqués. These data sources become less accessible as time progresses.

8.4.2 Phase 2 – Investigation of ICT-integration

The generalisability of findings from Phase 2 of this study is limited by the nature of the participants and sampling methods used. Findings are based on experiences of only 28 participants, drawn from a single state (NSW), and do not represent all subject areas or levels of schooling. Additionally, the experience of technology use could only be gained from participants who were actually using the technology (criterion sampling). Because of this, conclusions cannot be drawn about ICT-integration generally in all contexts and levels of schooling. The purpose of a phenomenological approach is to reduce individual experiences to a general description (essence of the phenomenon). Though not generalisable, results from phenomenological studies can suggest experiential patterns that may be relevant to other teaching and learning contexts (Pollio et al., 1997). This study has provided detailed descriptions of the context,

participants and analysis process so that the reader can make a judgement about transferability to other contexts.

Data collected for the second phase of the study were self-reported. This data-collection method aligned with the philosophical underpinnings of phenomenology and it was important to the research design that an understanding of ICT-integration was grounded in teachers' experiences. The limitations with this data-collection method, however, are that participants may only report data they think the interviewer may want to hear or that casts themselves in a more favourable light. A study of teachers' practice reported that teachers were observed using many more types of teaching strategies than they themselves described during an interview (Ayres et al., 1999), and this may have been the case in this study too. Caution, therefore, needs to be taken in interpreting participants' accounts.

Another limitation regarding data collection was that teachers were asked about their ICT use and not about how frequently either they or their students used a particular technology. This means that conclusions can be drawn about the range and types of ICTs used to support learning, but not about frequency of use.

Limitations relating to the TPACK framework must also be acknowledged. Technological knowledge, pedagogical knowledge, content knowledge and TPACK are foundational knowledge structures for good teaching. However, the constructs do not convey all knowledge and attributes important for successful teaching. Teachers' decision-making in complex and unpredictable situations (Bore & Wright, 2009), and the tacit knowledge acquired through experience of which the knower is unaware (Eraut, 2000) are examples of knowledge the manifestations of which may not be captured through TPACK's theoretical lens.

8.5   Further research

This section suggests further areas for research relating to education-policy processes, ICT use in senior secondary education and teachers' knowledge.

It is important that appropriate and useful evaluation measures are in place to inform future policy goals, and to ensure that the expenditure of public money is worthwhile and student learning is enhanced. This notion of policy evaluation is complex, particularly in the context of school education. Future research might focus on evaluation frameworks specific to ICT-related initiatives. Research suggests that stakeholder involvement in the form of participatory evaluation enhances the quality of the evaluation (Johnson et al., 2009). Therefore research into the role of participants (including school leaders, teachers, parents and students) in education-policy evaluation processes could inform future evaluation frameworks targeting ICT programs in school education.

Further research is also suggested in the area of policy effects at the local school level. It is unclear how intended changes articulated in national-level vision statements are devolved to a school-level plan of action. This is especially relevant in the context of Australian education, where national statements are not directly implemented by the government body promulgating the policy directives.

In relation to ICT-integration, further research is needed to determine whether uses identified in this study are representative of technology use more generally by senior secondary teachers in the context of highly prescribed curricula. For examples, studies focusing on a specific subject area with a greater number of teacher-participants would provide deeper understanding of students' ICT skills and teachers' knowledge requirements in specialist subject areas. In addition, while this study was able to comment on the types of uses, the frequency of use was not considered, and further research is recommended to ascertain the extent of technology use in senior secondary education. Also related to ICT use are recommendations for further research into the role of ICTs in assessment, particularly frameworks associated with high-stakes summative assessment in senior secondary school. Further research might explore assessment programs in a greater number of schools and across more subject areas to build a more comprehensive profile of school-based assessment practices in NSW senior secondary education.

Further study around students' ICT skills expected by senior secondary teachers is warranted. Results of recent national ICT literacy testing show that ICT competencies of Australian Year 10 students are declining (ACARA, 2015), despite increased access to ICT infrastructure and devices. This study showed that senior secondary teachers favoured applied uses of ICTs by students when collaborating and producing artefacts and in higher-order problem-solving. In addition, time was seen as a constraint to teaching subject-specific ICT skills. Future research could focus on explicating the ICT skills students require to maximise outcomes related to senior secondary learning and their relationship to the newly defined Australian Curriculum ICT Capability continuum.

Research in the area of teachers' knowledge relating to learners reading, viewing, responding and producing multimodal texts in the context of meaning-making in senior secondary education would be of benefit to teacher educators. Meaning-making is multimodal – embedded in the ever-increasing models of representations afforded by new technologies (Kress, 2004). Online authoring environments, such as Weebly, Google Sites and Edmodo, as well as learning management systems, are providing ways for school teachers to augment traditional face-to-face teaching and traditional printed texts. Clearly defining best practice for learning design relating to authoring and curating digital content would be of benefit in preparing teachers for their future work in "blended" learning environments and add to fundamental understandings of how students make meaning from and with multimodal texts.

Further research could contribute to conceptualisation of technological-content knowledge interactions. TPACK is a relatively new model that is unifying research in areas of ICT-integration. Conceptualisations based on this model would benefit from further knowledge about how different representations assist learners in making meaning from subject-specific content. For example, studies involving observations with secondary teachers working with students who are having difficulties grasping a concept or solving a problem may reveal what practices and representations they draw on to improve the students' understanding. Furthermore, the NSW Higher School Certificate provides an opportunity to study TPACK with teachers using the same curricular materials – state-mandated syllabus documents that detail the content of

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each course. This would enable studies that examine how teachers within the same subject discipline create different materials for teaching the same content with different learners, enabling a focus on different representations and their strengths and weaknesses in helping students learn.

8.6 Conclusion

The thesis presented here has investigated senior secondary school teachers' uses of ICT to support teaching and learning during a period of rapid change associated with Australia's Digital Education Revolution (DER). It did this by first exploring the role of government policy as a key component of large-scale, system-wide reform. This analysis contributed to understanding the context within which teachers were working by elucidating the characteristics of the intended changes that were articulated through government policy, the implementation of which would pose significant challenges for teachers. TPACK, a model that conceptualises teachers' knowledge, was employed to guide the second phase of the study exploring senior secondary teachers' use of ICTs to support and enhance learning in NSW schools. ICT use is complex and situated; by examining teachers' experiences, this study provides an understanding of the phenomenon of ICT-integration in the final years of secondary schooling. It is hoped that further clarification of the TPACK framework offered in the final part of this study fuels further scholarly dialogue about educational technology and its role in student learning.

CHAPTER 9: REFERENCES

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APPENDIX A: DECLARATION OF AUTHOR CONTRIBUTIONS

Four of the chapters presented in this thesis are in-preparation or published journal articles. The author contribution is outlined as follows and further detailed in the Thesis Structure in Chapter 1.
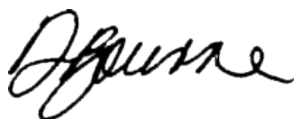
Chapter 4: Bourne, D., Bennett, S. & Lockyer. L.   'Australia's Digital Education Revolution – the characteristics of intended changes' prepared for publication in *Australian Journal of Education*

Chapter 5: Bourne, D., Bennett, S. & Lockyer. L.   'Information and communications technology integration in senior secondary education' prepared for publication in *Computers & Education*

Chapter 6: Bourne, D., Bennett, S. & Lockyer. L.   'ICT use in senior secondary high-stakes assessment' prepared for publication in *Assessment in Education: Principles, Policy & Practice*

Chapter 7: Bourne, D., Bennett, S. & Lockyer. L.   'Technology in school education – ICT-integration and teacher knowledge' prepared for publication *Technology, pedagogy and Education*.

The primary contribution in each of the in-preparation or published journal articles has been undertaken by the PhD candidate, Debra Bourne, and the contribution of co-authors, Professor Sue Bennett and Professor Lori Lockyer, was primarily through the provision of feedback and review.

Debra Bourne

PhD candidate

Professor Sue Bennett   Professor Lori Lockyer

Research supervisor   Research supervisor

APPENDIX B: LIST OF PAPERS SELECTED FOR THE LITERATURE REVIEW

Description	Other notes	Participant teachers	Participant students	Participant schools	Country
1. Aksela, M., & Lundell, J. (2008). Computer-based molecular modelling: Finnish school teachers' experiences and views. *Chemistry Education Research and Practice, 9*(4), 301-308.					
A Finnish case study of teachers' use of computer-based molecular modelling in supporting chemistry teaching. The study focused on different pedagogies employed; challenges in using the resource and demonstrated how molecular modelling enhances understanding of chemistry content. Adoption of the electronic resource was context dependent and affected by teachers' skills in using the application.	Qualitative; Not exclusively senior secondary teachers; number of schools not reported	19			Finland
2. Ashton, H. S., Beevers, C. E., Korabinski, A. A., & Youngson, M. A. (2005). Investigating the medium effect in computer-aided assessment of school Chemistry and college Computing national examinations. *British Journal of Educational Technology, 36*(5), 771-787.					
A Scottish study looking at the feasibility of e-assessment in Scottish Qualifications Authority (SQA) examinations. The study compared Higher Chemistry and Computing paper-based and electronic tests. The study found no significant difference in achievement scores between traditional and electronic tests.	Quantitative;		180	7	Scotland
3. Ashton, H. S., Beevers, C. E., Korabinski, A. A., & Youngson, M. A. (2006). Incorporating partial credit in computer-aided assessment of Mathematics in secondary education. *British Journal of Educational Technology, 37*(1), 93-119.					
A Scottish study looking at the feasibility of e-assessment, explored how partial credit could be awarded in a mathematics high-stakes assessment taken on computer. The study reports 'encouraging results' in this area of electronic, high-stakes test-item development; however, a number of challenges limit their use in formal exams. With further developments in technology, it was anticipated that these test items would be refined in future versions of the test engine.	Quantitative		188	5	Scotland
4. Awodeyi, T. O., & Tiamiyu, M. A. (2012). The development of mathematics e-learning tool for Nigerian senior secondary schools. *African Journal of Library Archives and Information Science, 22*(2), 99-116.					
Nigerian study reporting on the development of an e-learning application (E-Maths) to support the teaching and learning of some aspects of the mathematics curriculum in preparation for Senior Secondary School Certificate. The resource was designed to address problems associated with low income and/or isolated families' lack of access to learning materials and/or qualified teachers.	Qualitative data to informed the design of the E-Maths resource.	28	74	14	Nigeria

	Description	Other notes	Participant teachers	Participant students	Participant schools	Country
5.	Ayere, M. A., Odera, F. Y., & Agak, J. O. (2010). E-learning in secondary schools in Kenya: A case of the NEPAD E-schools. *Educational Research and Reviews, 5*(5), 218-223					
	A Kenyan comparison (survey) study evaluating schools that were resourced to become centres of ICT-integration excellence. eLearning was compared in schools who were part of the initiative and those that were not. The resourced schools more frequently used ICTs and eLearning; and had higher achievement scores in end of school exit examinations.	Mixed; (staff were not all teachers & included principals and district officials)	27	570	35	Kenya
6.	Ball, L. (2004). Researchers and teachers working together to deal with the issues, opportunities and challenges of implementing CAS into the senior secondary mathematics classroom. *ZDM, 36*(1), 27-31					
	An Australian study reporting on the introduction of graphics calculators in implementing a new Year 11 and 12 mathematics curriculum. The study considered the teachers transitioning to new ICTs (computer algebraic system – CAS calculators) and the teacher support mechanisms that promoted success with the devices.	Qualitative	4		3	Australia
7.	Bokhove, C., & Drijvers, P. (2012). Effects of a digital intervention on the development of algebraic expertise. *Computers & Education, 58*(1), 197-208. doi:http://dx.doi.org/10.1016/j.compedu.2011.08.010					
	A Dutch web-based intervention study involving digital units of work and diagnostic tools aimed at developing mathematics competence. ICTs added an advantage such as being able to learn anytime anyplace, receiving feedback and randomizing items. Authors also conclude that the ICT intervention was useful in preparing students for final examinations.	12th Grade	11	324	9	Holland
8.	Bonvallet, S., & De Luce, J. (2001). Roles for Technology in Collaborative Teaching. *CALICO Journal, 18*(2), 295-303.					
	A US study reporting on the introduction of a virtual learning environment (VLE) aimed at supporting collaborative teaching in Latin language and ancient Roman culture. The course was 'team-taught' with classes meeting separately at their institutions and together in the VLE. The pilot enabled the researchers to consider the careful design of the learning activities to enable learning outcomes for both institutions to be met. Additionally, the study demonstrates the importance of pilot studies in highlighting factors such as the need for students to learn to use VLE technologies and overcoming differences in online and face-to-face collaborative activities and assessment strategies.	Qualitative. Two institutions were involved; however, only one was a school. The school had three students, while the university undergraduate course had 6;	2	3	2	9.
9	Chang, C. Y. (2001). A problem-solving based computer-assisted tutorial for the earth sciences. *Journal of Computer Assisted Learning, 17*(3), 263-274.					

Description	Other notes	Participant teachers	Participant students	Participant schools	Country
A Taiwanese study reporting on the introduction of a computer-assisted tutorial aimed at developing problem-solving in Earth Science. A one-week 'intervention' comparing the computer-assisted, interactive tutorial with a Lecture-Internet-Discussion (LID) teaching approach. The intervention group achieved greater gains on students' earth science achievement than the comparison group. Note that both groups received ICT–integrated instruction; the test group; however, used a purpose-built CAI module.	Quantitative Tenth graders (16 Year olds); Senior school in Taiwan	1	137	1	Taiwan

10. Chang, C. Y. (2003). Teaching earth sciences: should we implement teacher-directed or student-controlled CAI in the secondary classroom? *International Journal of Science Education, 25*(4), 427-438.

Description	Other notes	Participant teachers	Participant students	Participant schools	Country
A Taiwanese study reporting on the introduction of a computer-assisted tutorial system aimed at developing problem-solving in Earth Science. In this study, Chang compares different pedagogical approaches (teacher-directed vs student controlled) using the same ICTs in comparison groups. The teacher-directed CAI was more effective at improving. The role of the teacher is a critical factor in success of ICT-integrated teaching and learning.	Quantitative; Tenth graders at a senior high school	1	232	1	Taiwan

11. Chang, C. Y. (2004). Could a laptop computer plus the liquid crystal display projector amount to improved multimedia geoscience instruction? *Journal of Computer Assisted Learning, 20*(1), 4-10.

Description	Other notes	Participant teachers	Participant students	Participant schools	Country
In this paper, Chang reports on the details of pedagogies employed in teacher-directed CAI This time, the instruction takes place outside of the computer laboratory, in a more traditional class structure. Whole-class instruction supported by LCD projector displaying the CAI Earth sciences material and teacher-directed pedagogies. The study 'demonstrates the effectiveness of a multimedia teaching method' enhanced by visualisation technologies.		1	119	1	Taiwan

12. Crawford, R. (2009). Secondary school music education: A case study in adapting to ICT resource limitations. *Australasian Journal of Educational Technology, 25*(4), 471-488.

Description	Other notes	Participant teachers	Participant students	Participant schools	Country
An Australian investigation into availability and use of ICT in supporting music education. Crawford argues that authentic music instruction in schools must be reflective of contemporary music practice. However, specialist music creating ICTs in schools is limited. Teachers require creative pedagogies that adapt to resource limitations to enhance authentic learning.	Mixed; Survey and case study; Not strictly senior secondary. Upper secondary (Yr 10 teachers)				Australia

13. Cuban, L., Kirkpatrick, H., & Peck, C. (2001). High access and low use of technologies in high school classrooms: Explaining an apparent paradox. *American Educational Research Journal, 38*(4), 813-834.

Description	Other notes	Participant teachers	Participant students	Participant schools	Country
	Qualitative; observations and interviews	21	26	2	
	Situated in High School; not specific about the year levels.				

14. Gaudioso, E., Hernandez-del-Olmo, F., & Montero, M. (2009). Enhancing e-learning through teacher support: Two experiences. *IEEE Transactions on Education, 52*(1), 109-115.

Description	Other notes	Participant teachers	Participant students	Participant schools	Country
This is a descriptive study investigates two ICT-integrated courses, one undergraduate IT course and one upper secondary Physics course. The web-based adaptive Physics system provided insight into student's interactions and performance. This study is an example of how electronic tutoring systems can provide rich data on interactions and even compare students' interactive behaviours to knowledge. As well as achievement, the system enabled analyses of learning processes, suggested appropriate clustering of students and helped teachers identify learners in need of additional assistance. The study also highlights the importance of supporting teachers in designing the ICT-integrated learning experiences for students	Mixed	12	266	9	Spain

15. Ghosh, J. B. (2011). Exploring Fourier series and Gibbs phenomenon using Mathematica. *Australian Senior Mathematics Journal, 25*(1), 7-22

Description	Other notes	Participant teachers	Participant students	Participant schools	Country
An Indian study providing an example of how learning of mathematics content (Fourier series and Gibbs phenomenon) can supported by the *Mathematica* application. The author considered meaning-making and engagement and details how the mathematics was taught. The author found that the visualisations were important in giving meaning to the paper-and-pencil calculations.	Qualitative– Year 12.	1	32	1	India

16. Goos, M., Galbraith, P., Renshaw, P., & Geiger, V. (2000). Reshaping teacher and student roles in technology-enriched classrooms. *Mathematics Education Research Journal, 12*(3), 303-320.

Description	Other notes	Participant teachers	Participant students	Participant schools	Country
An Australian longitudinal study looking at integrating graphics calculators and display technologies. Sociocultural theory guides an in-depth analysis of teacher-student-technology interactions. While ICTs facilitated the collaborative activities of small group and whole class discussions, "the relationship between technology usage and teaching/learning environments is not one of simple cause and effect." (pg 87) and technology was found to be re-shaping student and teacher roles.	Qualitative; lesson observations and interviews. The numbers of students in each class was not stated; 5 classes in total.	4		3	Australia

17. Goos, M., & Bennison, A. (2008). Surveying the technology landscape: Teachers' use of technology in secondary mathematics classrooms. *Mathematics Education Research Journal, 20*(3), 102-130

Description	Other notes	Participant teachers	Participant students	Participant schools	Country
An Australian study reporting on a survey of Qld Mathematics teachers' use of ICTs in in response to a revision of senior secondary Mathematics syllabi. The descriptive data provides a useful 'snapshot' of the range of ICTs and access to ICTs for Year 11 and 12 teachers at that time. In addition, data described attitudes of participant teachers to ICT-integration, confidence with ICTs and frequency of use across grade levels (more use was observed in the Year 11 and 12 courses). Three sets of factors affected use: pedagogical knowledge and beliefs; access to ICTs and participation in professional development.	Quantitative; Not specific to Year 11 and 12; however, there was a focus on senior secondary with 82 out of 89 responding schools offerings these courses and at least one third of responding teachers taught a senior class.	485		89	Australia

18. Handal, B., Cavanagh, M., Wood, L., & Petocz, P. (2011). Factors leading to the adoption of a learning technology: The case of graphics calculators. *Australasian Journal of Educational Technology, 27*(2), 343-360.

An Australian case study focusing on adoption of graphics calculators (GCs) in NSW senior Mathematics, where GC use is encouraged, but not mandated. Four factors were related to adoption: perceptions of self-competence, faculty support, training and personal interest towards GCs. Responding teachers were categorised at the *Understanding and application the process adoption stage* – the third lowest on a six-point scale. Researchers conjectured that there was a contradiction between what teachers' believed would enhance instruction and prescribed syllabi not allowing their use in final examinations.	Mixed; Questionnaire was designed to ensure stages of adoption and attitudes towards GCs	587		235	Australia

19. Hauptman, H. (2010). Enhancement of spatial thinking with Virtual Spaces 1.0. *Computers and Education, 54*(1), 123-135.

An Israeli study reporting on the development of a 3D geometry learning environment (VLE) based on the cognitive processes students bring to bear when learning 3D geometry. Careful construction of 'self-regulating questions' more effectively supported learning with the VLE.	Quantitative; '10th graders' are part of the Israeli upper secondary school		52	5	Israel

20. Kaberman, Z. and Y. J. Dori 2009 Question Posing, Inquiry, and Modeling Skills of Chemistry Students in the Case-Based Computerized Laboratory Environment International Journal of Science and Mathematics Education **7** 3 597-625

An Israeli study investigating new learning units in computerised chemistry laboratory and computerised chemistry molecular modelling and their effects on higher order thinking skills. Skills targeted wre question posing, inquiry and modelling. Pre and post-test questionnaires assessed skills. The learning model that included case studies with computerised inquiry activities had positive effects on student's higher-order thinking skills.	Quantitative (longitudinal) 12th Grade chemistry honours students – number of teachers and schools was not stated		769		

21. Karlsson, G. (2010). Animation and grammar in science education: Learners' construal of animated educational software. *International Journal of Computer-Supported Collaborative Learning, 5*(2), 167-189

Description	Other notes	Participant teachers	Participant students	Participant schools	Country
A Swedish upper secondary school study focusing on how students interpreted their task and made meaning out of what they observed in science animations. The study contributes knowledge on the ways that representations are used and construed in a learning situation. Also demonstrated that teacher guidance is essential to ensure that the construction of meanings depicted in animations is accurate.	Qualitative; Upper secondary. Number of teacher participants was not reported		65		Sweden

22. Kaufman, D., Sauve, L., & Renaud, L. (2011). Enhancing Learning through an Online Secondary School Educational Game. *Journal of educational computing research, 44*(4), 409-428.

Description	Other notes	Participant teachers	Participant students	Participant schools	Country
A Canadian study focusing on effectiveness of (computer) game-based learning. The game was developed to "enhance 21st century skills such as critical thinking and problem solving" (p. 417) as well as develop knowledge of health-related issues.	Quantitative; Years 9, 10 and 11		133	4	Canada

23. Kay, R., & Knaack, L. (2005). Developing Learning Objects for Secondary School Students: A Multi-Component Model. *Interdisciplinary Journal of E-Learning and Learning Objects, 1*(1), 229-254.

Description	Other notes	Participant teachers	Participant students	Participant schools	Country
This study details the development process of five learning objects. It assessed their quality and perceived benefits from students' & teachers' points of view. Motivational interactive and visual qualities were valued by students; however, quality of the learning object was rated poorly. The study provides insights into characteristics of quality learning objects and the processes involved in creating and evaluating learning objects.	Quantitative Included grade 9 students; most participants were Year 11 and 12		143	30	Canada

24. Lagrange, J.-B. (2010). Teaching and Learning about Functions at Upper Secondary Level: Designing and Experimenting the Software Environment Casyopee. *International Journal of Mathematical Education in Science and Technology, 41*(2), 243-255.

Description	Other notes	Participant teachers	Participant students	Participant schools	Country
A French study that designed an algebraic software application and teaching unit focusing on student-computer interactions. Explored the potential for the application to support students' meaning making in mathematics. The success of the ICT-integration was attributed to its role within well-designed learning activities and the teacher's interventions during 'crucial episodes'.	Qualitative; Observations of lessons with students. Numbers of participants were not stated; although analysis focused on a team of two students and discussion of 'teachers'.	1	2		France

25. Lindberg, J. O., & Sahlin, S. (2011). Bridging school-subjects and distances in upper secondary schools. *Campus-Wide Information Systems, 28*(3), 144-153

	Description	Other notes	Participant teachers	Participant students	Participant schools	Country
	A case study reporting on the participation in the *Bridging Insula Europea* project from the Swedish perspective where students and teachers collaborated on various thematic units of work through an online platform. The initiative was successful in terms of student engagement, collaboration with students from other countries and authenticity of the materials. Challenges were faced around scheduling, mapping objectives, integrating subjects and meeting requirements of the Swedish prescribed syllabi and coordinating work with other schools.	Qualitative	3	13	2	Sweden

26. Love, K. (2002). Mapping Online Discussion in Senior English. *Journal of Adolescent & Adult Literacy, 45*(5), 382.

	Description	Other notes	Participant teachers	Participant students	Participant schools	Country
	An Australian Year 11 English study examining challenges in working with a new mode of interaction (online discussion tools). Challenges were associated with teachers working with 'electronic language'; topic selection that aligned to the medium; and regulating online relationships. The study provides an example of an ICT-supported (high-stakes) assessment task where students were responding to various texts.	Qualitative; Year 11	7	170	1	Australia

27. Macintyre, T., & Forbes, I. (2002). Algebraic skills and CAS--could assessment sabotage the potential? *The International Journal for Technology in Mathematics Education, 9*(1), 29

	Description	Other notes	Participant teachers	Participant students	Participant schools	Country
	This study reports on the impact that dedicated access to hand-held CAS had on the 'algebraic skills' in Scottish schools. Students that access to the graphics calculators (GCs) performed better than students in the control group. Student performance in an algebraic test was compared with that of students in control schools who did not have access to the same technology. Challenge included teachers feeling restrained in their use of GCs as they were not permitted in examinations and students choosing not to use them for fear of being disadvantaged.	Mixed – student achievement + teacher interviews. Quantitative; Year 12 (16 to 18 years old) SQA courses. Number of teachers not stated; but at least 6: "interviews with staff from all of the schools.."	6	227	6	Scotland

28. Olatoye, R. A. (2009). Influence of Computer Anxiety and Knowledge on Computer Utilization of Senior Secondary School Students. *Electronic Journal of Research in Educational Psychology, 7*(3), 1269-1288.

	Description	Other notes	Participant teachers	Participant students	Participant schools	Country
	The study investigated the influence of computer anxiety and knowledge on computer utilisation in Nigeria. Computer knowledge (rather than anxiety) was a contributing factor in student utilisation. Gender was also a contributing factor with males using computers more frequently than females.	Quantitative – questionnaire of students.		400	20	Nigeria

29. Penney, D., Jones, A., Newhouse, P., & Cambell, A. (2012). Developing a digital assessment in senior secondary physical education. *Physical Education and Sport Pedagogy, 17*(4), 383-410

	Description	Other notes	Participant teachers	Participant students	Participant schools	Country
	An Australian investigation into the feasibility of the use of reliable, digital forms in high-stakes assessment capable of being scaled-up for state-wide implementation. It increased the types of opportunities for students' to demonstrate their learning of physical education knowledge and skills as well as providing valid means for high-stakes assessments.	Mixed	5	72	4	Australia

30. Scherer, R., & Tiemann, R. (2012). Factors of problem-solving competency in a virtual chemistry environment: The role of metacognitive knowledge about strategies. *Computers & Education, 59*(4),

	Description	Other notes	Participant teachers	Participant students	Participant schools	Country
	A German study investigating the problem solving processes students bring to bear during when solving complex chemical problems. A theoretical framework describing the problem solving competency and its components is presented as well as an interactive virtual environment designed to assess problem solving skills.	Quantitative; Year 10 and 12 students. The number of schools is not reported.		162		Germany

31. Sengel, E., & Ozden, M. Y. (2010). The Effects of Computer Simulated Experiments on High School Students' Understanding of the Displacement and Velocity Concepts. *Egitim Arastirmalari-Eurasian Journal of Educational Research, 10*(39), 191-211.

	Description	Other notes	Participant teachers	Participant students	Participant schools	Country
	A study from Turkey, comparing the effectiveness of computer simulated experiments (CSE) and hands on laboratory inquiry in Physics. The CSE group out-performed the hands-on group – attributed to learner control enabling re-examination of lesson components; response checking and immediate feedback.	Quantitative Achievement scores. 10th Grade students	1	61	1	Turkey

32. Solhaug, T. (2009). Two configurations for accessing classroom computers: Differential impact on students' critical reflections and their empowerment. *Journal of Computer Assisted Learning, 25*(5), 411-422.

	Description	Other notes	Participant teachers	Participant students	Participant schools	Country
	A Norwegian study offering a comparison of the 'learning environments' in upper secondary schools. The environments are either computer laboratories or one-to-one laptops. 'critical reflection is enhanced in classrooms with laptops' (pg 411)	Quantitative; Student survey & critical reflections		719	6	Norway

33. Taasoobshirazi, G., Zuiker, S. J., Anderson, K. T., & Hickey, D. T. (2006). Enhancing inquiry, understanding, and achievement in an astronomy multimedia learning environment. *Journal of Science Education and Technology, 15*(5-6), 383-395.

	Description	Other notes	Participant teachers	Participant students	Participant schools	Country
	A US design-based study that investigated the use of an inquiry-based online learning platform (Astronomy Village) is supporting science learning as well as assessments in standardised tests. It provides an example of aligning ready-made resources to prescribed curriculum and mandated (high-stakes) assessment processes. The second implementation had a stronger focus on pedagogies associated with the ICT and stronger gains in student learning.	Mixed; 11 and 12th grade	3	48	3	US

34. Tanaka-Ellis, N. (2010). Factors limiting learners' success in achieving task outcomes in CALL. *Innovation in Language Learning and Teaching, 4*(3), 213-233.

	Description	Other notes	Participant teachers	Participant students	Participant schools	Country
	A study of task-based Japanese language teaching in an Australian and Japanese secondary schools. The study focuses on CALL classes and reports on factors that limited success in achieving learning outcomes.	Qualitative; Yr 10 Australian students and Yr 12 Japanese students	2	61	2	Australia

35. Udo, M. E., & Etiubon, R. U. (2011). Computer-based science simulations, guided-discovery and students performance in chemistry. *Modern Applied Science, 5*(6), 211-217.

	Description	Other notes	Participant teachers	Participant students	Participant schools	Country
	A Nigerian study comparing the effectiveness of three pedagogical approaches to chemistry teaching on achievement: computer-based science simulations; guided discovery and expository teaching. The researchers found that computer-based science simulation software packages have a greater enhancing effect on students' performance. Achievement was also dependent on pedagogies employed.	Quantitative	3	89	3	Nigeria

36. Urhahne, D., Schanze, S., Bell, T., Mansfield, A., & Holmes, J. (2010). Role of the teacher in computer-supported collaborative inquiry learning. *International Journal of Science Education, 32*(2), 221-243

	Description	Other notes	Participant teachers	Participant students	Participant schools	Country
	This research focuses on the role of the teacher in inquiry based, collaborative learning activities that integrate ICT. A model is introduced to describe the central part that the teacher plays who "holds an equally active role as the learners themselves in technology-enhanced classrooms" p237. Additionally, the use of several online science instructional materials are demonstrated.	Qualitative. It is not clear where all classrooms are situated (Germany, Holland) 7 out of 8 participants are upper secondary	7			Germany

37. van Rooy, W. S. (2012). Using information and communication technology (ICT) to the maximum: Learning and teaching biology with limited digital technologies. *Research in Science and Technological Education, 30*(1), 65-80.

	Description	Other notes	Participant teachers	Participant students	Participant schools	Country
	An Australian study exploring the pedagogical decision making by experienced teachers when ICT resources are limited. A focus on multimodal digital representations and a consideration of the interchange of language between students and teachers is also presented.	Qualitative. Number of students not reported; at least 12 students in each class.	3	36	3	Australia

38. Varsavsky, C. (2012). Use of CAS in secondary school : a factor influencing the transition to university-level mathematics? *International Journal of Mathematical Education in Science and Technology, 43*(1), 33-42.

	Description	Other notes	Participant teachers	Participant students	Participant schools	Country
	This Australian study looked at whether CAS graphics calculators in upper secondary mathematics improved performance in undergraduate mathematics. Students without CAS showed a slight advantage; more important was students decision to take advanced-level mathematics. Not really grounded in use.	Qualitative				Australia

39. Williams, J.-L. (2009). Managing student conceptions about evolution using the integration of multiliteracies in the classroom. *Teaching Science, 55*(1), 10-14.

Description	Other notes	Participant teachers	Participant students	Participan t schools	Country
An Australian *intervention* study examined the influence of ICT supported learning activities on student misconceptions related to evolution. ICT-based learning objects (aligned to the prescribed syllabus) were developed. A range of pedagogies were employed that assisted student's in correcting misconceptions and meaning making of course content.	Qualitative	1	17	1	Australia

40. Williams, P. J. (2012). Investigating the feasibility of using digital representations of work for performance assessment in engineering. *International Journal of Technology and Design Education, 22*(2), 187-203

An Australian study reporting on the feasibility of using ICTs in high-stakes school-level performance assessment in Engineering Studies. It investigated authentic, valid and reliable assessment of outcomes that do not lend themselves to traditional pen-and-paper assessment. Additionally, the problem of summative, high-stakes marking (task judgement) was also considered. Several (not insurmountable) issues associated with the technologies and with differences in scores awarded by different marking methods were highlighted.	Mixed; Year 11	8	94	8	Australia

41. Xu, H. L., & Moloney, R. (2011). Perceptions of interactive whiteboard pedagogy in the teaching of Chinese language. *Australasian Journal of Educational Technology, 27*(2), 307-325

An Australian case study of the application of the interactive whiteboards in LOTE classrooms is presented. The ICT played a positive role in areas such as fostering collaboration and co-construction of meaning as well as visualisation of Chinese characters. aided recall. The teacher's disposition was also important in the successful integration of the IWB in the language classroom. Year 12 students were less receptive to the activities presented with the IWB.	Mixed; Years 10 - 12	1	18	1	Australia

42. Yang, S. C., & Chen, Y. J. (2007). Technology-enhanced language learning: A case study. *Computers in Human Behavior, 23*(1), 860-879

A Taiwanese study reporting on a technology-enhanced language learning (TELL) project. It involved a multimedia English learning environment and both synchronous and asynchronous discussion activities. It supported a number of pedagogical processes such as discussion, collaboration, communication and writing activities.	Mixed; 10th Grade (senior high school).	1	44	1	Taiwan

43. Yang, Y. C., & Wu, W. I. (2012). Digital storytelling for enhancing student academic achievement, critical thinking, and learning motivation: A year-long experimental study. *Computers and Education, 59*(2), 339-352

A Taiwanese study exploring the impact of digital storytelling (DST) on achievement, critical thinking and motivation in language learning. The use of the DST learning design significantly improved English proficiency, critical thinking and motivation and demonstrated collaborative second language learning environment.	Mixed; 10th Grade (senior high school)	1	110	1	Taiwan

	Description	Other notes	Participant teachers	Participant students	Participant schools	Country
44.	Young, S. S. C. (2003). Integrating ICT into second language education in a vocational high school. *Journal of Computer Assisted Learning, 19*(4), 447-461					
	A Taiwanese study that investigated 'potential impacts' of ICT-integration in language learning. An online learning environment was established to support computer-mediated English language communication in and out of school. It provides an useful example of 'Internet use' for language learning and raises several issues for further investigation, including the time-burden associated with teachers' preparation of digital materials.	Mixed; ('third-year high school students in a vocational senior high school)	1	29	1	Taiwan
45.	Yusuf, M. O., & Afolabi, A. O. (2010). Effects of computer assisted instruction (CAI) on secondary school students' performance in biology. *Turkish Online Journal of Educational Technology, 9*(1), 62-69.					
	A Nigerian study investigating the effect of a 2 ½ hour computer self-instructional, interactive package (designed by the authors) on performance in Biology. CAI was effective in enhancing performance, with students working cooperatively out-performing those working singly.	Quantitative; First year senior secondary school students		120	3	Nigeria
	Totals		1237	4546	482	

APPENDIX C: INTERVIEW PROTOCOL

The following was used to guide the dialogue during the semi-structured interview process for data collection for Phase 2 of the project.

Question Area	To gather data about:
1. General Questions a. Tell me about your teaching career (prompts: Training/Majors/Minors; Subject areas b. How many years have you been teaching/ teaching that subject. c. How long teaching at this school	CK
d. What are your students like? e. What is the technology like at your school? (Prompts: 1:1/labs etc./ IWBs available/Staff access) f. Does your school provide an intranet or course management system (LMS or CMS such as Moodle or Blackboard) for uploading resources or creating online resources & activities?	Context PK (knowledge of learners and learning)
g. Is there a means for parents to access their son/daughter's school work (E.g. online portfolios), assessment marks or academic reports?	Policy links – greater engagement with parent/parent portals.
2. Personal ICT use a. How would you rate your own ICT skill level & confidence? (prompts - Fix own HW or SW problems; connecting to wireless network; helping others with their problems)	TK - About technology; How to use different ICTs
b. Tell me about your own use of ICT? (Prompts – report writing/preparing resources)	TPK How ICT can be used in teaching
c. Are you using ICT to communicate or correspond with Colleagues (here or in other schools) – co-creating or sharing resources; d. Do you use ICT to communicate with parents (regarding student progress) e. Can parents access student class work, course resources (e.g. assessment schedules) or track student progress remotely f. Are you using ICT to communicate or correspond with students, e.g., providing student feedback	Policy links – greater engagement with parents/flexible learning environments

3. Current and recent experience a. Can you give me an overview of what you have been doing in [subject] recently? (Prompts: Topics; what area of the syllabus does that come from?)	CK Structure of their subject matter content PK Knowledge of relationship to syllabus – unit development/programming
b. Tell me about the types of learning activities or teaching strategies do you like to use when covering this this content/topic area/ unit of work? Prompts: Learning activities and Teaching strategies that work best with your students or content area	PK & PCK Differs depending on subject area and topics Combines teaching methods (PK) with knowledge of syllabus requirements (curriculum) with knowledge of learners & learning
c. Are ICTs supporting the delivery of these content/skill areas? d. Tell me about a lesson on [that topic area] where you have used ICT. (Prompts – Types of hardware, software or online tools; what were the students doing with the ICTs?/ How does it help delivery or understanding of that topic?)	TPACK Aware of ways that ICT can support high quality teaching in a curriculum area Content specific activities, topic specific representations using ICT Awareness of purpose for using ICT How students use & learn with ICT Is there evidence of "a way of thinking" of about T, P, C & relationships between them?
e. Where Is ICT used in other parts (units of work) of the course (Prompts: Topic area (connection to syllabus content/outcomes; Experiences that have been particularly successful or unsuccessful)	TPACK
f. Tell me about how you plan for those lessons/units that use ICT (What are you thinking about during that planning)	TPK affordances/constraints/ awareness of limitations Understanding that ICT can change teaching The use of technology as part of a pedagogical strategy

4. Online Resources a. What sort of online resources or activities do you use? b. Why is it appropriate/useful for that part of the syllabus c. What about resources or learning objects provided by *The Learning Federation* through the *Scootle* portal? d. How do you use your Intranet/Course management system	TK and TCK - How ICT can create new representations for specific content Applications of ICT that may change the way learners practice and understand concepts in a specific content area TPK - How ICT can change teaching Policy links – Online content provision
5. ICT Literacy a. What are your student's ICT skills like? b. Do you need to explicitly include ICT skills in your instruction (E.g. WP, SS, search engines, ethical use of resources)	?TCK → students must learn how to use the technology, particularly technologies that are specific to a given content area, in order to successfully implement it
6. Planning and lesson/unit preparation a. Is ICT explicitly included in your teaching programs or unit of work plans or registers? b. Do you prepare the course programs (No – faculty/ school/region prepares)?	PK and TPK - Unit development/programming Conception of the purposes for incorporating ICT in teaching
7. Assessment a. Tell me about the formal assessment used in [subject]. (Prompts: strategies & types; when are they used (what part of the course) b. Is ICT part of that strategy? (Prompts: What ICTs; what products are created; how does it help assess; c. How is it used – (In class, independent learning, own time, research, project management/support, collaboration, motivation, display) d. Does ICT feature in the marking criteria applied to your assessment tasks?	PK - Assessment strategies/BOS requirements TPK Creatively uses available ICT in a pedagogical context; Understanding of ICTs, their affordances & constraints
8. Potential Applications a. Is there anything that you would like to do with technology that you are not doing now? • What part of the course? • With particular teaching strategies	TPK Thinking critically about technology use in the classroom TPACK - Aware of ways ICT can support high quality teaching in curriculum areas Relationship between T, P & C (interdependence)

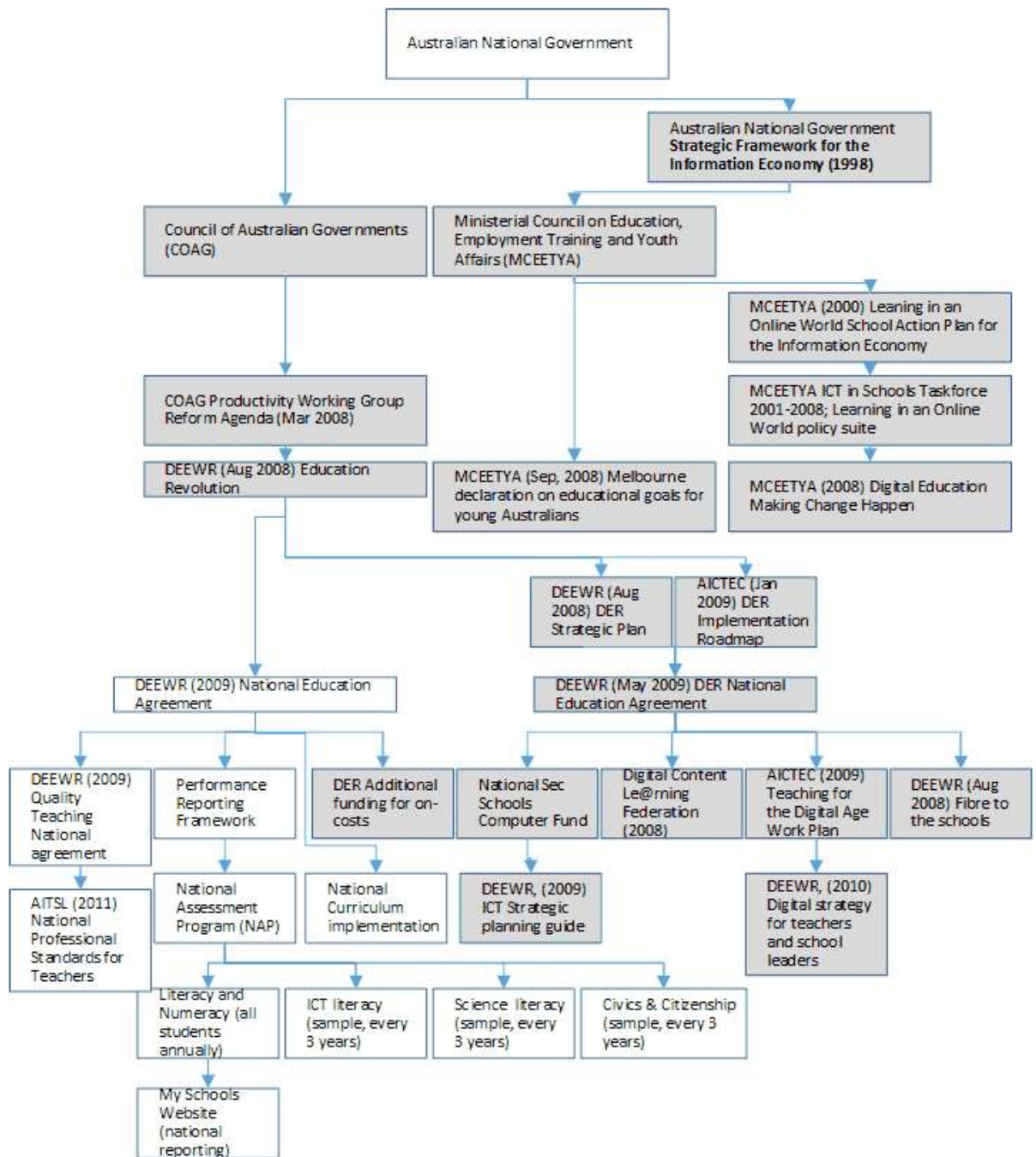|	
9. Policy Links/ beliefs a. Do you feel there are benefits to (i) students; (ii) teachers in embedding ICT in your curriculum area	

Figure 12: Visualisation of the policy field active during Australia's Digital Education revolution. DER-specific documents and agencies are shaded. Other policy agendas are included to illustrate concurrent initiatives that were underway.

The earliest part of this research project involved a policy analysis focusing on ICT-integration in schools. The search for documents began prior to the announcement of the Digital Education Revolution (DER) policy agenda. The exploratory stage

involved looking at policy that was informing curriculum related to ICT education, policy that had a focus for technology use in schools and policy aimed at teaching and learning with technologies.

The following list of government documents were analysed using a framework informed by Fullan's (2007) characteristics of change as described in the methodology (Section 4.4.2). Although many were not cited in the final results paper presented in Chapter 4, they were important in developing a historical picture of the development of ICT education in the Australian context. Their analysis provided a background that informed thinking about DER policy that became the main focus for Phase 1 of the investigation. Policy documents relating to Australia's Digital Education Revolution are highlighted.

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Summary of Comments on MinisterStatement1.indd

Page: 1

Number: 1
Australia NEEDS 'technology enriched learning environments that enable students to achieve high quality learning outcomes and productively contribute to our society and our economy.

Therefore ICTs are needed because they are integral to contemporary society; they are powerful tools for education; They enable transformation of the curriculum and the way learners and educators operate, learn and interact

Number: 2
Clarity - not an implementation plan but a vision where ICT has transformed curriculum, learning and teaching.

Number: 3

Number: 4
CLARITY - a vision for the future - students will learn in 'technology rich learning environments'

Number: 5
COMPLEXITY - secure and robust infrastructure

- an indication that software, computers, ICT equipment, network systems, tech support, high speed broadband and online services will be provisioned

Number: 6
COMPLEXITY
-cross sectoral collaboration (Independent, Catholic and Govt Schools) means ICT systems need to work together and PEOPLE need to work together - complex array of activity

CLARITY - teachers and learners will access discoverable and shareable digital repositories of resources
Also COMPLEXITY - change to resources

Number: 7
CLARITY - the vision for the future
Teachers will deliver 'world class education'

Number: 8
CLARITY - the vision - what teachers will do: 'Educators will enhance twenty first century student learning outcomes by effectively and ethically incorporating ICT into their teaching and learning programmes and methods and collaborating in the creation of flexible learning environments

Do we have 21C learning outcomes already in our curricular?

COMPLEXITY - teachers need a definition, ICT skills and pedagogies that can support the creation of 'flexible learning environments' as well as good school leadership that also understands these concepts.

Number: 9
COMPLEXITY
Teachers will require ICT skills and how to use
-pedagogies that use ICT to facilitate 'new forms of learning'
-pedagogies that use ICT to support 'collaboration, innovation and communication'
-practices that use ICTs to support 'learning that is personalised'

Joint Ministerial Statement on Information and Communications Technologies in Australian Education and Training: 2008-2011

Australia will have technology enriched learning environments that enable students to achieve high quality learning outcomes and productively contribute to our society and economy.

Developing the potential of all learners to be confident, informed citizens, equipped for success and for contributing to Australia's society and economy, is central to Australia's education and training goals. These are outlined in the Education Revolution (2007), the Digital Education Revolution (2008-12) and jurisdictional and sectoral policies

The provision of world class education and training is fundamental to ensuring learners have the skills and knowledge required for success. Education and training environments must effectively respond to society's changing expectations, promote life long learning and broaden options for learners that create pathways to productive and new careers

Information and Communications Technologies (ICT) are integral to contemporary society. Technologies are powerful tools for education and training. They are enabling the transformation of the curriculum and changing the way learners and educators operate, learn and interact. Technologies provide the potential to enable access to: nationally consistent curriculum, collaborative communication and knowledge building tools; flexible and distance learning opportunities; seamless transition of students and information within and between institutions; engaging learning materials; online services and repositories of knowledge.

Technology rich learning environments will be underpinned by a secure and robust infrastructure, where software, computers and ICT equipment, networked systems, technical support and access to high speed broadband and online services, will support educators in the delivery of world class education and training. Jurisdictional and cross sectoral access to networks and digital repositories of resources that are affordable, reusable, discoverable and shareable, will be supported by policy, sustainable resourcing and technical systems and standards that enable the building and exchange of knowledge and resources.

Educators will enhance twenty first century student learning outcomes by effectively and ethically incorporating ICT into their teaching and learning programmes and methods and collaborating in the creation of flexible learning environments. To that end, educators will be supported to enhance their ICT capabilities. Leadership will be key to achieving this.

Learners are active participants in knowledge creation and will engage with state of the art tools which enable new forms of learning, collaboration, innovation and communication. Learning will be personalised, and not restricted by place or time.

To achieve this, Ministers of education and training commit to:
- National collaboration across Australian education and training jurisdictions and sectors to share resources and expertise, and to leverage existing initiatives while recognising the importance of innovation and experimentation.
- National, cross jurisdictional and cross sectoral approaches through the Australian ICT in Education Committee to address the ICT enablers of technology rich learning environments: developing educators' capabilities; access to computers and ICT equipment; secure and robust infrastructure, including broadband; systems and architectures that support access, transfer and sharing of information within and between institutions; and affordable access to appropriate online learning resources.

MINISTERIAL COUNCIL ON EDUCATION, EMPLOYMENT, TRAINING AND YOUTH AFFAIRS

ENDORSED JUNE 2008

MINISTERIAL COUNCIL FOR VOCATIONAL AND TECHNICAL EDUCATION

APPENDIX F: THEMATIC ANALYSIS OF POLICY DOCUMENTS

Table 29: Format of the grid used to organise data during thematic analysis of policy documents – for example, (MCEETYA, 2008c): Melbourne Declaration on Educational Goals for Young Australians

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	DEEWR (2008). Quality Education: The case for an Education Revolution in our Schools.	**DEEWR (2008). Success through partnership. Achieving a national vision for ICT in schools Strategic Plan to guide the implementation of the DER**	**MCEETYA (2008). Melbourne declaration on educational goals for young Australians**
N E E D	*Released in 2008 following the election of the Labour Govt to outline the Government's election promise of an 'Education Revolution' for Australia. The purpose of Quality Education is to justify the need for the Education Revolution in Australia.* - almost entirely focussed on justifying why major changes to school education are warranted. -Reform is needed quality teaching; increasing attainment levels, retention rates and engagement and transitions for students, particularly those in disadvantaged communities; and improvements in accountability and transparency in school systems. There are many statistics and referenced papers offered to justify the benefits of education such as the relationship between school attainment and employment and wages (pg 9) and social economic status, numeracy and literacy levels and Year 12 completion rates. The main justification for change the need for more productivity to invest in the skills of the workforce in order to promote economic growth in order to build human/social capital and promote higher living standards.	-Only a minority of teachers and students are reaping the full benefits of the information technology revolution -Collaboration between governments to develop Australia's human capital and productivity – DER provides a once-in-a-generation opportunity to establish and enable a future-directed vision for education in Australia -Digital techs should play a role in delivering better education outcomes -Aust students should be confident, creative and productive users of new technologies, particularly ICT' (Adelaide Dec) Like earlier (pre 2007) ICT education documents, *The Plan* acknowledges Goal 1.6 (Adelaide Dec) and continues the theme of transformation of education through ICT. Reference is made to the 2000 *Learning in an Online World* action plan and concedes that 'progress to date has been slow'.	The Melbourne Declaration continues the Common and Agreed National Goals for Schooling initially set down in 1989 in the Hobart Declaration and in 1999 in the Adelaide Declaration. The update is needed because of new demands on Australian education brought about by major changes over the last decade including greater global integration and mobility; Asian nation influence on the world and Australia; globalisation and technological change; environmental and economic pressures; and advancement of ICT. There is an acknowledgement by the Ministers that "Melbourne Declaration is highly congruent with the COAG Productivity Agenda outcomes agreed by first ministers"(Tas Govt 2008). *A need for Successful learners that have the essential skills in literacy and numeracy and are creative and productive users of technology, especially ICT, as a foundation for success in all learning areas. pg 9*
C L A R I T Y	The Government has stated many admirable goals in *Quality Education;* however this is a 'big picture' statement document and details about how the vision will be obtained are scarce; $1.2 billion Digital Education Revolution, the Australian Government is providing $11.5 million to support professional development in information and communication technology, and $32.6 million over two years to supply students and teachers with online curriculum tools and resources National Partnership on Quality Teaching -clear national standards against which teachers can be accredited. All students have access to a comprehensive national curriculum that sets out the knowledge, understanding, skills and values they should acquire	This document is intended to be an implementation plan. Consequently, there are many references to what the vision for ICT in education would mean in practice. 'A vision for ICT enabled learning' and how the DER will contribute to the achievement of this vision. In practice: - Students undertake challenging and stimulated learning activities; supported by access to global information resources & powerful tools for information processing, communication and collaboration - Teachers devise student centric programs of learning - Parents support student in their learning - Commitment to national ICT infrastructure - Access to National Curriculum - Access to ICT PD DER will provide computers – NSSCF; high speed broadband connections; online content; web portals for parents Four strands of change – leadership, infrastructure, learning resources, teacher capability Table 1 sets out aspiration goals of the strategic plan that illustrate what ICT in education would look like,	ICT features as an action area for curriculum reform: ensure world-class curriculum in Australia to enable every student to develop: a foundation for further learning and adult life including practical knowledge and skills development in areas such as ICT and design and technology, which are central to Australia's skilled economy and provide crucial pathways to post-school success. Although ICT was listed as a cross-disciplinary area in Federalist Paper 2, it seems to have been upgraded to a Learning Area in its own right under the title *Information and Communication Technology and Design and Technology.* This clearly continues importance of ICT in school education and suggests that ICTs role throughout the curriculum will be strengthened via the National Curriculum.

Education & Training
NSW GOVERNMENT

Mrs Debra Bourne
Faculty of Education
University of Wollongong
Northfields Ave
WOLLONGONG NSW 2522

DOC 11/62225

Dear Mrs Bourne

SERAP Number 1010197

I refer to your application to conduct a research project in New South Wales government schools entitled *An Investigation of ICT Implementation in NSW Senior Secondary Education*. I am pleased to inform you that your application has been approved. You may now contact the Principals of the nominated schools to seek their participation. You should include a copy of this letter with the documents you send to schools.

This approval will remain valid until 02/03/2012.

No researchers or research assistants have been screened to interact with or observe children for the purposes of this research.

I draw your attention to the following requirements for all researchers in New South Wales government schools:

- School Principals have the right to withdraw the school from the study at any time. The approval of the Principal for the specific method of gathering information for the school must also be sought.
- The privacy of the school and the students is to be protected.
- The participation of teachers and students must be voluntary and must be at the school's convenience.
- Any proposal to publish the outcomes of the study should be discussed with the Research Approvals Officer before publication proceeds.

When your study is completed please forward your report marked to Manager, Schooling Research, Department of Education and Training, Locked Bag 53, Darlinghurst, NSW 2010.

Yours sincerely

Dr Max Smith
Senior Manager
Student Engagement and Program Evaluation
14 April 2011

NSW Department of Education & Training – Student Engagement and Program Evaluation Bureau
Level 1, Oxford St, Darlinghurst, NSW 2010 T 9244 5619 F 9266 8233 serap@det.nsw.edu.au

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**APPENDIX H: ETHICS APPROVAL – UNIVERSITY OF WOLLONGONG
HUMAN RESEARCH ETHICS COMMITTEE**

University of Wollongong

9 March 2011

Mrs Debra Bourne
Faculty of Education
University of Wollongong

Dear Mrs Bourne

I am pleased to advise that the application has been approved and forwarded to the Department of Education and Training for approval of your SERAP application.

Ethics Number:	HE11/072
SERAP No:	2010197
Project Title:	An Investigation of ICT implementation in NSW Senior Secondary Education
Researchers:	Mrs Debra Bourne, Professor Susan Bennett
Approval Date:	3 March 2011
Expiry Date:	2 March 2012

The University of Wollongong/SESIAHS Humanities, Social Science and Behavioural HREC is constituted and functions in accordance with the NHMRC *National Statement on Ethical Conduct in Human Research*. The HREC has reviewed the research proposal for compliance with the *National Statement* and approval of this project is conditional upon your continuing compliance with this document. As evidence of continuing compliance, the Human Research Ethics Committee requires that researchers immediately report:

- proposed changes to the protocol including changes to investigators involved
- serious or unexpected adverse effects on participants
- unforseen events that might affect continued ethical acceptability of the project.

You are also required to complete monitoring reports annually and at the end of your project. These reports are sent out approximately 6 weeks prior to the date your ethics approval expires. The reports must be completed, signed by the appropriate Head of School, and returned to the Research Services Office prior to the expiry date.

Yours sincerely

A/Professor Garry Hoban
Chair, Human Research Ethics Committee

cc: Professor Susan Bennett, Faculty of Education

APPENDIX I: SCHOOL PARTICIPANT INFORMATION PACK

Letter to Principals

University of Wollongong

LETTER TO PRINCIPAL

TITLE: *An investigation of ICT implementation in NSW Senior Secondary Education*

Teachers at your school have been invited to participate in a research project conducted by Debra Bourne. It is part of a PhD being supervised by Associate Professor Sue Bennett from the Faculty of Education. The project is investigating how senior secondary educators use Information and Communication Technologies (ICTs) in their teaching and in supporting student learning.

The information from the study will improve our understanding of ICT-integration in the context of senior secondary education and may guide practice or professional development programs with ICT to better support the learning of HSC students. We will report the results of the study in a PhD dissertation and through relevant professional conferences and journals.

Approval is sought to visit the school for one day. At this visit a researcher would like to interview teachers who agree to participate for approximately 60 minutes each. Typical questions will focus on the types of ICT used; teaching strategies and ICT related professional development undertaken. Confidentiality is assured, and the school and staff involved will not be identified in any part of the published research. Please find attached to this letter the Participant Information Sheets for the teachers.

Teachers' involvement with the study is voluntary. They may withdraw their participation from the study at any time, even after the study or interview has started. Their decision not to take part will not affect their or the school's relationship with the University of Wollongong or the Department of Education. Interview times will be organised that are convenient to the teacher and the school. If a suitable time cannot be organised for a face-to-face interview, then a telephone interview can take place.

We would ask that you or your administration staff distribute the information sheets included to the Year 11 and 12 teachers in your school.

This study has been reviewed by the Human Research Ethics Committee (Social Science, Humanities and Behavioural Science) of the University of Wollongong. If you have any concerns or complaints regarding the way this research has been conducted, you can contact the UoW Ethics Officer on (02) 4221 4457.When you have read this information Debra Bourne or any members of the research team are available to answer any questions you may have.

Debra Bourne	Associate Professor Sue Bennett	Professor Lori Lockyer
Researcher		Faculty of Education
Faculty of Education	Principal Supervisor	Supervisor
University of Wollongong	Faculty of Education	University of Wollongong
Northfields Ave	University of Wollongong	Northfields Ave
NSW, 2522 Australia	Northfields Ave	NSW, 2522 Australia
0408968291	NSW, 2522 Australia	42215511;
dtb389@uow.edu.au	42215738;	llockyer@uow.edu.au
	sbennett@uow.edu.au	

Information Sheet for Teachers

University of Wollongong

PARTICIPATION INFORMATION SHEET FOR TEACHERS

TITLE: *An investigation of ICT implementation in NSW Senior Secondary Education*

The study is being conducted by Debra Bourne. It is part of a PhD being supervised by Associate Professor Sue Bennett from the Faculty of Education. We are inviting you to take part in a project that is trying to find out how senior secondary educators use Information and Communication Technologies (ICTs) in their teaching and in supporting student learning.

The information from the study will improve our understanding of ICT-integration in the context of senior secondary education and may guide practice or professional development programs with ICT to better support the learning of HSC students. We will report the results of the study in a PhD dissertation and through relevant professional conferences and journals.

If you choose to be included, you will be asked to participate in an interview with a member of the research team. We will organise a time that is convenient to you and conduct an interview. If a suitable time cannot be organised for a face-to-face interview, then a telephone interview can take place.

The interviewer will ask you questions about your experiences with ICTs in your senior classes. Questions will cover topics like your reasons for using ICT, the types of ICT you use and how it supports learning; teaching strategies that support ICT use with students and lesson/unit planning with ICTs. The interview is expected to take approximately 60 minutes of your time.

Your involvement in the study is voluntary and will only take place if you agree. You may withdraw from the study at any time. If you do decide not to take part, it will not affect your relationship with the University of Wollongong, the Department of Education or the School. If you change your mind about taking part, even after the study has started, just let the researcher know verbally or by email or even during the interview and any information already collected will be destroyed. No-one will be able to identify you or your school from the results of the study

Data will be collected during the interview as written notes and as a digital audio recording. We will use the recordings to transcribe the interview. The notes, recordings and transcripts will be secured in Associate Professor Sue Bennett's office (the principal supervisor) at the University of Wollongong. After 5 years, the data will be destroyed. Only the researchers will have access to this information during the study and storage period. If you would like to check that you are OK with the information collected about you, contact the researchers and request copies of your recording or transcript.

This study has been reviewed by the Human Research Ethics Committee (Social Science, Humanities and Behavioural Science) of the University of Wollongong. If you have any concerns or complaints regarding the way this research has been conducted, you can contact the UoW Ethics Officer on (02) 4221 4457. When you have read this information Debra Bourne or any members of the research team are available to answer any questions you may have.

Debra Bourne	Associate Professor Sue Bennett	Professor Lori Lockyer
Researcher	Principal Supervisor	Faculty of Education
Faculty of Education	Faculty of Education	Supervisor
University of Wollongong	University of Wollongong	University of Wollongong
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0408968291	42215738; sbennett@uow.edu.au	42215511;
dtb389@uow.edu.au		llockyer@uow.edu.au

Participant consent form

University of Wollongong

CONSENT FORM FOR TEACHERS

AN INVESTIGATION OF ICT IMPLEMENTATION IN NSW SENIOR SECONDARY EDUCATION

DEBRA BOURNE

I have been given information about the study *"An Investigation of ICT Implementation in NSW Senior Secondary Education"* and discussed the research project with Debra Bourne who is conducting this research as part of a Doctor of Philosophy degree supervised by Associate Professor Sue Bennett in the Department of Education at the University of Wollongong.

I have been advised of the potential risks and burdens associated with this research, which include undertaking a 60 minute interview that will collect information about your experiences with Information and Communication Technologies (ICT) as a senior secondary teacher. I have had an opportunity to ask Debra Bourne any questions I may have about the research and my participation.

I understand that my participation in this research is voluntary, I am free to refuse to participate and I am free to withdraw from the research at any time. My refusal to participate or withdrawal of consent will not affect my relationship with the University of Wollongong.

If I have any enquiries about the research, I can contact Debra Bourne on 0408968291 or Associate Professor Sue Bennett on 42215738 or if I have any concerns or complaints regarding the way the research is or has been conducted, I can contact the Ethics Officer, Human Research Ethics Committee, Office of Research, University of Wollongong on 4221 4457.

By signing below I am indicating my consent to participate in the research through an audio recorded interview with the researcher asking me about my work and teaching experiences. I understand that the data collected from my participation will be used primarily for a PhD thesis, and will also be used in summary form for journal publication, and I consent for it to be used in that manner.

Signed   *Date*

..../......./......

Name (please print)

....