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Learning in a digitally connected classroom: Secondary science teachers' pedagogical reasoning and practices

Julie Boston
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Learning in a digitally connected classroom: Secondary science teachers' pedagogical reasoning and practices

This thesis is presented for the degree of
Doctor of Philosophy

Julie Boston

Edith Cowan University
School of Education
2019

Emeritus Professor Mark Hackling
Associate Professor Geoffrey W. Lummis

Preface

Apparently, I was born asking why, how, when, and where so it came as no surprise this curious nature developed into a passion for science. Originally having qualified with a Bachelor of Science (Biochemistry) and a Graduate Diploma of Education, I eventually became a high school science teacher, and later Acting Head of Learning Area (HOLA) of a Science Department. I attained the status of a Level 3 Classroom Teacher, a Department of Education of Western Australia (DoE) qualification recognising exemplary teaching practices. My passion for sharing the wonder of science and its benefit to society resulted in being the recipient of some significant teaching awards, including Premier's Teacher of the Year, Western Australian Education Awards (2009) and a National Excellence in Teaching Award (NeiTA) for Western Australia (2009).

I now share this passion for science and teaching experience as a science education specialist at an Australian university where I am involved in the initial and post-service teacher education of teachers. Science, technology, and innovation are highly interdependent, where science can be a direct source of technological innovation and vice versa. It is this, the importance of preparing teachers to educate students for a technologically driven and digitally connected world that set the scene for this thesis.

Notes on Style

Throughout this thesis italicised text is used to denote specific brand names for both technological hardware and software applications. For consistency, references to the Australian Curriculum, Assessment and Reporting Authority (ACARA) science curriculum study area will use the words *Australian Curriculum: Science*. Throughout Chapters Four, Five and Six, italicised text is used to denote vignettes of data shared by the participants during observations and interviews to distinguish between participant voices and information quoted from the literature.

Abstract

Despite decades of research surrounding Information Communication Technology (ICT) use in schools, the pedagogical reasoning required to provide meaningful ICT enabled learning opportunities is rarely analysed in the literature. The purpose of this research was therefore to investigate teachers' pedagogically reasoned practice. This study involved three exemplary Australian secondary science teachers, renowned for their expertise in utilising ICT working in classrooms where students had school issued one-to-one computers and reliable network access. The research utilised qualitative methods, including semistructured interviews, video-based observational data, and an array of lesson artefacts. The study followed a naturalistic multiple-case study design to explore the pedagogical reasoning and actions of these science teachers.

The study identified different forms of pedagogical reasoning and action for a digitally connected world. Many aspects of this iterative model bear close resemblance to Shulman's (1987) original conception of pedagogical reasoning and action. In each case, sophisticated reasoned decision-making drawing upon a range of teacher knowledge bases, most notably technological pedagogical content knowledge took place. The pedagogical reasoning and action model presented demonstrates a backward mapping approach where the use of ICT was directed at supporting the development of scientific content and educational outcomes of the mandated science curriculum. The research also found that these teachers held social constructivist beliefs for the use of ICT and intentionally designed ICT enabled opportunities from a learning affordance perspective. The research also demonstrated a reflexive relationship between the teacher's beliefs and their pedagogical practices. Teacher activity involved significant preparatory work in the selection and curation of motivating, authoritative and multimodal Internet accessible ICT resources and tools aligned to the mandated science curriculum. In each case, the teachers had purposefully created a customised classroom online presence or website, offering students a flexible learning environment, an uncommon practice at the time of the study.

The teachers designed ICT enabled learning opportunities following a guided inquiry model, frequently involving collaborative problem-based strategies. In each case, the students were the dominant users of ICT in the classroom using ICT for discovering knowledge, constructing knowledge and for sharing knowledge. The teachers' role was

predominantly one of orchestration of the learning environment, scaffolding and questioning students as they engaged with guided inquiry-based learning tasks.

Ultimately the research revealed the critical role of the teacher in mediating the affordances of ICT for meaningful learning. Overall the findings offer useful insights into how exemplary science teachers' reason and act about the use of ICT in a digitally connected classroom. An important implication for the development of initial science teacher education programs arose from the study, notably that preservice teachers require ongoing and authentic course opportunities to support the development of the technology, pedagogy, and content knowledge relevant for a digitally connected classroom.

Declaration

I certify that this thesis does not, to the best of my knowledge and belief:

- i. Incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education;
- ii. Contain any material previously published or written by another person except where due reference is made in the text; or
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Signature:

Date: 20 December 2019

Dedication

This thesis is dedicated to the late Associate Professor Paul Newhouse, Edith Cowan University, whose academic work in this field helped inspire this thesis. I will be forever grateful to you Paul. Your calmness, kindness, generosity, and your intellect made working with you a true pleasure and a privilege.

Acknowledgements

Emeritus Professor Mark Hackling your eloquence, patience, and your superb academic mentorship are the reason I kept going. I hope to emulate you one day.

Associate Professor Geoff Lummis, ditto. Saying thank you to you both somehow seems inadequate. Your efforts to jump in Geoff and help see this thesis through during the tragic loss of Associate Professor Paul Newhouse have made this journey seem worthwhile. Mark, Paul, and Geoff, without your first-class guidance this thesis was simply not possible.

I would also like to give my deepest thanks to Associate Professor Karen Murcia who offered me the incredible chance to commence my academic career and for her mentorship in getting this thesis out of the starting gates.

To the participants of the study; it was a privilege to witness your exemplary practice which you shared so generously, consequently providing me with a rich reservoir of data that could be analysed; along with many ideas to inspire my practice and that of the many teachers with whom I now engage.

Finally, to Keely and Indiya, the loves of my life, I am so excited to be back and be more present in your lives as your Mum. And, to my own Mum and Dad, your unwavering love, support, and belief that I could do it, even when at times I did not think this was possible; and the rest of my beautiful family and gorgeous friends, I am just so very lucky to have you all in my life.

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Glossary of Terms

The following definitions and acronyms are applied throughout this thesis which is consistent with the wider Australian education sector. It is acknowledged this terminology may differ from that used overseas.

ACARA	Australian Curriculum, Assessment and Reporting Authority. An Australian national government body charged with the responsibility for a national curriculum, assessment and reporting program for Kindergarten to Year 12. https://www.acara.edu.au/
AICTEC	Australian Information and Communications Technology in Education Committee. An Australian national, cross-sectoral committee established in 2008 to provide advice to all Australian Ministers of Education and Training on the effective utilisation of information and communications technologies in Australian education and training.
AITSL	Australian Institute for Teaching and School Leadership. An Australian government endorsed body, established in 2010, to provide leadership across the Australian, State and Territory Governments and whom is responsible for developing and promoting the national professional standards for teachers and school leaders. https://www.aitsl.edu.au/
ATAR	Australian Tertiary Ranking. An ATAR refers to the ranking number which determines student's entry into undergraduate university programs. It is calculated based on the sum of the four highest scoring subjects that the student has completed at a Year 12 standard.

BYOD	Bring Your Own Device (BYOD). A policy adopted by many schools permitting students to bring personally owned digital devices to school for educational purposes.
COAG	Council of Australian Governments. An Australian government body, chaired by the Prime Minister, which focuses on improving the current and future wellbeing of all Australians. https://www.coag.gov.au/
DER program	Digital Education Revolution program. A collection of Australian Government policy documents, commencing in 2008, that committed more than \$2.4 billion to enhance the integration of information and communication technology (ICT) into teaching and learning in Australian schools. This intervention involved investment in computers and software, school-based infrastructure, leadership, professional development and digital resources across all Australian education systems and sectors. A key objective of the DER initiative was to provide every student in Years 9–12 with access to technology required for contemporary learning to ‘contribute sustainable and meaningful change to teaching and learning in Australian schools that will prepare students for further education, training and to live and work in a digital world’ (DEEWR, 2011).
DoE	Department of Education; in this thesis referring to Department of Education, Western Australia.
HOLA	Head of Learning Area. A title often afforded to the head of a curriculum disciplinary area in a K-12 school setting.
html	Hyper Text Markup Language. This is the main language used for building web pages.

ICT	Information communication technologies. This covers any product that will store, retrieve, manipulate, transmit or receive information electronically in a digital format.
Internet	Refers to the ultimate network infrastructure that connects all networked computers around the world to one another.
K-12	Kindergarten to Year 12. A short form term often used in Australian education to refer to school grades, kindergarten (K), the 1 st grade through the last year, 12th grade (12).
LMS	Learning Management System. A type of software application used to administer, track, and deliver online learning and training.
Multimedia	As used in this thesis, multimedia pertains to media and content that uses a combination of different forms such as; text, audio, video, still images or animation.
NSSCF	The National Secondary School Computer Fund was the main component of the \$2.4 billion DER program used to provide information and communication technology (ICT) equipment for all secondary schools with students in Years 9 to 12.
PCK	Pedagogical content knowledge. A theoretical framework to understand and describe the complex knowledge base that teachers draw upon to make subject knowledge comprehensible to learners (Shulman, 1986).
SCASA	School Curriculum and Standards Authority, the Western Australian governing authority for K-12 curriculum, assessment, standards and reporting for all Western Australian Schools https://www.scsa.wa.edu.au/

TPACK	Technological pedagogical and content knowledge. A theoretical framework to understand and describe the kinds of knowledge needed by a teacher for the meaningful use of ICT in a technology enhanced learning environment (Mishra & Koehler, 2007).
URLs	Uniform resource locators. A specific protocol for locating a website, commonly referred to as a web address.
WA	Western Australia. A state of Australia where this present research was conducted.
WACE	Western Australian Certificate of Education. This nationally accredited certificate is awarded to senior secondary school students who complete two years of senior secondary study, normally in Years 11 and 12. https://senior-secondary.scsa.wa.edu.au/the-wace
www	The world wide web, or more commonly referred to as the Web, is a subset of the Internet system that links websites and users around the world using the hypertext transfer protocol (HTTP) allowing users to access networked information and media via their computer

CHAPTER ONE: Introduction

For over 40 years educational research (Tamin, Bernard, Borokhovski, Abrami, & Schmid, 2011) have grappled with understanding the integration of technology and how it facilitates student learning. In Australia, massive investments in Information and Communication Technologies (ICTs) have been made over the past decade, specifically for use by teachers and students in schools (Digital Education Advisory Group, 2013). This investment was expected to transform the classroom into a learner-centered environment, where ICT provided more affordable possibilities for authentic learning in schools and to support the acquisition of 21st century skills (Australian Information and Communications Technology in Education Committee (AICTEC), 2009). However, this chapter establishes that meaningful ICT use does not emerge unplanned, and can provide a range of instructional options to support learning only when purposefully thought out and guided by teachers.

The term Information and Communication Technology (ICT) has different interpretations in different countries, however, as used throughout this study the term ICT is used to encompass the range of digital hardware, for example, desktop computers and mobile computers such as laptops, tablets and smartphones; television, projectors, interactive whiteboards; as well as the diverse range of digital systems, often accessed via the Internet which allows or enhances the storage, processing, presentation, and communication of information between people. The term ICT is often used interchangeably with technology and is used in this way in this study. This research primarily examined science teachers' pedagogical reasoning and practices in providing ICT enabled learning in secondary science classrooms when provisioned in a one-to-one laptop environment.

This introductory chapter establishes the current context and key drivers of ICT use in Australian secondary schools. It describes the research and provides a rationale for conducting the study, as well as presenting the research questions. This is followed by an overview of the ensuing chapters.

1.1 Learning science in a digitally connected world

Interaction with the Internet, the ultimate network connecting all computer networks, is now taken for granted in our everyday lives for work and play. The worldwide web, or Web for short, a term often confused with the Internet, was developed by Tim Berners-Lee, a computer scientist at CERN in 1989 (World Wide Web Foundation, 2018) allowing computer users a simplified system to directly access the Internet. This led to a proliferation of Internet services such as instant messaging and electronic mail (email) revolutionising telecommunication for businesses and governments. The Internet continues to grow along with more innovative services created and driven by ever greater amounts of online information. Presently the Web is commonly referred to as Web 2.0, or the interactive or the social web, allowing people around the world to collaborate in real-time. With the growing popularity of smart mobile devices along with the *Internet of Things* era, we are presently moving towards a more artificially intelligent Web, a version known as Web 3.0 or the semantic web, bringing further transformative potential to how work, play and learning may occur in the future.

It is fair to say the current cohort of school students has a digital expectancy (Howell, 2012) to use technologies as part of their learning, having been born into a digital world. The present Australian Bureau of Statistics (ABS) research conducted during 2014 and 2015 revealed that 85% of Australians were Internet users, with digital technology use highest amongst people 15-17 years of age (99%) (Smart, 2018). A range of reports, highlighting trends in the Australian economy and workforce, emphasised the importance of preparing children for a digitised future through the acquisition of specific intellectual and creative skills and social competencies, commonly referred to as 21st century skills, for what is now being termed the Information Age (Committee for Economic Development of Australia (CEDA), 2015; Deloitte Access Economics, 2015). The Foundation for Young Australians report (FYA Foundation for Young Australians, 2017) recently analysed over 20 billion hours of work completed by 12 million Australian workers and concluded that as new digital technologies develop this will lead to the disruption of existing business models and affect the value proposition of existing goods and services resulting in significant work implications for young Australians. The assertion proposed by FYA (2017) that education systems equip students with new ‘work

smarts' in preparation for the Information Age. The Internet is clearly positioned as both a potent driver of the Information Age and a significant disruptor to economies and therefore the impetus behind world-wide whole-of-government approaches to intensify educational access.

Hackling (2015) amongst others, has been arguing that the unprecedented digital disruption to the global economy requires urgent reform of the Science, Technology, Engineering, and Mathematics (STEM) curriculum and their pedagogies so that educators need to consider both what children should learn, and how they should learn in preparation for an Information-based society. The unprecedented level of networked access to the Internet in the Australian secondary school education setting as provisioned by the Australian Governments Digital Education Revolution (DER) since 2008 requires education professionals to think differently as to how they might perform their job (MCEETYA, 2005, 2008, 2009). Other significant drivers of digital expectancy in the Australian classroom include the range of educational policy frameworks, driving the reform of curriculum and teaching practice given the increasing digitisation of the world (MCEETYA, 2008). This includes a technology-based reform effort to promote collaborative learning approaches, particularly project and inquiry-based strategies, where knowledge building is focused on higher-order thinking skills, and where students are viewed as creators rather than consumers of information (Istance & Kools, 2013). However, as noted, existing research highlights a significant gap between this transformative vision and how ICT is leveraged in the classroom to create these types of learner-centered and knowledge building learning environments (Law, Pelgrum, & Plomp, 2008; OECD, 2015) suggesting more teacher-related factors are at play (Law et al., 2008; OECD, 2010a, 2010b, 2013a, 2015).

There is general agreement in the literature that learning how to interpret the diverse ways that science is represented for example, texts, diagrams, models, tables etc. is a highly complex endeavour for students (Carolan, Prain, & Waldrip, 2008). Evidence would also suggest that students scientific literacy benefits greatly from being offered many opportunities to construct representations of their developing ideas of science topics (Hubber, Tytler, & Chittleborough, 2018). This is strengthened when coupled with a pedagogy involving discursive classroom interaction so the teacher and students engage in meaningful discussion to clarify and refine the representation (Tytler & Aranda, 2015).

It has been demonstrated for some time that ICTs can increase the range of authentic and relevant opportunities to visualise, collect, process, analyse, evaluate and communicate scientific understandings (Anderson & Barnett, 2013; Beauchamp & Kennewell, 2008; Becta, 2003; Jonassen, Carr, & Yueh, 1998; Linn & Hsi, 2000; Webb, 2005). The multimodal and interactive nature of the freely available Internet based ICT resources and multimedia tools is showing much promise in engaging and supporting learners to actively construct scientific representations (Becta, 2007). Access to the Internet can also afford opportunities for authentic collaboration between students and professional scientists including access to real-world data (Osborne & Hennessy, 2003). Furthermore, a significant array of physical technologies now exists to collect experimental and observational data such as data loggers and probes, digital microscopes, and gel electrophoresis kits, affording students opportunities to practice science much as it occurs in the real world.

It has also been shown for some time that the meaningful integration of ICT in the science classroom can provide a greater capacity for teachers to support pedagogical practices such as problem-based and project-based learning (Mistler-Jackson & Songer, 2000) allowing students to actively construct knowledge (science content) and develop higher-order thinking skills in more authentic ways (Hmelo-Silver, 2004). More recently the call has been to engage students in digitally connected classrooms with problem-based approaches by involving students with real-world problems (Newhouse, 2016). In this study, the primary focus was on the use of student laptops to facilitate meaningful science learning opportunities including the array of visualisation, simulation, and digital media creation tools, consequently vastly increasing the range of options for students to engage with the scientific phenomenon and to creatively demonstrate and communicate their scientific understandings.

Analysis of teacher's responses to ICTs in the classroom reveal complexities associated with changing pedagogic practice to successfully merge ICTs and education (Scrimshaw, 2004; Tamin et al., 2011; Underwood & Dillon, 2011). According to Underwood and Dillon (2011) integrating ICTs in the classroom requires educators to "think differently about how learners learn and teachers teach" (p. 318). A range of studies have now suggested that technology-enhanced learning environments require the convergence of several teacher knowledge bases, including pedagogical content

knowledge (Shulman, 1986), the technological know-how for using ICT, and instructional knowledge of how and when to integrate ICT into the classroom (Becta, 2004, 2007; M. Cox et al., 2004; Osborne & Hennessy, 2003; Ruthven, Hennessy, & Deaney, 2004; Webb, 2005). Mishra and Koehler (2006) first coined the term *Technological Pedagogical Content Knowledge* or TPACK to encompass this new knowledge base required for teaching in the digital age. A detailed outline of TPACK is provided in Chapter 2.

1.2 Critical literacies and capabilities for the 21st century

Here in Australia, the unprecedented digital access and Internet connectivity as afforded by the Digital Education Revolution (DER) program was set to nurture new critical literacies and capabilities, often termed 21st century skills and capabilities. These 21st century skills and capabilities have subsequently been framed as essential educational foundations for improving one's employment chances in the Information Age (Beale, 2014; European Union (EU), 2007; Hennessy, Ruthven, & Brindley, 2005; P21 (Partnership for 21st Century Skills); Voogt, Erstad, Dede, & Mishra, 2013). Despite the elusiveness of a universally accepted definition and an understanding of how to transform teaching and learning practices for 21st century skills and capabilities to develop in the classroom (Dede, 2010), these concepts have emerged as common terms of reference in the literature (Voogt, Erstad, et al., 2013) and education policy directives. The notion of digital competence, referring to the convergence of a range of higher order thinking skills, knowledge, attitudes, and strategies related to ICT capability, media literacy, Internet literacy and information literacy (Ferrari, Punie, & Redecker, 2012) is now embedded within Australia's school education policy documents, curriculum frameworks and teacher accreditation practices. A range of digital competence frameworks have been popularised in the discourse for teachers surrounding ICT integration, the most popular will now be discussed briefly.

1.2.1 P21 Partnership for 21st Century Learning

The P21 Partnership for 21st Learning Framework, commonly known as P21, is a widely referenced framework for defining 21st-century skills and capabilities. This US-based consortium largely consists of representatives from the technologies business community including *Microsoft®*, *Intel*, *Cisco*, *Blackboard*, *Adobe*, *Apple*, and *Dell* (Moyle, 2010). This K-12 framework reflects both the development of subject area content with an emphasises on the interdisciplinary synthesis of knowledge using an overall digital skills approach to teaching and learning. The P21 framework promotes digital and multimedia-based literacies using pedagogies that engage students in authentic inquiry to promote deeper learning capabilities and skills such as lifelong learning, and creativity, ICT literacy, and collaborative problem-solving skills. An adapted version of the P21 framework is summarised in Table 1.(P21(Partnership for 21st Century Skills), 2015)

Table 1.1: P21 21st century learning skills and capabilities framework adapted from P21 (2015)

Learning and Innovation Skills	Information, Media, and Technology Skills	Life and Career Skills
Creativity and innovation	Information literacy	Flexibility and adaptability
Critical thinking and problem solving	Media literacy	Initiative and self-direction
Communication and collaboration	ICT (Information, Communication & Technology) literacy	Social and cross-cultural skills Productivity and accountability ^{[1][2]} _{SEP} Leadership and responsibility

1.2.2 *International Society for Technology in Education (ITSE) Standards for Students*

Another highly referenced digital competence framework that promotes the educational use of technology to empower students (and teachers) was developed by the International Society for Technology in Education (ITSE), formerly known as the National Education Technology Standards (NETS); a not-for-profit US-based organisation (ISTE (International Society for Technology in Education), 2016) . The focus of this framework is not merely on ICT technical skills, instead, the ITSE perspective emphasises using ICT in the classroom to develop future work-related competencies including:

- Empowered learners;
- Global collaborators;
- Creative communicators;
- Computational thinkers;
- Digital citizens;
- Knowledge constructors; and;
- Innovative designers.

1.2.3 *Australian Curriculum: General Capabilities*

In 2008, the Australian Government passed legislation to create the Australian Curriculum, Assessment and Reporting Authority (ACARA) to develop and establish a national curriculum. This curriculum was to incorporate the educational goals in schooling as identified in the *Melbourne Declaration on Educational Goals for Young Australians*. This declared that as a priority, teachers should ensure that students develop, “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” (MCEETYA, 2008a, p. 9). The ITSE standards and the P21 framework are not dissimilar to the *General Capabilities* framework developed by ACARA which underpins the Australian Curriculum (ACARA, 2015b). The *General Capabilities* framework, illustrated in Figure 1.1, outlines seven broad skills, behaviours and dispositions teachers

are required to address. These capabilities include: literacy; numeracy; ICT capability; critical and creative thinking; personal and social capability; ethical understanding and intercultural understanding. Together these cross-curricula capabilities form a framework seen as essential for all young people to prepare for successful citizenship in a global society. Where a variety of ICT literacies embedded across all subject areas of the Australian Curriculum is promoted in schools (Newhouse, 2013). The most recent review on achieving excellence in Australia's schooling system now argues for more attention on problem-solving skills, social skills, and critical thinking as essential capabilities for preparing students for a world rapidly undergoing a digital transformation (Gonski et al., 2018).

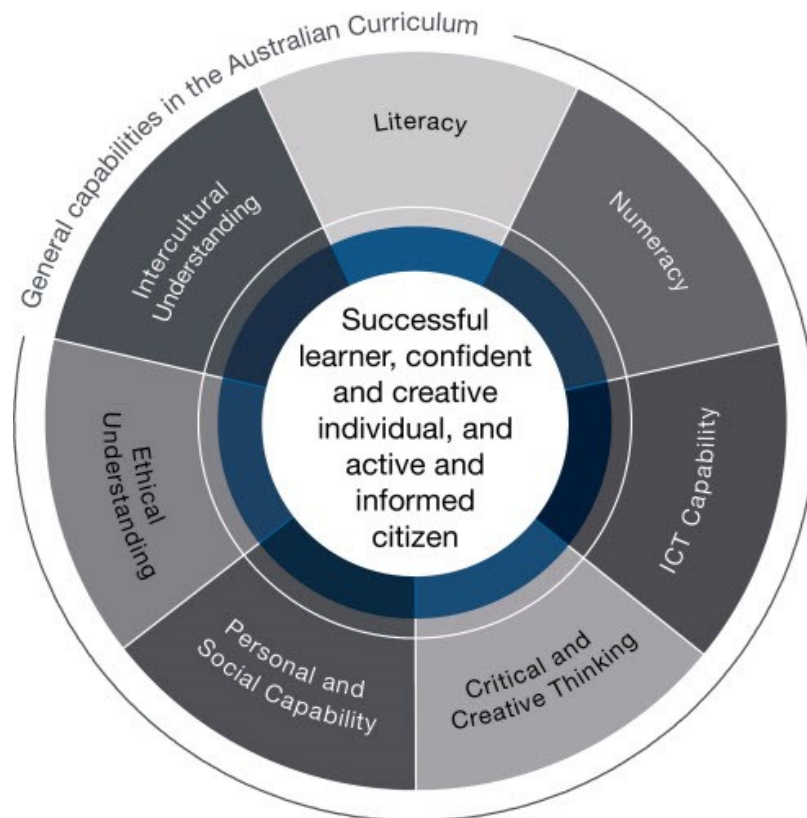


Figure 1.1: Organising elements of the General Capabilities of the Australian Curriculum (ACARA, 2015b)

It is argued here that many of the knowledge bases and skills as outlined in the digital competency focused frameworks discussed here represent learning dispositions (Perkins, 1993), or habits of mind (Costa, 2000), and character skills (Fullan &

Langworthy, 2014). Most of the skills and dispositions represented in these frameworks are reminiscent of the earlier work of the American philosopher and educator, John Dewey, who believed the primary role of education was to create lifelong learners and active citizens (Dewey, 1897). On the other hand several authors assert that 21st century skills and capabilities relate more to the contextual knowledge, skills and intellectual activity made possible by ubiquitous access to ICT, in particular access to the Internet, including the development of sophisticated information, media and ICT literacies (Dede, 2010; Voogt, Erstad, et al., 2013).

Since December 2011, the *Australian Curriculum: Science* has formed the mandatory basis of planning, teaching, and assessment of science across all Australian states and territories (ACARA, 2015a). This requires as an outcome all students are to develop ICT capability in terms of communicating ideas, problem-solving and for collaboration in the context of each learning area. The specific emphasis on ICT capability, as it is understood in the Australian Curriculum is shown in Figure 1.2, however, in the context of learning science, ICT capability is specifically embedded across all three science sub-strands of this mandated curriculum, some examples of which are shown below:



Figure 1.2: Organising elements of the ICT Capabilities according to Australian Curriculum (ACARA, 2015b)

Example 1: Students develop ICT capability when they research science concepts and applications, investigate scientific phenomena, and communicate their scientific understandings. They employ their ICT capability to access information; collect, analyse and represent data; model and interpret concepts and relationships; and communicate scientific ideas, processes, and information.

Example 2: Digital technology can be used to represent scientific phenomena in ways that improve students' understanding of concepts, ideas, and information. Digital aids such as animations and simulations provide opportunities to view phenomena and test predictions that cannot be investigated through practical experiments in the classroom and may enhance students' understanding and engagement with science. (ACARA, 2015b)

Therefore, teachers are expected to use ICT during science instruction and to promote the development of student ICT capability. However, the reality is many existing science teachers were not taught to teach their subject matter using technology. This raises concerns about the ability to address the ICT capability elements students are now expected to acquire, along with the dispositions to successfully live and work in the 21st

century using these digital skills. These curriculum requirements not only demand science teachers have knowledge of a range of appropriate ICT tools and technological devices to support the learning of science, but also the practical skills to use these tools from both a technical and pedagogical perspective. This implies further sophisticated pedagogical repertoires are required if ICT is to be used meaningfully in the science classroom.

1.3 Key drivers of ICT transformation in Australian schools

An emphasis on the acquisition of 21st century skills and capabilities by Australian teachers and students began in earnest in 2008 with a federal initiative that launched a large scale and rapid technology infrastructure boost into all Australian secondary schools collectively known as the Digital Education Revolution (DER) (MCEETYA, 2005, 2008, 2009). Underpinning the DER was an explicit goal to provision ubiquitous student access to ICT and subsequently ignite transformational teaching and learning opportunities. Enabling access to the Internet with the potential for creating enriched and more effective learning environments. Via a series of three rounds of funding under the National Secondary School Computer Fund (NSSCF) secondary schools across public, independent, and Catholic school sectors were able to procure new ICT equipment for students in Years 9 to 12.

Since the introduction of the DER \$2.4 billion (Auditor General, 2011) has now been invested in secondary schools where guidance was provided to schools by the Australian Information and Communications Technology in Education Committee (AICTEC, 2009) on this implementation. This significant investment of public funding saw \$1.4 billion allocated to the NSSCF for the purchase of ICT equipment in secondary schools, as well contributed to the production of digital curriculum resources distributed by a national curriculum portal known as *Scootle*. A \$40 million allocation was given towards the professional development of leaders and teachers across all school jurisdictions during the rollout. According to AICTEC, one-to-one computing access was achieved for all students in Years 9 to 12, resulting in almost 1 million new computers across 2900 Australian secondary schools (Digital Education Advisory Group, 2013). This study was situated in Western Australia, in Department of Education (DoE) public

secondary schools where each school had chosen to provide students with individual laptops—in all instances, this was a 13-inch *MacBook Air*.

According to the federal government the DER program resulted in Australian secondary classrooms having almost universal access to ICT and the Internet. Despite digital technologies renowned for exponential growth and rapid obsolescence, the National Partnership Agreement ceased ending access to the NSSCF in June 2013, leaving each state authority with the financial burden of reinvesting in ICT. It is fair to say the DER program left schools, parents, and students with an ongoing digital expectancy for classroom learning environments. Given ICT was deemed as pivotal to teaching and learning according to the DER suite of policies (Beale, 2014) since terminating the NSSCF the federal government has been strongly criticised and accused of overlooking and under-budgeting for ongoing technology infrastructure including the professional development of teachers (Education and Health Standing Committee, 2012). New models for the deployment and use of technology in schools, such as Bring Your Own Device (BYOD) and Bring Your Own Technology (BYOT), are the subject of much debate and angst currently amongst school leaders (Janssen & Phillipson, 2015; Newhouse, Cooper, & Pagram, 2015; Twining, Raffaghelli, Albion, & Knezek, 2013).

As found in other OECD countries that had attempted similar large scale ICT infrastructure projects and despite the transformational visions espoused in the raft of DER policies, there is still little evidence to suggest that ICT is being used to transform the classroom learning environment (Australian Communications and Media Authority, 2015; Halverson & Smith, 2009; OECD, 2010a, 2015; Underwood & Dillon, 2011). Instead, the research indicates that ICT is largely being used by teachers to present declarative knowledge and by students to consume this information; in other words, instructivist pedagogies are still the norm (Cuban, 2001; Cuban, Kirkpatrick, & Peck, 2001; Loveless & Ellis, 2001; OECD, 2015). The International Computer and Information Literacy Study (ICILS), a global-scale computer and information literacy survey of Year 8 students and their teachers, when last reported in 2013, revealed that of those countries surveyed the highest proportion of teachers using teaching-centered ICT practices were Australian teachers (DeBortoli, Buckley, Underwood, O'Grady, & Gebhardt, 2014). Furthermore, this ICILS study also reported that despite a plethora of digital resources now being freely available via the Internet here in Australia, for example

via online curriculum repositories like *Scootle*, that two-thirds of Australian students in Year 8 attended schools where the teachers reported insufficient time to prepare ICT mediated lessons (Thompson, 2015).

Compounding the low-level adoption of ICT by teachers to support learner-centered knowledge building is the lack of convincing evidence surrounding the use of ICT to improve student cognitive learning outcomes (Bebell & O'Dwyer, 2010; Cuban et al., 2001; Roblyer & Doering, 2010), instead, the literature reveals largely *ad hoc* findings. It has been suggested that the top-down ICT innovation approach as suggested by Australia's DER initiatives and other similar international large scale enterprises, has conflicted with other teaching priorities such as formal assessments and the demands of a crowded curriculum (Becta, 2004; Buchanan, 2011; Karasavvidis, 2009; Lim, 2006). Criticism of the general global ICT educational policy reform trend includes the deterministic representation of technology in these policies, "one which results in ICT being represented both as driving economic and social change and as providing a solution to change" (Jordan, 2011, p. 421). Others argue that many of the claims in these digital education policies are debatable, representing values rather than contestable claims (Beale, 2014; Moyle, 2010; Selwyn, 2012a) and furthermore, many of these policies have not attended to the reality of the complex ecology of schools and the dynamic nature of the typical workings of the everyday classroom (Somekh, 2008).

Along with the technological infrastructure investment, the preparation of teachers in the educational uses of technology has been appearing as a critical component of reform efforts mandating the requirement of teachers to utilise ICT for teaching and learning for over a decade now in Australia. The *National Professional Standards for Teachers*, published by the Australian Institute for Teaching and School Leadership (Australian Institute for Teaching and School Leadership (AITSL), 2011), explicitly detail the requirement for all school teachers to use ICT in teaching and learning. As a result, teachers are required to use ICT whenever possible and particularly model these ICT teaching standards whilst working in the classroom. This includes using ICT across all three AITSL professional teaching domains to; design, implement, assess learning experiences, engage students, and improve learning, enrich professional practice, and provide positive models for students, colleagues, and the community.

The *Teaching Teachers for the Future Project* (Australian Institute for Teaching and School Leadership (AITSL), 2014), was a federally funded initiative established to target systemic change in the ICT proficiency of graduate teachers, provided a set of elaborations known as *ICT Elaborations for Graduate Teachers*. These ICT elaborations were grounded in a theoretical model known as Technological Pedagogical Content Knowledge (Mishra & Koehler, 2006). The TPACK model describes the kinds of knowledge bases needed by a teacher for the meaningful use of ICT in learning environments. The TPACK model is elaborated later in Chapter 2. As evidenced by the graduate-level exemplars shown in Table 1.2, a sophisticated level of technological knowledge and pedagogical content knowledge is required to meet the proficiency of this teaching standard. Creating authentic and relevant technology-supported learning experiences is known to be both time-consuming and a daunting challenge for graduate teachers, given the plethora of online resources currently available via the Internet (Butcher, Leary, Foster, & Devaul, 2014).

Table 1.2: ICT Descriptors for Graduate Teachers for AITSL adapted from AITSL (2014) *Teaching Teachers for the future*

AITSL focus area	ICT descriptor standard 3: Plan for and implement effective teaching and learning
3.1 Establish challenging learning goals	Demonstrate how to set goals that include the use of digital resources and tools to support differentiated approaches to teaching and learning.
AITSL focus area	ICT descriptor standard 3: Plan for and implement effective teaching and learning
3.2 Plan, structure, and sequence learning programs	Select and sequence digital resources and tools in ways that demonstrate knowledge and understanding of how these can support the learning of the content of specific teaching areas and effective teaching strategies.
3.3 Use teaching strategies	Demonstrate knowledge and understanding of how to support a range of teaching strategies using digital resources and tools. These ways may include the

	promotion of creative and innovative thinking and inventiveness, engagement of students by exploring real-world issues and solving authentic problems, the promotion of student reflection and promotion of collaborative knowledge construction.
3.4 Select and use resources	Demonstrate knowledge of the use of digital resources and tools to support students in locating, analysing, evaluating, and processing information when engaged in learning.
3.5 Use effective classroom communication	Use a range of digital resources and tools to support the effective communication of relevant information and ideas, considering individual students' learning needs and backgrounds, the learning context, and teaching area content.
3.6 Evaluate and improve teaching programs	Demonstrate the capacity to assess the impact of digital resources and tools on students' engagement and learning when adapting and modifying teaching programs.
3.7 Engage parents/ carers in the educative process	Describe how digital resources and tools can support innovative ways of communicating and collaborating with parents/carers to engage them in their children's learning.

The most recent OECD (2015) report, *Students, Computers, and Learning*, presented an international comparative analysis of students' digital skills as evidenced by the Programme for International Student Assessment (PISA) and the classroom learning environments designed to develop these skills. The report damningly revealed that: "the results show no appreciable improvements in student achievement in reading, mathematics or science in the countries that had invested heavily in ICT for education" (p. 3). Strikingly one major finding contained in this report was that:

Building deep, conceptual understanding and higher-order thinking requires intensive teacher-student interactions, and technology sometimes distracts from

this valuable human engagement. Another interpretation is that we have not yet become good enough at the kind of pedagogies that make the most of technology; that adding 21st-century technologies to 20th-century teaching practices will just dilute the effectiveness of teaching (p. 4).

It is fair to say that Australian teachers now operate within demanding DER policy mandates that emphasise technology-mediated learning. Furthermore, they are now subjected to accountability for the teaching and learning of the General Capabilities as stated in the Australian Curriculum. The importance of mastering ICT from a technical and communicative perspective, and as a tool to develop intellectual capacity is evident within the science learning area of the Australian Curriculum, and the overarching ICT General Capability focus

1.4 Teachers' beliefs as predictors of ICT integration

As previously highlighted, systemic enablers such as supportive educational policies and frameworks and a high-level provision of ICT infrastructure is now in place in Australian schools (DEEWR, 2013). However, other more teacher-related variables must also converge to mobilise ICT in alignment with the transformative visions proposed by these policies and frameworks to make these a concrete reality. It has been known for some time that a complex array of variables affect the meaningful adoption and integration of ICT in classrooms including; teacher confidence or self-efficacy in the use of ICT, teacher skills from both a pedagogical and technological training perspective, along with institutional leadership and responsive classroom level technical assistance (Ertmer, 2005; Somekh, 2008; Voogt, 2010).

It has been of interest for some time in the literature that attendance to unpacking how technology is used is highly reflective of the assumptions and individual beliefs teachers make about the nature of knowledge and learning (Ertmer, 2005). Embedding ICT for meaningful learning into the everyday classroom can challenge the very nature of how we teach, even what we teach and why we teach (Ertmer & Ottenbreit-Leftwich, 2010; Loveless, 2011; Selwyn, 2012b). Meaningful learner-centered environments as envisioned in ICT educational policies have not fully eventuated, suggesting more fundamental issues are at play (Voogt, Erstad, et al., 2013). Teachers' pedagogical beliefs

and their subsequent influence on ICT use and teaching practices are discussed in further detail in Chapter 2.

1.5 Pedagogical reasoning and action

The evidence so far indicates that unrestricted ICT access in classrooms does not guarantee conducive 21st century learning environments or 21st century learning opportunities (OECD, 2015). The research explicated in Chapter 2 suggests that mobilising ICT in alignment with current educational frameworks and policies is highly dependent on the pedagogical reasoning and actions of the classroom teacher. For the purpose of this study the concept of pedagogy, an often-disputed generic term, follows the definition of Watkins and Mortimore (1999), who described pedagogy as “any conscious activity by one person designed to enhance the learning of another” (p. 3), and importantly “advances the learner’s conceptions of learning, improving what they learn and increases the likelihood that they will see themselves as active agents in learning” (p. 8).

Central to teacher’s professional daily work is the conceptual and practical planning of classroom learning activities. As highlighted in this Chapter, decision making, along with the associated practicalities are now made even more complex by the Australian educational policy requisite to meaningfully integrate technology into the learning environment. Interest in the way teachers transform subject matter knowledge to render subject matter or content ‘learnable’ has grown considerably, particularly since Shulman first coined the concept of pedagogical content knowledge or PCK in 1986. This study generally follows Shulman’s (1986:1987) definition and model of pedagogical reasoning and action (PRA), or the process of generating new PCK, and his later work with Wilson and Richert to expand the PRA construct. The PRA model refers to a suite of teacher thinking decisions and actions that underpin the processes of planning, teaching, assessing, and evaluating, leading to observable elements in teaching practice. The PRA model is a reflective inquiry approach to the professional judgments and actions that teachers make before, during and after a learning activity have taken place. A brief introduction to Shulman’s (1986) original conception of PCK is provided, and is

elaborated further in Chapter 2, along with Shulman's notion of teaching as a professional act.

Firstly, it is important to acknowledge that Shulman (1986) in his research on teaching and teacher education emphasised PCK as a knowledge base that defined an expert subject teacher. Shulman (1986: 1987) also referred to several other essential knowledge bases required for teaching including content knowledge, curricular knowledge, knowledge of educational purposes and contexts, general pedagogy, and learners and their characteristics. Shulman (1986) first defined PCK as: "Pedagogical content knowledge is not simply a repertoire of multiple representations of the subject matter. It is characterised by the way of thinking that facilitates the generation of these transformations, the development of pedagogical reasoning" (p. 15). According to Shulman (1987) pedagogical reasoning or professional teacher thinking is developed "through the process of planning, teaching, adapting the instruction, and reflecting on the classroom experiences" (p.17). Ultimately comprehensive and sophisticated pedagogy arises from this process of reasoning, requiring teachers to "use their knowledge base to provide the grounds for choices and actions" (p. 13) and in doing so develops and enhances a teacher's PCK.

The PRA or teacher thinking model was an attempt to clarify the reasoning process behind the development of the knowledge base of PCK and consists of a set of six planning and decision-making processes that draw upon teachers' existing PCK base. Briefly, these decision-making processes include *comprehension* of the subject matter; *the transformation* of ideas for representation to students; *instruction*; *evaluation*; *reflection* and *new comprehensions* (pp. 14-19). Whilst the PRA model (1987) is often depicted linearly, it was emphasised that teachers use and generate new PCK via an iterative cycle of thinking and practice (Wilson, Shulman, & Richert, 1987).

Since its original conception the knowledge base that constitutes PCK, and importantly how PCK is created, has been somewhat elusive given thinking is largely a tacit construct. However, there has now been significant evidence that teachers' beliefs and values influence pedagogical reasoning and actions by serving as selective 'filters' (Ertmer, 2005; Ertmer & Ottenbreit-Leftwich, 2013; Loughran, Berry, & Mulhall, 2012; Prestridge, 2012; Webb & Cox, 2004). More recently a consensus model of PCK has been reported in the literature (Neumann, Kind, & Harms, 2018) which posits that " (1)

teacher beliefs, orientations, prior knowledge and context and (2) student beliefs, prior knowledge and behaviours” serve as amplifiers or moderators of PCK (p. 9). The notion of pedagogical reasoning for the provision of meaningful ICT-enabled science learning environments is explored in further detail in Chapter 2.

1.6 Statement of the problem

Today’s high school students have grown up with ICT in a world often characterised as ‘a global village’ with a ‘look-it-up culture’ (Mishra & Koehler, 2008), where the term Google is used more frequently as a verb rather than a noun. Pervasive Internet connectivity and access to a range of ICT tools in classrooms have resulted in the democratisation of knowledge, in stark contrast to classrooms before the DER, best described as information scarcity models. Furthermore, it is fair to say that many science teachers have not been taught to teach their subject matter where technology is an integral tool for learning and communication (Niess, 2005) and nor have their teacher educators. The research still suggests that effective engagement of teachers with ICT pedagogical practices for a digitally connected world is still an ever-present challenge (Collins & Halverson, 2010; Lim, 2006; OECD, 2015).

As articulated in Chapter 2, mandating the incorporation of ICT into the curriculum does not guarantee consistent mobilisation. Nor does providing one-to-one access to ICT and Internet connectivity necessarily result in meaningful learning. Rather, ICTs are best viewed as a set of teaching and learning tools that can potentially amplify learning when teachers have pedagogically reasoned its use (Howland, Jonassen, & Marra, 2012; Shulman, 1986; Voogt, Fisser, Pareja Roblin, Tondeur, & van Braak, 2013). Despite one-to-one laptop provision now made widely available across Australian high schools, the extant literature still reveals that the teaching and learning benefits of ICT do not emerge unplanned.

There is now ready access via the Internet to a plethora of free multimodal resources to support learning science, however, the research is still limited in regards the complexities associated with promoting student learning in ICT-rich learning environments (Cuthell, 2006; Ertmer, 2005; Starkey, 2010). Despite decades of research surrounding ICT use in schools the literature surrounding the pedagogical motivations

and actions of teachers who provide technology-enabled learning experiences remains somewhat limited. Rarely analysed in the literature is the actual reasoning process used to provide meaningful teaching and learning in ICT enriched classrooms.

1.7 Rationale for the study

This study focuses on the teacher as the key variable affecting meaningful technology integration (Mishra & Koehler, 2008; Newhouse, Trinidad, & Clarkson, 2002). Whilst it is acknowledged that other significant variables, such as effective school leadership, professional learning, and supportive school-based ICT policies are also at play, fundamental to the creation of meaningful ICT-enhanced learning environments is the teacher (Tondeur, Cooper, & Newhouse, 2010). Overwhelmingly the research at this point indicates that the daily workings of the classroom are most influenced by the pedagogical assumptions and practices of the teacher, regardless of top-down policies and standards (Hattie, 2009).

It is for these reasons that furnishing schools with computers or other types of technologies, will not in and of itself lead to proficiency in 21st century skills or favourable learning environments. Transforming learning environments is not simply a matter of placing computers in students' hands; it requires purposeful planning of desirable technological, cognitive, and social outcomes. Pedagogical guidance is still needed to establish the 21st century learning environments envisioned by the DER suite of policies, frameworks, and standards.

This argument infers the ongoing need for a comprehensive research agenda to capitalise on the huge financial investment into computers and digital infrastructure in Australian schools. Further exemplars of successful pedagogical practices in science education are also required to assist teachers in overcoming the pitfalls of technology integration (Voogt, Knezek, Cox, Knezek, & ten Brummelhuis, 2013). Evidence is suggesting that more technological advancements, such as 3-dimensional visualisation tools and animations, hand-held data-loggers, augmented and virtual reality and networked databases offer much in support of inquiry-based learning in the science classroom (Beauchamp & Kennewell, 2008; Harlow & Cowie, 2010; New Media Consortium, 2014, 2015a, 2015b; Osborne & Hennessy, 2003; Webb, 2005). Yet, large-

scale adoption of these technologies in the classroom has not eventuated and suggest that more fundamental pedagogical issues are at play (Bai & Ertmer, 2008; Ertmer & Ottenbreit-Leftwich, 2013; Hennessy, Deane, & Ruthven, 2005; Jordan, 2011).

Further research, closely linked to classroom practice, is needed to examine the rationale and pedagogical issues associated with using computers in the classroom (J. Harris, Mishra, & Koehler, 2009; J. Harris & Phillips, 2018). This study will address the pressing need to explore the reasoning and actions of science teachers who effectively employ ICT in science teaching consistent with 21st century learning.

1.8 Purpose of the study

The central purpose of this study was to investigate the pedagogical reasoning of teachers in secondary classroom environments where students had one-to-one access to laptops and connectivity to the Internet, in other words, ubiquitous access to networked technology. Specifically, it investigated the reasoning and practices of three highly effective secondary science teachers known for providing quality ICT-enabled learning environments and harnessing opportunities to foster meaningful learning in science. This study is especially important in Australia where there is an explicit requirement for high school students to use appropriate digital technologies for learning, and to leave school equipped with ICT capability across all learning areas.

1.9 Research questions

The following research questions formed the basis of the inquiry:

1. What are the pedagogical beliefs of teachers who are effective users of ICT in teaching and learning? (i.e., why teachers act as they do?)
2. What pedagogical reasoning do these teachers employ in creating meaningful ICT based learning experiences? (i.e., how do teachers decide what strategies and representations and tasks to employ?)
3. How do these teachers create a learning environment conducive to student learning with ICT? (i.e., what do they do to create a conducive environment?)

4. What pedagogical repertoire do these teachers use to engage students in learning science using ICT? (i.e., how do they implement their instructional plan?)

1.10 Significance of the study

The objective of this classroom-based study was to engage with the nature of the pedagogically reasoned action. Accordingly, this study contributes to the literature about the pedagogical reasoning and practices needed to effectively capitalise on the benefits of ICT in the teaching and learning of science in Australian secondary schools. Research of this kind also has implications for offering richer ways of demonstrating the pedagogical reasoning and expertise required to apply the teachers' standards in practice.

The findings of the research will inform the development of professional learning materials designed to support pre-service and in-service teachers to provide meaningful technology-enabled science learning experiences. Since teacher preparation programs require prioritisation of teacher knowledge, the use of digital video technology to capture data in this study provides initial teacher educators with a range of authentic exemplars. Sherin (2007) referred to teachers' abilities to analyse teaching episodes as professional vision, consisting of both selective attention and knowledge-based acts of reasoning. It is hoped that the vignettes produced from this study will give pre-service teachers a professional vision of meaningful ICT-enabled science learning experiences.

Research of this kind also has design implications for ICT school planning and the development of pedagogically sound educational ICT tools, curriculum resources and software applications specifically targeted to the Australian Curriculum.

1.11 Overview of the methodology

The overall research design used to address the study's main research questions was a naturalistic multiple-case study (Yin, 2014) within an interpretivist paradigm. Three case studies formed the collection of cases. The research was designed using purposive sampling (Patton, 2002) with a set of carefully constructed criteria to select three exemplary science teachers located in Western Australian (WA) Department of Education (DoE) secondary schools.

1.12 Thesis organisation

This thesis is comprised of eight chapters. The first chapter has set the context and scope of the present research and introduces the research questions. [Chapter 2](#) presents a literature review of successful ICT pedagogical practices and the theoretical underpinnings for the changing models of pedagogy associated with the provision of ICT-enabled learning experiences. [Chapter 3](#) outlines and justifies the methodological approach adopted in this study, along with its methods. This chapter presents the rationale for adopting a qualitative, interpretive case study methodology. The strengths of these approaches for the present research, and the associated steps to ensure credibility, transferability, dependability, and confirmability are discussed. Chapters 4, 5 and 6 present the findings of the respective case studies. [Chapter 4](#), the first case study, presents Michael, a Western Australian (WA) Department of Education (DoE) science teacher situated in an academic extension Year 10 classroom. [Chapter 5](#) describes the second case study in the thesis with an examination of Ruby, a WA DoE science teacher in a Year 8 classroom situated in a middle school teaching environment. [Chapter 6](#), the third and final case study, highlights Patricia, a WA DoE science teacher of academically talented Year 9 students. [Chapter 7](#) sets out a cross-case analysis (Miles, Huberman & Saldana, 2014) of the key findings presented in Chapters 4, 5 and 6, interpreted in the context of the existing literature and which presents assertions in terms of the research questions posed in Chapter 1. While [Chapter 8](#) concludes the thesis and summarises the conclusions from the research, including a discussion of their implications. Chapter 8 also proposes further research directions built on the limitations of this study.

CHAPTER TWO: Literature review

This literature review will begin with a brief discussion on the growing emphasis on the use of ICT in the science curriculum here in Australia followed by a focus on what is currently known about sound ICT pedagogical practices. The pervasive technological availability in classrooms now constitutes a major change to teachers' pedagogy (An & Reigeluth, 2012). Evidence from the literature will be discussed that reveals that teachers who regularly infuse technology into their classrooms for learning tend to have constructivist pedagogical orientations (Baker, 2010; Becta, 2004; Drent & Meelissen, 2008; Hennessy et al., 2007; Herrington, 2007; Howland et al., 2012; Linn & Hsi, 2000). The influence of teacher's beliefs upon pedagogical practices is considered, followed by the changing pedagogies associated with the provision of ICT-enabled experiences. This review also considers a variety of technology integration models from the research literature and positions the technology into the context of this study.

Importantly, the review will examine the limited literature associated with ICT pedagogical reasoning models. Consideration of Shulman's (1986) pedagogical and reasoning and action model (PRA), later expanded by Wilson et al. (1987) is offered in the context of this study. The relevance of affordance theory is appraised, including an argument for using this concept in relation to ICT-enabled teaching and learning. Finally, an examination of Engeström's (1987) cultural historical activity theory (CHAT) and its relevance to studying the changing models of pedagogy associated with the provision of ICT-enabled learning experiences is considered. A conceptual framework for this study was developed from a synthesis of this literature review.

2.1 Technological reform of science curriculum

A very short history of the technological worldwide reform of the science curriculum is presented. Whilst there are other documents and frameworks in the literature, two seminal science educational reform documents known as the *Benchmarks for Scientific Literacy* by American Association for the Advancement of Science (AAAS, 1993) and the *National Science Education Standards* by the National Research Council (NRC, 1996) set the scene for a worldwide reform of science curriculum in most OECD

countries. Since the late 1990s the key science curriculum reform agenda has been the achievement of scientific literacy, rather than knowing scientific facts and information *per se* (Bybee et al., 2006; Lederman, Lederman, & Antink, 2013; Millar, Osborne, & Nott, 1998; Osborne & Hennessy, 2003; Tytler, 2007) with an emphasis on understanding science disciplinary content in the context of inquiry, including the integration of the nature and history of science. These seminal frameworks set the scene for making technology a highly visible component of science curriculums worldwide; where technology was promoted for learning activities that emulate authentic student-centred inquiry-based practices (Flick & Bell, 2000; S. Guzey & G. Roehrig, 2009).

In addition, the key foci of the *Australian Curriculum: Science* place a clearer and stronger emphasis on the development and understanding of the need for future citizens to understand that science and technology are shaped by human thought and actions, and these are inextricably bound. This notion accommodates a reflexive process where science advances technology, and technology enhances science. Therefore, it is no longer enough to use ICT to locate science information for simple recall. Instead science teachers are expected to harness the interactive affordances of ICT to explore science concepts and processes in more depth and make scientific views more accessible to students in a social constructivist manner.

According to the *Australian Curriculum: Science* contemporary science teachers are expected to embed technology related activities in the classroom which are directed towards the development of student science investigative (inquiry) skills, in other words higher order reasoning and processing skills. The use of specific technologies, for example, the Internet, spreadsheets, presentation media, publishing software and specific scientific devices such as data loggers and probe ware are embedded within each of the three science strands of this mandated science curriculum. Technology related science activities are expected to involve the applied use of digital technologies to explore topics in depth, identify problems, identify reliable sources of information, collaborate, formulate conclusions, solve problems, and create ideas. As well, teachers are now expected to support the development of a range of sophisticated digital literacies to communicate these understandings to a diverse range of socially active audiences. Ultimately the use of ICT in science classrooms along with the General Capability in ICT, as now promoted in the *Australian Curriculum :Science* is positioned as learner–

focused within a socio-cultural setting (ACARA, 2015b).

It is fair to say that technology use has been positioned in these education policy reform efforts as a central tool to support the implementation of authentic scientific practices in classrooms. Various studies have revealed that fostering scientific inquiry using related technologies in any meaningful way is a highly complex endeavour (Waight & Abd-El-Khalick, 2007; Waight, Chiu, & Whitford, 2014). Success is highly dependent upon the synergies between the teacher beliefs, learning goals, the role of the teacher and the role of the student in the learning activity itself, including careful attention to the level of classroom discourse, in other words the whole learning environment. Amongst others, these authors contend that it is simply naïve to position technology as a panacea for inquiry practices to emerge without addressing all of these factors.

Complicating the extent to which ICT may or not be used to transform science learning activities is the disjointed and limited evidence surrounding the positive effect of ICT integration upon student attainment, despite technologies being available for many decades. A second-order meta-analysis encompassing the past 40 years of investigations comparing technology use versus no technology by students and its impact on student achievement concluded a low to moderate mean random effect size of 0.33 (Tamin et al., 2011) where effect size refers to a measure of the standardized difference between two groups. The researchers concluded that the success of student use of ICT for learning is highly dependent on a teacher's ability to purposefully plan, select and orchestrate meaningful uses of ICT implying teachers must critically appreciate how to engage the ICT from an appropriate pedagogical perspective.

Hattie's (2009) earlier meta-synthesis for pupil use of technology upon attainment concluded a similar relative effect size result of 0.31. According to Hattie (2009), by means of comparison, the average relative effect size of various other non-technology based educational interventions sits at 0.4. In fact, he found that teacher-related interventions have far more influence on student attainment compared with technology use *per se*, for example: teacher expectation of student achievement (effect size 1.62); teacher credibility (effect size 0.9), and teacher clarity (effect size 0.75). More recently, Higgins, Xiao and Katsipataki (2012) provided a meta-analysis of 48 experimental studies linking the provision and use of technology with educational outcomes for

students (5-18-year olds). The research revealed only small positive associations and concluded that:

The range of impact identified in these studies suggests that it is not whether technology is used (or not) which makes the difference, but how well the technology is used to support teaching and learning. There is no doubt that technology engages and motivates young people. However, this benefit is only an advantage for learning if the activity is effectively aligned with what is to be learned. It is therefore the pedagogy of the application of technology in the classroom which is important: the *how* rather than the *what*. This is the crucial lesson emerging from the research (Higgins, Xiao & Katsipataki, 2012, p. 3).

More recently the OECD (2015) report titled *Students, computers, and learning: making the connections* revealed no demonstrable improvements in pupil learning outcomes for mathematics, science and reading, despite huge investments of public resources in ICT in education contexts. Furthermore, this report did not reveal a consistent relationship between the average amount of ICT use and its apparent effectiveness in improving learning outcomes. Instead the report similarly concludes that teachers have not yet acquired the type of pedagogies required to leverage technology for higher order thinking.

In summary, despite education policy reform efforts which have also included major investments in ICT infrastructure in schools, the evidence base supporting the impact of technology use on student academic attainment is not strong. Therefore, the return on this investment without reasoned and embedded pedagogy is not meeting expectations.

2.2 Teachers pedagogical beliefs: a barrier or an enabler?

It has long been recognised that teachers' pedagogical approaches are grounded in their own assumptions of learning and teaching (Bai & Ertmer, 2008; Ertmer, 2005; Ertmer & Ottenbreit-Leftwich, 2013; Loughran et al., 2012; Mayes & de Freitas, 2004; Pajares, 1992). Teachers' beliefs represent the hidden, unobservable elements of practice; however, are known to strongly influence the selection of instructional methods and student organisation, facets of pedagogy which can be physically observed (Gess-Newsome, 1999; Watkins & Mortimore, 1999). Pajares' (1992) significant attempt to synthesise the concept of teacher beliefs revealed the construct was confounded, or

‘messy’. Pajares’ (1992) contended that teacher beliefs referred to subjective concepts such as attitudes, opinions, and ideology rather than empirical knowledge bases *per se*. Nonetheless, Pajares’ (1992) work served to establish that teacher beliefs serve to act as filters for teachers’ decision making and instructional practices.

A large body of evidence now suggests that alignment of teachers’ beliefs about the role of technology for learning is a critical determinant, if not the primary contributing factor for the meaningful integration of ICT, in other words what a teacher thinks, the teacher does (Bai & Ertmer, 2008; Becta, 2004; Chai, Koh, & Tsai, 2013; Donnelly, McGarr, & O’Reilly, 2011; Drent & Meelissen, 2008; Ertmer, 2005; Ertmer & Ottenbreit-Leftwich, 2013; Inan & Lowther, 2010). Despite the global trend to establish ubiquitous access to technology in classrooms, changes in teaching beliefs do not necessarily occur, nor do changes in instructional practice emerge (Cuban, 2001; Hew & Brush, 2007; OECD, 2015). What is known though, is that teachers who hold the belief in knowing as constructivist and whom adopt social constructivist teaching practices tend to be the most frequent users of technology in the classroom (Ertmer, 2005; S. Guzey & G. Roehrig, 2009; M. Hammond, 2011; Mishra & Koehler, 2007; Prestridge, 2012)

The literature reviewed revealed the various metaphors used by teachers to describe the role of ICTs in pedagogical design including; ICT as a resource; ICT as a servant; ICT as a tutor; ICT as an environment; ICT as mind tools and ICT as a teaching aid (Jonassen et al., 1998; Loveless, 2011; Ross, Morrison, & Lowther, 2010; Stevenson, 2008). These metaphors provide insight into the pedagogical reasoning and ICT instructional practices of teachers. Understanding how teachers conceive of the role of technology is important in developing the pedagogical rationale for ICT use in classrooms. Higgins, Xiao and Katsipataki (2012) provide a set of useful questions to uncover the beliefs surrounding the rationale of ICT use in the classroom including:

- How does technology bring knowledge into the class?
- How does technology help us to work?
- How does technology help us to communicate?
- How does technology help us to interact?

Uncovering these beliefs from each of the participants generates a critical line of evidence that informs this research.

Emphasis in the belief in ICT as an intelligence tool or cognitive partner, along with the belief in the teachers role as a facilitator of learning, has long been espoused as the key to a meaningful use of technology in science classrooms (Sandholtz, Dwyer, & Ringstaff, 1997). Over 20 years ago, Jonassen (1996) stressed that computers in classrooms should serve as mind tools where, “mind tools are computer applications that, when used by learners to represent what they know, necessarily engage them in *critical thinking* about the content they are studying” (p. 24). Like Seymour Papert, who will be discussed later in this Chapter, Jonassen also emphasised that technology should be used by students to interpret and create knowledge, and used in a constructional fashion rather than used by the teacher to impart declarative knowledge. Accordingly, Jonassen’s mind tools made possible by ICTs include those applications as shown in Table 2.1. Therefore, what is underscored by this approach, is conducive constructivist epistemologies rather than reductionist knowledge constructs.

Table 2.1: A range of examples of ICT applications that potentially serve as mind tools, or critical thinking device adapted from Jonassen, Carr, and Yueh (1998)

Semantic organisational tools	Knowledge construction tools	Information interpretation tools	Collaboration and conversational tools
Data bases	Hypermedia	Search engines	Asynchronous: e-mail, discussion boards, wikis, listserv’s
Concept mapping tools		Blogs	Synchronous: instant messaging, video conferencing

In keeping with the current educational reform rhetoric of 21st century skills and learning teachers are asked to position the role of ICT as cognitive partnering tools to support critical thinking and problem solving like the way Jonassen first advocated in 1996. Teachers should be deploying ICT in ways that serve to enhance the way a student works and thinks so they may actively produce, create, and communicate their science

understandings rather than to consume science information, in other words, learning with computers not from them (Jonassen, 1996).

A strong argument in the literature now appears that fundamental to creating meaningful technology enhanced learning environments should be a deep appreciation of the science of how learning occurs (Darling-Hammond, 2006; Packer & Goicoechea, 2000). However, this is known to be difficult if teachers epistemological assumptions are oriented towards transmissive teaching and learning (Nilsson, 2009). The seminal US Committee on Developments in the Science of Learning in their report *How People Learn: Brain, Mind, Experience, and School* (1999) and the National Research Council reports such as *How people learn* (Bransford, Pellegrino, & Donovan, 2000) and *How people learn history, mathematics and science* (Bransford, Brown, & Cocking, 2005) highlight the contemporary research on the nature of learning, instruction and assessment.

Arising from this work was the *How people learn framework* (HPL) designed to support teachers to organise their pedagogical thinking around four key components for creative learning environments; knowledge centeredness, learner-centeredness, community centeredness and assessment centeredness which is shown in Table 2.2 (Darling-Hammond & Bransford, 2005). Explicating teachers' beliefs and assumptions using the HPL framework potentially then serves as a useful referent in this study for interrogating pedagogical approaches and practices in relation to meaningful technology use.

2.2.1 Other technology enablers and barriers

Ertmer (1999) first elucidated the concept of first-order barriers as those inhibiting technology integration as variables external to the teacher, such as technical infrastructure, professional learning and classroom technical support (Ertmer, 1999). Clearly teachers have no direct influence over these system level supports, however, as revealed in Chapter 1, the DER funding and the associated policies and frameworks has done much to address these first-order barriers here in Australia. According to Ertmer (1999), second-order barriers are those which are teacher related, including beliefs, motivation, knowledge, and skills. However, despite teachers holding constructivist views, and expressing motivation to use ICTs for learning it must still be recognised that

teachers operate within specific contextual constraints that can facilitate or hinder the meaningful integration of ICT into the curriculum.

Table 2.2: How people learn (HPL) framework adapted from Darling-Hammond and Bransford (2005)

Learning environment component	Definition of learning environment component	Questions to ask
Knowledge-centeredness	The knowledge, skills, and attitudes we want people to acquire and how they may be able to do so to transfer what they have learned	What should be taught, why is it important, and how should this knowledge be organised?
Learning environment component	Definition of learning environment component	Questions to ask
Learner-centeredness	The learner, and his or her strengths, interests, and preconceptions	Who learns, how, and why?
Community-centeredness	The community within which learning occurs, both within and outside the classroom.	What kinds of classroom, school and school community environments enhance learning?
Assessment-centeredness	The assessment of learning that both makes students thinking visible, and through feedback, guides further learning.	What kinds of evidence for learning students, parents, teachers, and others can use to see if effective learning is occurring?

Strong arguments exist that unrealistic visions for ICTs had been established in policies without attendance to the systemic institutional culture, regulatory frameworks

and power structures leading to superficial treatment in classrooms rather than as transformational learning tools as espoused in the prevailing policy rhetoric (Somekh, 2004). In a later study analysing the factors which affected teachers' pedagogical adoption of ICTs Somekh refuted the prevailing assumption that failure to embed ICT in pedagogy was the result of teachers' resistance to change (Somekh, 2008). Instead she argued the need to account for the complex interplay of school cultural contexts, regulatory frameworks including curricula and assessment regimes and national educational policies; an argument that still plays out here in Australia (Lee, 2011). Studies examining teachers' views on the factors that affect technology use in classrooms also revealed a dynamic interplay between the teacher-controlled factors including: beliefs, motivations technology skills, along with a constructivist orientation to pedagogy; and, the school level factors, including effective leadership, technical support, including access to quality professional development support (Levin & Wadmany, 2008). There are now numerous studies revealing a complex interplay between the teacher, the school leadership team along with the school's technological infrastructure, in other words the entire socio-cultural-technical environment that enables or constrains ICT use at the classroom level (Drent & Meelissen, 2008; Hechter, Phyfe, & Vermette, 2012; Tondeur et al., 2010; Voogt, Knezek, et al., 2013). Consequently, a holistic view must be then considered when examining why and how technology is used (or not) at the classroom level suggesting that research such as this should capture pertinent contextual school related information.

In addition, a large number of studies have revealed that the decision to infuse lessons with technologies not only depends upon teacher beliefs, but also upon their technological and pedagogical competence, even when access to technology is not a problem (Ertmer, 2005; Halverson & Smith, 2009; M. Hammond, 2011; Keengwe & Onchwari, 2011; Koehler & Mishra, 2009; Neiss, 2005). Furthermore, the evidence also suggests that even when teachers are highly motivated, and access to technology is not an issue, specific guidance and ongoing professional development in the form of models and measures is still required (Bebell & O'Dwyer, 2010; Gerard, Varma, Corliss, & Linn, 2011; Prestridge, 2012). Furthermore schools must allow teachers ample time to practice these integration skills, however, global surveys of professional development efforts still

continue to reveal this practice time is still largely lacking (Ananiadou & Claro, 2009; Twining et al., 2013).

Here in Australia, since the DER initiative, professional support to build teachers' technological and pedagogical capacity has ranged from; structured professional learning; personal networking; online inquiry driven communities of practice; and, the use of online repositories of digital learning objects aligned to ACARA curriculum e.g. *Scootle* (MCEETYA, 2009). Whilst significant DER system level efforts have now been established, gaining planning time to access these resources along with access to professional development opportunities have been highly variable. A report by the Education and Health Standing Committee, *The role of ICT in Western Australian Education: Living and working in a digital world* (2012) presented to the Legislative Assembly was highly critical of the lack of coherence in the professional learning strategy currently adopted across the public education sector. However, the report recognised the complexity of the interplay and dependencies including teacher motivation, availability of head office and school ICT funding and resources and importantly, supportive leadership teams (Education and Health Standing Committee, 2012). Strategic management by school leadership of ICT progression plans are known to be critical determinants that can empower teachers in the application of technology in the classroom for learning (Bingimlas, 2009). Critically, the level of technical support deployed in each school, along with Internet bandwidth and strong reliable connectivity, is also known to be a key factor influencing teachers' uptake of ICT. Becta's (2004) earlier investigation of UK schools found not only recurring technical faults, however, even the expectation of these faults occurring were likely to cause teachers to avoid using ICT in future lessons. Clearly though these technical variables are outside of the control of a teacher. Here in WA, ICT technical infrastructure and support in classrooms is still known to be highly variable, particularly once outside of the metropolis (Education and Health Standing Committee, 2012), although the recent national broadband program may see an alleviation of these issues.

Here in Australia, a wide variety of professional bodies now exist to support teachers and provide advocacy for educational technology integration. For instance, the Australian Council for Computers in Education (ACCE) is a professional organisation that targets professional learning for its K-12 members. Notably ACEC has conducted

several major Australian education technology projects for K-12 contexts in consortia with various universities and industry partners. ACCE is also affiliated with the US based International Society for Technology Education (ISTE), widely referenced for its teaching with technology standards and promoting promising new technology enable practices. More recently the federally supported online teaching resource *Digital Technologies Hub* was launched (ESA (Education Services Australia), 2016). This was with major support from Google and the Computer Science Education Research Group (CSER), based at the University of Adelaide. This online hub disseminates a range of massively open online courses (MOOCs) offering professional learning opportunities aimed at promoting the Digital Technologies curriculum for Australian teachers. Whilst these MOOCs are primarily aimed at the promotion of computer science pedagogies, the Digital Technologies Hub has much to offer teachers in other learning area disciplines. In WA, the site of research in this thesis, the Educational Computing Association of Western Australia (Inc.) (ECAWA), a volunteer association, offers a wide range of professional learning opportunities.

Whilst there has been a proliferation in the range of professional learning networks aimed at improving technology integration, many of which can now be accessed freely online, teachers require both the motivation and sustained planning and reflective time to develop engaging technology-enabled learning programs (Inan & Lowther, 2010). Data driven accountability, teacher accreditation requirements and National Assessment Program-Literacy and Numeracy (NAPLAN) preparation regimes tend to currently dominate teacher planning time here in Australia (Education HQ News Team, 2017). Notwithstanding the range of professional development opportunities and plethora of digital resources now available for interested teachers, there has been no significant changes to the fundamental teacher workload model since the Digital Education Revolution (DER). In fact, a very recent large scale survey of teachers (n= 18,234) in New South Wales reports an overwhelming majority feeling overburdened by administrative functions, and furthermore this bureaucratic work had increased overtime leaving less time for lesson preparation (McGrath-Champ, Stacey, Wilson, & Fitzgerald, 2018).

More specifically, early findings by Gerard, Varma, Corliss, and Linn (2011) surrounding the professional development of science teachers for technology enhanced

inquiry teaching methods found that professional learning programs needed to be sustained for a period of one year or more. Those that were of shorter duration were seen to encounter either technical and or pedagogical obstacles relating to meaningful integration. As found in Lim and Chai's (2008) study of Singaporean teachers local contextual constraints, such as curriculum and formal assessment demands were also known to restrict and drive teachers' actual practices (Lim & Chai, 2008). Lim and Chai (2008) found that whilst these Singaporean teachers all expressed constructivist views of teaching and learning the, "need to complete the syllabi according to stipulated schedules so as to get the students ready for examination" (p. 807) was a key barrier to using ICT in ways more consistent with constructivist and inquiry processes.

Analysis of senior school teachers use of ICT has rarely been addressed in the literature, where prescriptive syllabi and standardised assessments drives much of what is done in the form of the Australian Tertiary Ranking System (ATAR) university examination entrance system. The ATAR system primarily measures senior school syllabus content reproduction (Pilcher and Tori, 2018). Yet now in the digital age, the recall of information has largely been subsumed by access to the Internet. The pace of systemic change in terms of assessment and accountability structures across the Australian schooling system has been much slower than the rapid pace of technological change leaving a tension as to how to deploy ICT in the classroom (Higgins, Xiao, & Katsipataki, 2012). Common still across the literature is the assertion that assessment still fundamentally drives much of what is taught in schools (Fullan & Donnelly, 2013), and to a large degree influences the pedagogy of how it is taught, resulting in students leaving school without understanding how this content is enacted in the real world (Fullan & Langworthy, 2014). If assessment structures, particularly in senior school, fundamentally value curriculum content proficiency and do not align more closely to the 21st learning skills and competencies enabled by pervasive access to technology, as characterised in Chapter 1, it is argued here in this thesis that didactic and instructivist teaching and learning approaches are still likely to remain the norm.

2.2.1.1 Implications for professional learning

Ultimately a teacher's motivation and a belief in the intrinsic pedagogical value of ICT to support student learning is critical to overcoming some of the barriers presented here

(Ertmer & Ottenbreit-Leftwich, 2013). For inexperienced and preservice teachers professional learning efforts should be directed towards quality pedagogies like those outlined in the report on *How people learn*; the emphasis being to leverage ICT as a cognitive partner in classroom learning environments (Darling-Hammond & Bransford, 2005). Several authors have contended that despite the plethora of new and exciting educational technologies hitting the market at an almost exponential rate, professional learning efforts should not be limited in their focus to technocentric skills alone (Lawless & Pellegrino, 2007; Luckin et al., 2012; Twining et al., 2013). In fact strong arguments now exist that the failure of widespread and meaningful uptake of ICTs into the classroom has been due to the limited opportunities for teachers to focus on understanding the pedagogic purpose of ICTs for learning (Keengwe & Onchwari, 2011; Laurillard, 2012). It has long been known that even when sustained professional learning has taken place, embedding these new pedagogies also requires *in situ* work as a community of practice (Wenger, 1998). In summary, the literature strongly suggests that professional learning requires a sustained approach, importantly where the focus is directed towards the educational or learning affordances of this technology, not simply the technology itself.

2.3 Changing pedagogies associated with ICT use

The impact of technology-enriched classrooms has long been touted as an opportunity to transform a teacher's pedagogy from teacher-centred pedagogies to constructivist student-centred practices (Becta, 2004; Collins & Halverson, 2009; Keengwe, Onchwari, & Wachira, 2008; Selwyn, 2012a). As such, there has been more prominence given to the investigation of the pedagogical principles and practices surrounding the design of successful technology enriched learning environments. An earlier synthesis of 174 case studies across 28 OECD countries in 2003 investigated how technology enriched environments were changing the instructional practices of teachers and the ways students were working in these classrooms (Kozma & Anderson, 2002). The commonalities of innovative practice found in this international study revealed pedagogies where teachers supported students to develop ICT skills, communication skills and interpersonal skills through student-centred, collaborative and project-based

learning. This study also found that a transformation occurred in these teacher's pedagogy from transmissive and didactic approaches to more facilitative and interactive offering students more formative feedback; that is, the teachers became facilitators or orchestrators of the learning environment.

Hennessey, Deaney and Ruthven's (2005) study of science teachers in the UK reaffirmed Kozma and Anderson's (2002) earlier work, again revealing the primacy of the teacher's role in orchestrating meaningful learning in ICT rich learning environments. This was contrary to the prevailing view that the teacher's role would diminish as student use of ICT increased. The emerging successful ICT pedagogical strategies arising from this later study revealed:

- A shift from a transmission role in teaching towards helping learners to locate, select, filter, edit, interpret and summarise important information;
- pre-structuring tasks and establishing clear objectives;
- maintaining students focus on subject learning with proactive; interventions, responsive assistance, and opportunistic interactions;
- structuring (constraining) internet research activity; and,
- developing new pupil skills for information finding, selection and critical analysis.

(Hennessy, Deaney, et al., 2005)

A further study by Hennessy et al, (2007), as part of the *InterActive* and *SET-IT* project in the UK, examined the interactive pedagogical approaches and the specific ICT tools used by science teachers to support students' understanding of science. This study revealed that ICT tools such as virtual experiments, simulations, data logging and animations were useful cognitive tools that encouraged scientific reasoning and were helpful in bridging the gap between scientific concepts, theories, scientific relationships, and informal knowledge. This study also revealed the importance of the pedagogic expertise required for overcoming the constraints of some ICT tools. Skillful science teachers were observed to deploy strategic questioning by focusing student attention to key underlying scientific processes and concepts by posing *what if* type questions during ICT-enabled science learning activities. In other words, the potential of ICT is realised when the teachers subject, pedagogical and technological knowledge merge.

Drent and Meelissen's (2008) case study involving Dutch teachers investigated the factors that obstructed or stimulated educators to use ICT innovatively and observed a

direct relationship between student-centred pedagogical approaches along with innovative uses of ICT. Arising from this study was a useful profile for an innovative ICT teacher which included the following characteristics:

- The teacher educator is willing to keep extensive contacts with colleagues and experts in ICT for the sake of their own professional development (personal entrepreneurship).
- The teacher educator sees and experiences the advantage of the innovative use of ICT in their education (ICT attitude and perceived change).
- The pedagogical approach of the teacher educator is student-centred.
- The ICT competence of the teacher educator complies with their pedagogical approach. (Drent & Meelissen's 2008, p. 197)

Shifting pedagogy from teaching-centred to student-centred learning necessitates a fundamental change in teacher and student roles more consistent with that of a learning partnership (United Nations Educational Scientific and Cultural Organization (UNESCO), 2002). Nonetheless, the literature reviewed reveals that focused enquiry and proactive teacher guidance through the zone of proximal development (Vygotsky, 1978) is required, even when students learn to become more self-directed in ICT rich environments. Several studies have shown that teachers need to strategically balance freedom of choice, pupil responsibility and self-regulated learning with structured learning activities (Roblyer & Doering, 2010; Webb, 2010). The metaphor of 'orchestrating learning' is now commonly used to conceptualise the pedagogic role of the teacher in ICT rich learning environments (Prieto, Dimitriadis, Asensio-Pérez, & Looi, 2015).

The argument presented in the literature suggests that the transformational gains of ICT for student learning require thoughtful ICT tool selection mapped to specific learning goals, deployment, and classroom facilitation. In other words, that attendance to the learning environment is critical to the effective deployment of ICT.

2.4 Models of technology integration and instructional design frameworks

Research has shown that integration of ICTs into the curriculum generally progresses along an evolutionary scale, ultimately from teachers having more technological concerns to more nuanced pedagogical considerations of its use for student learning (Becta, 2004; Voogt, Fisser, et al., 2013). There is no doubting the breadth and depth of available ICT resources and tools available today affords diversity in terms of possible learning environments (OECD, 2013b), however, as discussed, the integration of ICT is contextually influenced (constrained or afforded) particularly at the school-based level and more over by the selections made by the teacher. Various technology integration models and instructional design frameworks that characterise the assimilation of digital technologies and pedagogy now exist; some popular models relevant to this research will now be clarified in chronological order.

2.4.1 Flick and Bells' guiding principles for using ICT in science (2000)

Whilst not a technology integration model as such, Flick and Bell (2000) proposed a set of five guiding pedagogical principles specifically for preparing pre-service science teachers for considering the purposeful use of technology in the classroom. These pedagogical guiding principles were offered to pre-service science teachers to support the design of instructional applications of technology in ways aligned to the seminal science education reform documents mentioned earlier in this Chapter.

These five guiding principles included:

1. Technology should be introduced in the context of science content.
2. Technology should address worthwhile science with appropriate pedagogy.
3. Technology instruction in science should take advantage of the unique features of technology.
4. Technology should make scientific views more accessible.
5. Technology instruction should develop students' understanding of the

relationship between technology and science.

(Flick & Bell, 2000)

2.4.2 Newton and Rogers' ICT thinking framework for science (2003)

Similarly, Newton and Rogers in the UK (2003) offered a thinking framework for using ICT in the science classroom. This thinking framework prefaced both the mode of engagement of the learner, as well as the properties and potential learning benefits of ICT tools as the two key instructional determinants necessary for meaningful learning with ICT (Newton & Rogers, 2003). In other words, a learning affordance perspective to the selection of ICT tools. Shown in Table 2.3 are the learner modes whilst using ICT ranging from passive to active participation.

Table 2.3: Learning modes and teaching/learning activities using ICT adapted from Newton and Rogers (2003, p.114)

Purpose of ICT-enabled activity	Learner's role
Obtaining knowledge	Receiver
Practice and revision	Reviser
Exploring ideas	Explorer
Collating and recording	Receiver

2.4.3 Technology Integration Planning Model (TIP) (2004)

Wienke and Roblyer (2004) designed a five-phased Technology Integration Planning (TIP) Model to help teachers plan for, implement, and assess their use of technology in instruction that became very popular in USA pre-service teacher courses. The TIP Model represents a five-phased pedagogical process designed to limit possible integration issues, as well as increase the likelihood that technology will enhance instructional practices (Wiencke & Roblyer, 2004). The planning considerations of this problem-solving based model are summarised below:

- Determine the relative advantage: What is the problem I am trying to solve? Do technology-based methods offer a solution with enough relative advantage?

- Decide on learning objectives and assessment: How will I know students have learned? What are the best ways of assessing these outcomes?
- Design integration strategy: What kind of instructional methods or teaching strategies will work best? How can technology best support these methods? What do I need to do to prepare my students to use this technology method?
- Prepare the instructional environment: What equipment, software, media, and other resources will I need to support instruction?
- Evaluate and revise integration strategies: What worked well? What could be improved? (Adapted from Wienke & Robyler, 2004)

2.4.4 *Technology Integration Assessment Instrument (TIAI) (2005)*

Britten and Cassady (2005) in the US developed a technology integration assessment instrument (TIAI) intended for use as a planning and evaluative tool by school leaders and teachers. This rubric consists of seven dimensions of planning and evaluation of ICT-enabled learning including:

- Using technology to plan the lesson activity.
- Reference to the state ICT standards in planning the lesson activity [e.g. ACARA General Capabilities: ICT capability].
- Reference to the state content standards in planning the lesson activity [e.g. Australian Curriculum: Science Inquiry Skills using digital technologies to construct a range of text types to present science ideas].
- Attention to the use of technology to support student needs.
- Implementation of technology in the lesson activity impacts either the process or the product of teaching.
- Implementation of technology in the lesson activity impacts either the process or the product of learning.
- Technology is used in the product or in assessment.

The TIAI proposes a continuum of four levels of technology integration ranging from non-essential uses of technology through to technology being an essential component of the lesson activity (Britten & Cassady, 2005). This rubric serves as a useful reference

point for comparison between each of the lessons observed in this study, and as a point of comparison across the cases.

2.4.5 ICT-TPCK (2005) and Technology Mapping by Angeli and Valanides (2009)

Using Shulman's PCK (1986) construct as its theoretical basis (1986) Angeli and Valanides (2005) first proposed ICT-related PCK as a distinct form of knowledge that makes a teacher competent to teach with ICT. According to Angeli and Valanides (2005), "the outcome of this complex instructional decision process will be a series of powerful pedagogical transformations (p. 162) and in doing so take the position of a transformative view of this technology knowledge base. Later Angeli and Valanides (2009) offered five key instructional design principles of knowing how to use technology to:

1. Identify topics to be taught with ICT in ways that signify the added value of ICT tools, such as topics that students cannot easily comprehend, or teachers face difficulties in teaching them effectively in class.
2. Identify representations for transforming the content to be taught into forms that are comprehensible to learners and difficult to be supported by traditional means.
3. Identify teaching strategies, which are difficult or impossible to be implemented by traditional means, such as application of ideas into contexts not possible to be experienced in real life, interactive learning, dynamic and context-situated feedback, authentic learning, and adaptive learning to meet the needs of any learner.
4. Select ICT tools with inherent features to afford content transformations and support teaching strategies.
5. Infuse ICT activities in the classroom (p.294)

These authors later proposed *Technology Mapping* as an approach to developing ICT-TPCK, that is, for this knowledge base to develop it is necessary to understand the connections amongst software affordances, content representations and the pedagogical uses of specific technology tools (Angeli & Valanides, 2013).

2.4.6 Technology Integration Matrix (2006)

The Florida Centre for Instructional Technology at the University of South Florida first developed the Technology Integration Matrix (TIM) in 2006, a constructivist model of technology integration to support teachers in using technology meaningfully in K-12 settings (Allsopp, Hohfield, & Kemker, 2007). The TIM rubric incorporates characteristics indicative of meaningful constructivist learning environments, that is: active, collaborative, constructive, authentic and goal directed (Bransford et al., 2000; Howland et al., 2012) and then associates these characteristics with various levels of sophistication of technology integration: entry, adoption, adaptation, infusion and transformation, thus creating a matrix of cells. The TIM rubric can then be used as a tool to evaluate the current use of ICT in the classroom and to help teachers plan more meaningful uses. This popular US technology integration model is available at <http://fcit.usf.edu/matrix/>.

2.4.7 Substitution, Augmentation, Modification and Redefinition model (2006)

The SAMR model, popularised by Puentedura (2006) represents a pedagogical framework for categorising levels of sophistication in terms of teachers' progression of technology integration in the classroom including:

- *Substitution* – technology is used as a direct substitute for what you might do already, with no functional change
- *Augmentation* – technology is a direct substitute, but there is functional improvement over what you did without the technology.
- *Modification* – technology allows you to significantly redesign the task.
- *Redefinition* – technology allows you to do what was previously not possible (Puentendra, 2015)

The first two stages pertain to students using technology to enhance learning activities which in many instances could be achieved without technology; the latter two stages refer to more transformational and student centered uses of technology. The simplicity of this model has in part lead to its popularity, for example, the SAMR model now features on some Australian Department of Education portals (e.g., Victoria and Queensland),

however, only scant literature exists to support the assertions and possible learning outcomes as implied by this framework (Hamilton, Rosenberg, & Akcaoglu, 2016). In relation to pedagogical reasoning, like the TIAI rubric, this continuum reflects the non-essential use of technology through to an essential use of technology in regards to the learning activity in question.

2.4.8 Technological pedagogical and content knowledge framework (2006)

For over 20 years Shulman's (1986) notion of pedagogical content knowledge (PCK) has been emphasised as an important construct describing the key knowledge base required for the content specialist teacher. Shulman (1986) referred to PCK as an understanding of how particular teaching approaches fit together with content knowledge to employ "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 it makes it comprehensible to students" (p. 9). Shulman also referred to two other key forms of content knowledge categories; content knowledge, referring directly to the substantive and syntactic disciplinary knowledge base required for teaching a discipline and curricular knowledge. Curricular knowledge by Shulman's definition (1986) was;

The curriculum and its associated materials are the *materia medica* of pedagogy, the pharmacopoeia from which the teacher draws those tools of teaching that present or exemplify content and remediate or evaluate the adequacy of student accomplishments... How many individuals whom we prepare for teaching biology, for example, understand well the materials for that instruction, the alternatives texts, software, programs, visual materials, single concept films, laboratory demonstrations, or "invitations to enquiry" ..." (p. 10)

However, Shulman did not elaborate the relationship between harnessing the affordances of technology to transforming content and pedagogy. Instead it was much later in 2006 with the emergence of a new model, known then as the TPCK model, that the first serious theoretical construct of PCK into the domain of teaching with technology emerged. The TPACK model is now elaborated.

Mishra and Koehler (2006) conceived a theoretical model to represent a new type of knowledge base, they posited was necessary for teachers to successfully integrate

technologies in educational settings. This highly referenced model is known as the Technological Pedagogical Content Knowledge framework (TPACK) to include the interplay of technology knowledge (TK) on Shulman's (1986) original construct of pedagogical content knowledge (Koehler & Mishra, 2009). Shown in Figure 2.1 is the TPACK framework. This includes Shulman's original primary knowledge domains for teaching consisting of content knowledge (CK), pedagogical knowledge (PK) and pedagogical content knowledge (PCK). However, the TPACK model extends these teacher knowledge domains by including a further knowledge domain, technology knowledge (TK), to understand the role of technology in the process of teaching and learning. The intersection of these knowledge domains refers to a new sophisticated teacher knowledge construct known as TPACK. According to this model, growth in TPACK implies there has been growth in the knowledge domains of CK, PK and PCK and TK.

According to Mishra and Koehler (2007) teaching with technology is made more complex or constrained, depending upon the institutional contexts in which it is situated. Lack of TK and access to ongoing professional learning can be a significant constraining factor in terms of pedagogical reasoning therefore limiting meaningful ICT-enabled classroom practices. Furthermore, the authors of the TPACK model argue the over emphasis on the use of ICT tools as 'add-ons', rather than focusing teacher professional development around how to use ICT effectively with students for learning will be unproductive. In other words, favouring a pedagogical perspective rather than a technocentric view is more effective (Mishra & Koehler, 2007).

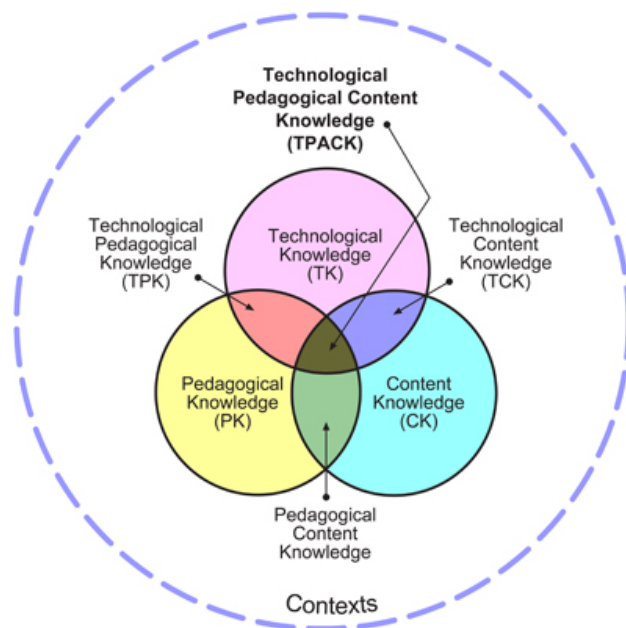


Figure 2.1: The TPACK framework and its knowledge components. Reproduced by permission of the publishers © 2012 by tpack.org

According to these authors teaching with technology is particularly confounded by the rapid evolution of technological innovations, presenting teachers with an overwhelming proposition of how to keep up, in other words technology integration is in itself a ‘wicked problem’ (Mishra & Koehler, 2007). Instead, they argue that maintaining one’s currency in TK should not be the goal *per se*, instead asserting that teachers should develop a thoughtful attitude towards the integration of technology, positioning teachers as designers of curriculum that co-opts technology to support meaningful learning. In using the TPACK framework they advocate that teachers must think creatively and playfully as designers of their own relevant curricula (Mishra & Koehler, 2008). Furthermore, they acknowledge that cultivating creative learning solutions is played out in very different classroom environments. Therefore, these solutions will be contextually constrained or afforded by the technological provisions made available in these different classroom environments.

The literature reviewed also reveals those who favoured ICT for student learning in the classroom are likely to have well developed TK. As mentioned, Cox et al, (2004) research surrounding ICT practices revealed that an understanding of the technical and cognitive affordances offered by different types of ICT was an important consideration in

ICT pedagogical reasoning. Reiterating these findings was Keengwe and Onchwari's (2011) study, which revealed teachers who had a personal proficiency in TK tended overall to favour ICT as a learning tool. Drent and Meelissen's (2008) study of Dutch teachers also revealed that TK competence does in fact positively influence the transformation towards a more student-centred pedagogy, and that this transformation takes place simultaneously along with experimentation in more innovative uses of ICT.

Whilst TPACK is now a highly cited framework for understanding the synergies of the knowledge bases required for meaningful ICT integration, the TPACK framework has come under considerable review as a usable construct. Voogt et al.'s (2013) review of the literature of the TPACK framework revealed three contrary views which included:

- “T (PCK) as extended PCK (S. Cox & Graham, 2009; Niess, 2005);
- TPACK as a unique and distinct body of knowledge (Angeli & Valanides, 2009), and
- TP (A) CK as the interplay between three domains of knowledge and their intersections and in a specific context”(Koehler & Mishra, 2009).

Recommendations for further research arising from this synthesis included the need to further understand the TPACK knowledge base in specific subject domains; understanding the complex relationship between teacher beliefs and ‘craft’ knowledge; and the development of valid and reliable subject specific instruments to assess TPACK, other than the commonly used self-assessment tools widely reported in the literature. A very recent measure of TPACK for a practical context in science, known as TPACK-P by Yeh, Hsu, Wu, Hwang, and Lin (2014) has appeared recently in the literature. The construct of TPACK-P is elaborated later in this Chapter in section 2.4.13.

2.4.9 UNESCO ICT Competency Framework (2008)

Recognising that that digital competency is a human right in a world rapidly undergoing technological change UNESCO developed an *ICT Competency Framework* (2008) for teachers. This framework identifies and defines a set of digital competencies required by teachers for the meaningful integration of ICT in teaching and learning. Designed as a framework for policy makers and practitioners, it aims to serve as a set of

guidelines highlighting how technology can be used to support pedagogy, curriculum, and assessment.

This framework is organised around three phases of knowledge acquisition; technology literacy, knowledge deepening and knowledge creation (United Nations Educational Scientific and Cultural Organization UNESCO, 2008). It has since been implemented in several pre-service teacher training programs across various countries including Guyana, Thailand, and Russia. This ICT competency framework for teachers is not dissimilar to the Australian National Professional ICT Teaching Standards (Australian Institute for Teaching and School Leadership (AITSL), 2011) and elaborated in the *Teaching Teachers for the Future* project (Australian Institute for Teaching and School Leadership (AITSL), 2014) discussed in Chapter 1.

2.4.10 Learning outcomes and pedagogy attributes (LOPA) instrument (2008)

In 2008, researchers at the Centre for Schooling and Learning Technologies (C-SaLT), Perth Western Australia, where this research is situated, established a range of rubrics primarily designed to assist Western Australian government schools with their ICT integration plans (Newhouse & Clarkson, 2008). One of these rubrics was known as the learning outcomes pedagogy attributes (LOPA) rubric (see Appendix A) and was designed to support teachers to integrate technology from a holistic perspective, that is, to consider the entire classroom learning environment. The LOPA rubric was theoretically grounded in the learning environment dimensions as advocated by the US Committee on Developments in the Science of Learning in their report *How People Learn: Brain, Mind, Experience, and School* (2005) which has been elaborated earlier in this Chapter. The LOPA framework also drew upon the work of *Productive Pedagogies* by the Queensland Department of Education (1999), *The Curriculum Framework* by the Western Australian Curriculum Council (1998) and was also substantiated by Jonassen's (1996) earlier work on constructivist learning environments using ICT.

The LOPA (2008) rubric focuses on the complexities and interdependences of the relationships that occur between the students, teachers, ICT, the physical environment as well as the curriculum and depicts this milieu of relationships in the schematic shown in Figure 2.2 (Newhouse, Clarkson, & Trinidad, 2005). Along with many other researchers

in this field, the C-SaLT researchers assert that explicating a causal link between the uses of ICT and learning outcomes is highly problematic, given that learning plays out within a specific contextual learning environment. Importantly classroom-learning environments are contextually constrained, and are most strongly influenced by the classroom teacher themselves. Instead the C-SaLT researchers advocate that collecting data on the entire learning environment is more useful. Taking an account of the factors then, as illustrated in Figure 2.2 will be helpful in seeking to understand the pedagogical reasoning and the instructional practices of the participants informing this study.

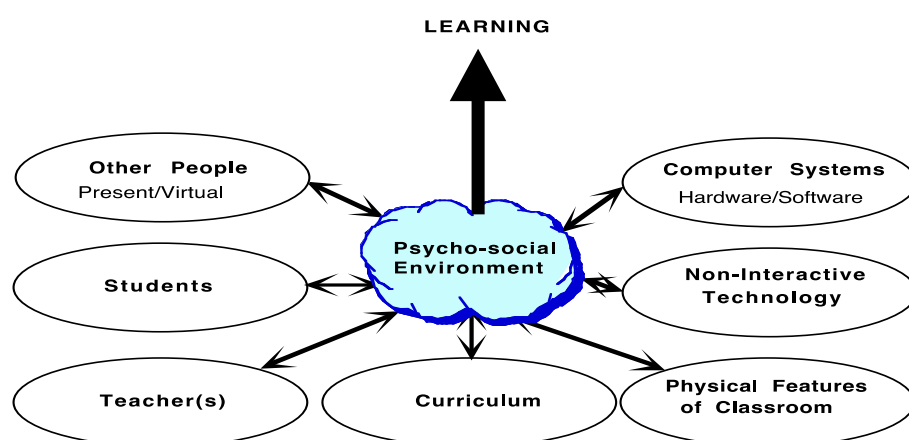


Figure 2.2: Entities that shape the entire learning environment within a classroom. As seen in Newhouse et al. (2005, p. 152)

2.4.11 Technology learning activity types taxonomy by Harris et al. (2010)

Earlier work on the TPACK construct revealed that effective technology integration required interdependent content, technological and pedagogical knowledge, emphasising the need for professional development efforts that did not simply focus on the development of technocentric skills. To support teachers' professional efforts a group of seven researchers and teacher educators in the US developed a technology instructional planning taxonomy. Stating that whilst these learning activity-types were intended to be pedagogically neutral; the taxonomy instead, provides a useful means to marry suitable digital tools and resources to best support particular science curricular content goals (J Harris et al., 2010). These learning activity types were broadly categorized by these authors as either:

- Conceptual knowledge building;
- procedural knowledge building, and/or;
- knowledge expression learning activities.

Over 40 activity types have been identified to date by this group where ICT could be used in the instructional design of various learning activities (J Harris et al., 2010). Shown in Table 2.4 is a snapshot of possible ICT tools and digital resources that align to science curricular content goals and are potentially useful for understanding the judgements made by the participants situated in this research.

Table 2.4: Technology integrated learning activity type exemplars adapted from Harris et al. (2010, pp. 586-587)

Conceptual knowledge building learning activity types		Procedural knowledge building learning activity types		Knowledge expression learning activity types	
Activity	Possible technology	Activity	Possible technology	Activity	Possible technology
Observe phenomenon	Presentation software, document camera, video clips, digital microscope	Practice	Web-based software or software tutorials, probe ware	Present or Demonstrate	Presentation software, video creation software, document camera, moviemaking software, podcast, vodcast
Organise/ Classify Data	Database, spreadsheet, concept mapping software	Collect data	Web-based data sets, Graphing calculators, video, audio, digital cameras, digital microscopes, web-based data sheets	Draw image	Drawing software, digital camera, image editing software
Explore a topic/concept	Web search engines, digital archives	Observe	Document camera, Webcams, digital/video cameras, digital microscopes	Concept mapping	Concept mapping software, interactive whiteboards, drawing software

2.4.12 *Understanding by design™ planning model by Wiggins and McTighe (2011)*

Whilst not a technology integration planning model *per se*, this popular teacher instructional design model is an extension of Wiggins and McTighe's earlier work in 1998 on the critical role of teacher as a designer of meaningful student learning programs (Wiggins & McTighe, 2011). Given that teachers, such as those featured in this research, work within accountability frameworks and standards driven curriculum there is applicability of this instructional design model in understanding their pedagogical reasoning. In practice, this model consists of a three-step backward design framework which considers:

1. Identifying the desired results using the national curriculum and then framing this around the following key questions: What should students know, understand and be able to do?
 2. Determining the required assessment evidence framing this around the following key questions: How will we know if students have achieved the desired results? What we accept as evidence of student understanding and their ability to use their learning in new situations? How will we evaluate student performance in fair and consistent ways?
 3. Planning the learning experiences and instructions framing this around the following key questions: How will we support learners as they come to understand important ideas and processes?" How will we prepare them to autonomously transfer their learning? What enabling knowledge and skills will students need to perform effectively and achieve the desired results? What activities, sequence, and resources are best suited to accomplish our goals?
- (Adapted from Wiggins & McTighe, 2011, pp.3-13)

2.4.13 *TPACK-P model by Yeh, Hsu, Wu, Hwang, and Lin (2014)*

Much scholarly work has ensued within the TPACK research community, however, the community has yet to reach consensus of its knowledge components including how the TPACK construct is developed and applied. However, more recently Yeh, Hsu, Wu, Hwang and Lin (2014) defined TPACK operationally for a practical

context in science teaching (and called this TPACK-P), as well as validated a measure of this knowledge base (Yeh, Hsu, Wu, Hwang, & Lin, 2014). They categorised the knowledge of TPACK-P set around three key domains:

- Assessment, planning and designing;
- practical teaching; and,
- developing a set of indicators for each of these domains.

These authors argued that “knowing the affordances of ICTs is not the whole picture of TPACK-P; instead, teachers must consider how to teach with appropriate selections of ICTs after considering essential instructional factors, like specific content, students, and the teaching environment” (2014, p. 78). The most important factor influencing the use of ICT as rated in this study, was using ICT to make content instruction more accessible and comprehensible to learners, in other words, curriculum related ICT resources and tools content was a primary pedagogical consideration. The next most important factor driving the use of ICT was the use of the rich reservoir of online resources both for updating teacher’s own content knowledge, as well as using this massive array of multimodal resources to help cater to the diversity of students’ needs. The knowledge dimensions of Yeh et al.’s (2014) TPACK-P model are summarised in Table 2.5.

Table 2.5: TPACK-P knowledge domains adapted from Yeh (2014, p. 79)

Assessment	Planning and designing	Practical teaching
Using ICTs to understand students	Using ICT to understand subject content	Infusing ICTs into teaching contexts
Using ICTs to assess students	Planning ICT-infused curriculum	Applying ICTs to instructional management
	Using ICT representations to present instructional representations	
	Employing ICT-integrated teaching strategies	

Following on from the validation of the TPACK-P instrument Yeh et al. (2015) conducted a longitudinal mixed methods study of 40 Taiwanese science teachers to

explore and identify various TPACK levels. Their cluster analysis revealed three distinctive levels of teachers' infusion of ICTs into the classroom. *Technology-infusive* teachers were found to be student-centred in their application of ICTs for teaching, learning and assessment; *technology transitional* types were teacher-centred in their approaches; and, *planning and design* focused teachers were proficient in planning and designing using ICTs, however, were still unfamiliar with or not confident about using ICTs in the classroom (Yeh, Lin, Hsu, Wu, & Hwang, 2015). This study also revealed that curriculum design and knowledge delivery were teachers overriding priorities in implementing ICTs in the science classroom. Importantly these authors found that TPACK evolves in context and with experience.

2.4.14 International Society for Technology Education (ISTE) Standards for Educators (2016)

ITSE is a US based not-for-profit professional organisation, boasting a global membership base of over 100 0000, founded with the aim of helping educators leverage the use of technology in K-12 classrooms for global citizenship. ITSE, offers student technology standards for the digital age, as discussed in Chapter 1, and offers teachers a goal setting framework for integrating digital technologies into the classroom (ISTE (International Society for Technology in Education), 2016). The rhetoric surrounding the ITSE teacher standards is that this approach to technology integration will lead to the development of 21st century competencies by students. The ITSE teacher standards consist of seven dimensions of teaching practice using technology as a; learner, leader, citizen, collaborator, designer, facilitator, and analyst, along with a set of indicators of meaningful practice. Implicit in these standards is the need for teachers to identify, orchestrate and manage learning activities that draw upon the relevant content areas so that students can engage with digital technologies as: (1) empowered learners, (2) digital citizens, (3) knowledge constructors, (4) innovative designers, (5) computational thinkers, (6) creative communicators, and (7) global collaborators.

2.4.15 Kolb's Triple E framework (2018)

A criticism of many of the technology instructional design models in the literature, including some of the models as featured in this review, is the lack of specificity surrounding the characterisation of the 'value added-ness' of the role of technology in the learning process (Kolb, 2017). Kolb's Triple E Framework is an attempt to alleviate this lack of classification and in doing so offer teachers a more distinct and strategic approach to using technology than simply as a substitute for traditional methods. Kolb's Triple E framework asks teachers to consider a range of pedagogical questions in relation to learning as enabled through technology tools and is summarised in Table 2.6.

Table 2.6: Triple E Framework adapted from Kolb (2017)

Phase of the framework	Pedagogical questions to ask
Engage learning	<ul style="list-style-type: none">• Does the technology allow students to focus on the task of the assignment or activity with less distraction?• Does the technology motivate students to start the learning process?• Does the technology cause a shift in the behaviour, where they move from passive to active social learners (co-use or co-engagement)?
Enhance learning	<ul style="list-style-type: none">• Does the technology tool aid students in developing a more sophisticated understanding of the content (higher-order thinking skills)?• Does the technology create scaffolds to make it easier to understand concepts, gather information, or generate ideas?• Does the technology create paths for students to comprehend or demonstrate their understanding of the learning goals in a way that they could not do with traditional tools?

Phase of the framework	Pedagogical questions to ask
Extend learning	<ul style="list-style-type: none"> • Does the technology create opportunities for students to learn outside of their typical day? • Does the technology create a bridge between school and everyday life experience? • Does the technology allow students to build skills that they can use in their everyday lives?

2.4.15.1 Implications for professional learning

It is not clear from the literature as to the theoretical underpinnings of some of the models presented here. As revealed, some models offer more prescriptive guidance to assist teachers in designing ICT-enabled learning opportunities whilst others are more conceptual. An implication common to these models, however, is the ability for teachers to determine the affordance or fit of using a technology as it relates to realising a learning goal/s. In other words, co-opting ICT as a genuine cognitive partner. Inherent in the models presented is the implication that integrating ICT into lesson activities, potentially amplifies both the reasoning complexity along with the amount of planning time to design such experiences. A further implication of these models is that the cooperation of teacher professional knowledge bases across pedagogy, content and technology is not independent of teachers' beliefs and importantly is situated and developed within practice.

2.5 Pedagogical reasoning and action models

Jonassen (1996), amongst others, has long since advocated that technology integration involves quality learning design requiring teachers to reason soundly. Various studies presented in this Chapter have recognised that successful integration of ICTs in the classroom consists of sophisticated planning and strategic design of the learning activity so that it marries relevant technologies to the learning or curriculum goals. Another important theme running through the literature is that “Teachers need to be self-motivated, interested, and willing to integrate technology into their courses” (Keengwe,

Onchwari and Wachira, 2008, p. 88). Whilst few models exist, several ICT pedagogical reasoning and action models are now discussed beginning with Shulman's original pedagogical reasoning and action model (PRA).

2.5.1 Shulman's (1987) pedagogical action and reasoning model (PRA)

The complicated and highly situational nature of teachers' work has challenged researchers to define and analyse the knowledge base that is required for the effective integration of ICT into teachers' praxis. Shulman, along with his Stanford University colleagues, Wilson, Richert and Shulman conducted the *Knowledge Growth in a Profession* project during the late 1980s. This research investigated the ways of developing and enhancing PCK in teacher preparation programmes and has since spawned much scholarship into this construct. However, since its inception PCK has proven challenging to elucidate, as much of teachers' thinking is tacit (Baxter & Lederman, 1999; Cochran, King, & DeRuiter, 1991; Gess-Newsome, 1999; Loughran et al., 2012). Complicating matters is that professional knowledge is acquired over extended periods of time. A similar pattern in the research community has emerged with investigating the construct of TPACK (S. Cox & Graham, 2009).

As stated by Shulman, teaching "begins with an act of reason, continues with a process of reasoning, culminates in performances imparting, eliciting, involving, or enticing, and is then thought about some more until the process can begin again (1987, p. 13). According to Shulman (1987) this reasoning and action generates "new comprehension by both the teacher and the student" (p. 8). Following on from Schön's (1983) seminal work on the characterisation and development of teacher thinking as *reflection-on-action* and *reflection-in action* which builds professional knowledge, Shulman (1987) presented a model for codifying the judgments and decisions teacher make, otherwise known as pedagogical reasoning, as teachers carry out the processes of planning, teaching, assessing, and evaluating.

During the Stanford University *Knowledge Growth in a Profession Project*, 21 secondary pre-service teacher's growth in knowledge through to graduate teachers was observed. As a result, a model to portray the reasoning and action process was developed, known as Pedagogical Reasoning and Action (PRA) model (Wilson et al., 1987). This

model was described involving six distinct actions or observable classroom behaviours beginning with: *Comprehension* of subject matter; *Transformation* of that subject matter into teachable representations; *Instruction* of both the students' learning and teaching performance; *Evaluation* of both the students' learning and teaching performance; *Reflection* upon actions leading to the development of *New Comprehensions*. These six processes were also delineated into sub-processes. Illustrated in Table 2.7 is the PRA model. Whilst it is depicted in a linear manner, Shulman carefully explained that this construct is dynamic and iterative in nature, as reasoning itself is an ongoing act; in action and on-action (Schon, 1983).

Table 2.7: Pedagogical reasoning and action model adapted from Shulman (1987, pp. 14-19)

Stage of reasoning	Key features of this aspect of pedagogical reasoning
<i>Comprehension</i>	Of educational purposes, subject matter structures, ideas within and outside the discipline, assessing prior knowledge of the learner
<i>Transformation</i>	<p><i>Preparation:</i> critical interpretation and analysis of texts, structuring and segmenting, development of a curricular repertoire, and clarification of educational purposes [SEP]</p> <p><i>Representation:</i> use of a representational repertoire, which includes analogies, metaphors, examples, demonstrations, explanations, and so forth that match the key ideas in the lesson</p> <p><i>Selection:</i> choice from among an instructional repertoire, which includes modes of teaching, organising, managing, and arranging</p> <p><i>Adaptation and tailoring:</i> Tailoring to pupil characteristics including consideration of pupil conceptions, preconceptions, misconceptions, and difficulties, language, culture, and motivations, social class, gender, age, ability, aptitude, interests, self-concepts, and attention.</p>

Stage of reasoning	Key features of this aspect of pedagogical reasoning
<i>Instruction</i>	Lesson mode such as direct instruction, presentations, lecture, demonstrations; classroom management and interactions such as group work, individual work, discussions, explanations, discipline, humour, questioning, praise, critiques and other aspects of active teaching, discovery or inquiry instructions, and other observable forms of classroom teaching
<i>Evaluation</i>	Interactively checking for pupil understandings and misunderstandings; reviewing the lesson outcomes and the suitability of materials and activities
<i>Reflection</i>	Reviewing, reconstructing, re-enacting and critically analysing one's own and the class's performance in relation to the ends that were sought, and grounding explanations in evidence
<i>New comprehensions</i>	New understandings of educational purposes, subject matter, students, and teaching resulting in a reconstituted repertoire

In working with this model Wilson et al. (1987) found that much of what is unique about the teaching process is the way in which teachers transform their subject matter knowledge or content knowledge (CK). This transformation process represents a significant proportion of thinking and planning time, as teachers must reflect on and interpret the subject matter and then find ways to represent this content suitable for their students, calling this sub-reasoning process *adapting* and *tailoring*. The introduction of ICTs into teachers' pedagogical reasoning is therefore likely to increase the time spent by teachers transforming their subject matter knowledge given the massive array and complexity of digital tools and materials that exist and continue to evolve. Furthermore, these judgments and actions are likely to require some form of technological knowledge base to draw upon. When Shulman first reported his PRA model for building PCK (1986) it did not refer to a specific technological knowledge base *per se* as a component of the professional knowledge base required for teaching.

Methodologies to capture PCK, given that reasoning is mostly an internal construct and tacit, tend to be qualitative in nature relying on interviews, concept mapping, observational data and planning artefacts such as lesson plans and assessment

rubrics (Baxter & Lederman, 1999; Loughran, Mulhall, & Berry, 2004). Furthermore the accumulation of this data can be time consuming, the ensuing analysis can be challenging and most particularly in terms of accurately portraying the full extent of an individual's PCK (Loughran et al., 2004). In Australia, Loughran and colleagues (2004) developed a holistic method to capture science teachers' PCK involving capturing the science content to be taught, which they termed Content Representation (CoRe), and the teaching practice related to this CoRe, which they termed Professional and Pedagogical Experience Repertoire (PaP-eR). These holistic tools have been used successfully to capture PCK to provide insights for the development of PCK with preservice science teachers (Loughran et al., 2012). Whilst there is still limited research capturing and portraying PCK Loughran, Berry and Mulhall's (2012) thinking framework has shown much promise in elucidating pedagogical reasoning and the decision making within the context of teaching science content.

2.5.2 *Feng and Hew (2005) ICT pedagogical reasoning model*

An earlier attempt to devise an ICT pedagogical reasoning model was conducted as a phenomenological study by Feng and Hew (2005) on seven American K-12 teachers who demonstrated a keen interest in the integration of technology in their classrooms. Whilst this study only interrogated the first two aspects of Shulmans' PRA (1987) model, (i.e., *Comprehension* and *Transformation*) these researchers found that within the sub-process of *Transformation* teachers carried out thinking around the interpretation of the curriculum. They re-named the *Preparation* sub-reasoning process calling it instead *Interpretation*. They also re-categorised the sub-reasoning processes of *Representation*, *Selection*, *Adaptation* and *Tailoring* into one thinking sub-reasoning process, redefining this as *Specification*. According to these researchers placing the emphasis on *Specification* allowed "for different teaching philosophies rather than structured instruction as referred to in Shulman's *Representation* sub-process" (p. 7), although clarification of this nomenclature change is not entirely clear in their study.

Feng and Hew's (2005) study also found that within the *Transformation* thinking sub-process the teacher participants made additional considered judgments surrounding the selection of technological tools in keeping with their instructional objectives. This

sub-reasoning process is not specifically referred to in Shulmans original PRA model. They also noted that this group of teachers made considered preparations for potential digital disruptions, a sub-reasoning process they named *Caution*. A comparison of Shulman’s (1987) PRA model with Feng and Hew’s (2005) pedagogical reasoning model is illustrated in Table 2.8.

Table 2.8: Comparison between Shulman's PRA model (1987) and Feng and Hew's (2005) ICT pedagogical reasoning model adapted from Feng and Hew (2005)

Shulman’s PRA reasoning processes		Feng & Hew’s ICT reasoning process	
Comprehension		Comprehension	
Transformation	Preparation	Transformation	Interpretation
	Representation		Specification
	Selection		Caution
	Adaptation & tailoring		
Instruction		Not investigated	
Evaluation		Not investigated	
Reflection		Not investigated	
New comprehensions		Not investigated	

2.5.3 Starkey (2010) Pedagogical reasoning and action for the digital age

Starkey (2010) proposed a model of teacher *Pedagogical Reasoning and Action for the Digital Age*. Starkey (2010) explored the pedagogies of six self-nominating “digitally able” (p. 236) beginning teachers and examined the pedagogies associated with integrating digital technologies. Using Shulman’s (1987) PRA model as a key referent Starkey observed that *Comprehension* is composed of both syntactic and substantive knowledge. Replacing *Transformation* and its five sub-reasoning processes Starkey proposes *Enabling Connections* as a key decision-making process that teachers use when planning lessons involving ICTs. As well as constructivism, Starkey’s (2010) model is also grounded in a relatively new learning theory known as Connectivism, after George Siemens (2004).

Very few academic accounts of Connectivism as a theory of learning, appear in the literature. According to Siemen (2005) central to Connectivism is the notion that “learning is a process that occurs within nebulous environments of shifting core elements—not entirely under the control of the individual” (para 23). Siemen (2005) acknowledges that Connectivism is based “upon a synthesis of chaos, network and complexity and self-organisation theories” (Siemens, 2005). Whilst Starkey’s (2010) study overall found that Shulman’s (1987) PRA model is still relevant today, she also claims an inherent assumption of Shulman’s PRA model is the transmission of knowledge from teacher to pupil “which was found to restrict innovation by digitally able teachers” (p. 233). As part of this study she identified six different types of learning aided by digital technologies classifying these as; doing; thinking about connections; thinking about concepts; critiquing and evaluating; creating knowledge and sharing knowledge and developed this into a digital age learning matrix tool (Starkey, 2011). This evaluative tool shows much promise in the preparation of pre-service teachers to assist in the selection and reflection of ICT tools from a learning affordance perspective. Importantly Starkey’s (2010) model advances the notion that pedagogy for the digital age should reflect the new ways that students can access knowledge via “open and flexible connections” (p. 243), as afforded by ICTs. A comparison of Starkey’s model of pedagogical reasoning in the digital age along with Shulman’s original PRA model is illustrated in Table 2.9.

Table 2.9: Comparison of Shulman's PRA (1987) model and Starkey's pedagogical reasoning model (2010) for the digital age adapted from Starkey (2010, p. 243)

Shulman's reasoning process	Starkey's ICT reasoning process	Starkey's elaboration of this reasoning process
Comprehension	Comprehension: of subject (content knowledge)	Includes substantive knowledge (concepts and principles) and syntactic knowledge (subject methodologies)
Transformation	Enabling connections: preparation for teaching (pedagogical content knowledge)	Selecting appropriate resources and methods to enable students to make connections between prior knowledge and developing subject knowledge; transforming existing knowledge into teachable content; enabling opportunities between groups and individuals to develop knowledge of the subject; adaptation and tailoring (personalisation) learning for the students being taught
Instruction Evaluation	Teaching and learning; knowledge of context	Formative and summative evaluations of pupil learning with feedback to the students (from a variety of sources), and modification of the teaching process where appropriate
Reflection	Reflection	Reviewing and critically analysing teaching decisions based on evidence
New comprehensions	New comprehensions	About the subject, students, and teaching

2.5.4 Webb (2011) revised model of ICT pedagogical practices and reasoning model

Very few models of pedagogical reasoning and action that take specific account of technology currently exist in the literature. To date there is still a need to deepen our knowledge of how the learning of skills, concepts and processes are facilitated by the use

of ICTs (Karakus, 2013: 2014; Rogers & Twidle, 2013). Webb (2002) first presented a revised model of the pedagogical reasoning process initially described by Shulman (1986), to incorporate the influence of ICTs. This model more specifically incorporated the influence of teachers' values and beliefs on the six key cognitive processes highlighted in Shulman's original PRA construct (Webb, 2002). Later studies in the UK by Webb and Cox (2004) on teachers' ICT practices and pedagogical reasoning revealed that during the pedagogical reasoning transformation process teachers not only decide what resources and instructional approaches are necessary to enable students to develop skills and concepts, they also needed to identify the affordances of the software. Furthermore, these authors also suggested a distributed model of pedagogical reasoning that is shared amongst the students and teachers. Webb (2011) later revised this model to reflect the influence of the TPACK knowledge base in the pedagogical reasoning process shown in Figure 2.3.

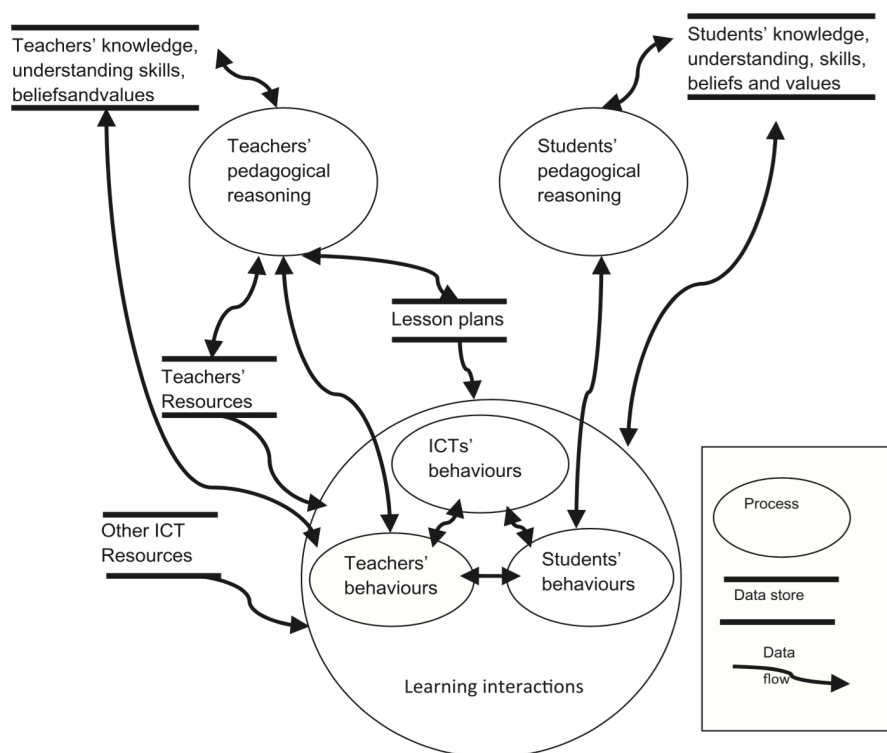


Figure 2.3: Webb's revised pedagogical framework related to ICT use (Webb, 2011, p. 3)

More recently, Harris and Phillip's (2018) expressed the view that if TPACK exists then the construct of technological pedagogical reasoning and action should too. The overriding rationale for using ICT in a given learning activity should be to allow students to achieve something that could not normally be achieved in the classroom without it, i.e., a tools affordance perspective. An obvious assumption in all the models presented here is that teachers have the pre-requisite technical knowledge to use whatever ICT tool has been chosen for the instructional setting. The various models presented also reveal the additional pedagogical reasoning process requirement to ascertain the relative cognitive, social, and technical affordances of new ICT tools.

An important point to reiterate is that our current understanding of pedagogy is not something that resides solely within a teacher (Perkins, 1993), that pedagogy is complex and dynamic (Loveless, 2011). Pedagogy is influenced culturally, historically and economically, and most importantly depends upon the way in which teachers and students interact, in other words pedagogy is not simply instruction (Watkins & Mortimore, 1999). As highlighted, pedagogical decision making is also constrained or afforded by the technical provisions of that environment (Lim, 2006). It is important then, that in studying the pedagogical reasoning adopted by the various participants in this study, that an account of the context of the teacher, context of the learner, expertise of the teacher and the students, as well as the technical affordances of the local environment are clearly documented. A further note of caution, any conceptualisation of pedagogical reasoning with ICT arising from this study must take careful account of the relationship to the community in which it was set.

2.6 Affordance theory and technology

It is important to translate the concept of *affordance* in relation to its use in the literature surrounding the use of ICT for teaching and learning and how this concept relates to informing this study. James Gibson, a perceptual psychologist first coined the term *affordance* in 1977. Affordance theory states that the world is perceived both in terms of object shapes and spatial relationships, as well as in terms of the objects possibilities for action, in other words, affordances (Gibson, 1977). According to Gibson (1977), features of the environment potentially compound the affordances of an object.

Gibson asserts that the affordances offered by an object or environment exist regardless of whether or not they are perceived (Angeli & Valanides, 2009; Greeno, 1994).

Norman (1998), an eminent researcher in the field of human-computer – interaction (HCI), later co-opted the term affordance in relation to the methods for evaluating and comparing computer system interfaces in terms of their perceived usability. Normans' view differs somewhat in that he ascribes to the view that affordances can be both perceived and actual (Angeli & Valanides, 2009). Conole and Dykes (2004) developed a taxonomy of ICT affordances for educational practice from a synthesis of the literature on ICT usage at that time which is most useful in regards to this study. This taxonomy includes; ICT affords immediate access to vast amounts of information; access to rapidly updated and real time (contemporary) information; ICT access affords diversity of perspectives beyond that of the person's immediate community including access to subject experts; the vast array of ICT collaboration and communication tools (software and hardware) afford new forms of sharing information and dialogue; and, finally the multimodal and non-linearity of the Internet enables the learner to adopt differentiated and more personalised approaches to learning than found typically in traditional classrooms.

The use of the term affordances is now widely synonymous with educational technology and is generally used to describe the learning opportunities provided to users in technology mediated learning environments (Hammond, 2010). However, the literature reviewed reveals that the affordances of ICTs are provided by the interactions between the hardware, software, non-ICT resources, the teacher and students, in other words the complex interplay of the whole learning environment (M Hammond, 2010; Webb, 2011). As a note of caution Freidhoff (2008) cautions teachers to examine how technology may in fact potentially constrain the intended learning outcomes.

Before concluding this section, it would be remiss not to acknowledge the work of Seymour Papert who is recognised as one of the founding fathers of computational literacy and facilitated much research surrounding how the use of computers in the classroom potentially transforms the learning environment. Papert's work (1999) also provided us with a useful simple classification tool for thinking about the educational affordances of software applications, referring to these as either *informational* or *constructional* tools (Rogers & Twidle, 2013). Amongst others, Spector (2016) cautions

that due to the rapid evolution of technological tools and their obsolescence, that a definitive list of the educational affordances for all educational ICTs is no longer possible, suggesting that it is wiser for teachers to think about the purpose of the learning activity itself and then linking this to the use of a ICT. A further implication of Papert's research was that the preparation of future teachers would require that they were equipped both with technological and procedural skills, in other words possess a body of TK (Koehler & Mishra, 2009).

2.7 Socio-cultural and historical perspectives on learning with ICT

As evidenced so far in this literature review, successful pedagogies with ICT emphasise socio-cultural and constructivist theories of learning as the basis for planning and making instruction and the learning environment more effective. Socio-cultural learning theory or social constructivism, as this is now commonly referred to, has its origins in the work of several soviet cognitive theorists including Vygotsky, Luria and Leontiev. However, it is Vygotsky with whom most educators attribute this learning theory.

Lev Vygotsky, was born in 1896 in Orsha (now Belarus), Russia, and initially trained in Law. He died an early death at the age of 37 from acute tuberculosis, however, his prolific writings in cognitive development left a legacy that continues to contribute to the field of educational psychology. As purported by Vygotsky (1978) learning occurs on two levels, both at a social and personal level;

Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level: first, between people (interpsychological) and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All higher functions originate as actual relationships between individuals (p. 57).

Thus, according to Vygotsky (1978) social interaction plays a critical role in the cognitive development of the child. Another important feature of Vygotsky's work was the notion that the construction of knowledge is mediated and indexed to the context in which it is encountered, implying that if knowledge is decontextualized it is likely to lead

to inert knowledge. The importance of this concept for teaching is the notion that authentic, relevant, and real-world examples should be used in the classroom.

Social constructivism, sometimes referred to as social learning theory, is not specifically guided by a prescriptive list of teaching strategies or tactics, instead it is best conceived of as a paradigm (Kuhn, 1962,1970) where the key focus of this worldview is to engage learners actively, rather than passively, in discussions, argumentation, debriefing, and meaningful problem-solving activities. Accordingly, Vygotsky stressed the importance of language as the key semiotic tool for the acceleration of cognitive development , where collaborative dialogue between learners is central to knowledge building and development by the individual; in other words learning is a socio-linguistic process (Roth, 2004).

2.7.1 First generation activity theory

Central to Vygotsky's (1978) theory of human learning is that tools, each possessing an evolutionary cultural component, are the fundamental elements that shape human activity and learning, the primary tool in human activity being language. Vygotsky (1978) believed that human psychological cognitive activity (learning) happens in a triadic relationship where the actions of the subject (or actor) acts to resolve a shared problem or goal (object), which is mediated using tools. According to Vygotsky's theory of human cognition, the primary unit of analysis is at the individual level. The basic triangular schematic of mediated cognitive activity as developed by Vygotsky (1978) is show in Figure 2.4 and is now known as first generation activity theory.

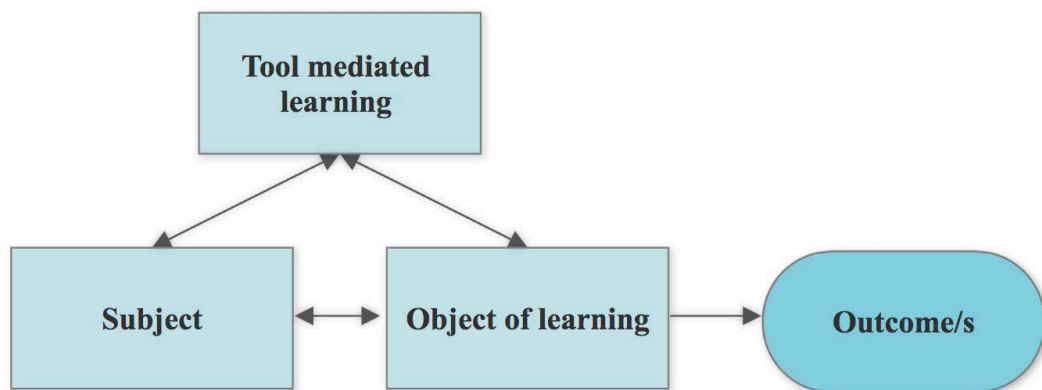


Figure 2.4: Vygotsky's first-generation activity theory: A triadic model of tool mediated learning adapted from Engeström (1987)

Tools, according to activity theory terminology are instruments of labour, to be used during learning (activity), and these may be conceptual, material or organisational (Nardi, 1996). Examples of tools in an educational sense, include; language, mnemonic techniques, algebraic symbol systems, works of art, writings, diagrams, maps and ICTs (Barab, Evans, & Baek, 2003). From an activity theory perspective teaching should be oriented towards supporting students to engage in the use of these tools, for example ICTs, and talk in ways that are consistent with the practices of the community to which students are being introduced e.g. scientists (John-Steiner & Mahn, 1996). The implication of first-generation activity theory for this thesis is that whilst all tools have an embedded cultural-historicity to them, this does not mean that at the individual level that these tools will be used in the same way, for example the use of laptops by students cannot be assumed to be uniform; and furthermore, the actions of the teacher can constrain or afford the use of these laptops in these settings.

An important element of Vygotsky's (1978) theory of learning is the concept of the zone of proximal development (ZPD), an idea that relates to how humans learn through social interaction, which is both culturally and historically situated. Vygotsky (1978) defined the ZPD as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (p. 86). From this perspective mediation within the ZPD occurs using

tools, and thus successful teaching requires the selection and alignment of appropriate tools. From Vygotsky's ZPD perspective, meaningful dialogue between the teacher and the students' that is oriented towards the construction of something new is critical. It has been known for some time that teacher-student interactive talk is vitally important to support scientific reasoning and problem solving in the science classroom (Tytler & Aranda, 2015). The literature reviewed reveals successful ICT integration efforts when ICT has been positioned as a cognitive partner and coupled with a learning environment that affords plenty of opportunities to discuss, inquire and problem-solve collaboratively with other students, the teacher and other experts within the ZPD (Engeström, 1987; Ertmer & Ottenbreit-Leftwich, 2013; Hackling, Murcia, & Ibrahim-Didi, 2013; Hardman, 2008; Jonassen et al., 1998; Postholm, 2008; Roth, 2004).

2.7.2 *Leont'ev's activity sequence*

Leont'ev (1978), a former student of Vygotsky, advanced Vygotsky's activity theory of learning to further situate goals and motives in terms of collective activity, that is individuals are part of sociocultural systems that shape the learning of its members (as cited in Nardi, 1996). Leont'ev's (1978) version is often now referred to as second generation activity theory. Leont'ev characterization of human activity further elaborated the activity structure into a sequence of actions and operations is shown in Figure 2.5 and has implications for this thesis which will now be explained.

According to Leont'ev (1978) the top layers an activity structure is the collective activity itself, which is oriented toward a motive, known in activity theory terminology as the object. According to Leont'ev an activity itself is composed of a sequence of actions each directed towards a goal. Activities are consciously driven and these in turn are composed of operations (as cited in (Kuutti, 1996). Operations are driven by the conditions and tools at hand and generally refer to routine processes (mostly unconscious acts), performed by the subject to adjust the ongoing situation so that the subject may achieve their goal. It should be noted that according to Leont'ev's expansion of activity theory, there is a mutual interplay between these elements, resulting in the outcome/s acting back on the system (Roth & Lee, 2010).

Given that pedagogy has been already distinguished in this thesis as purposeful or motive driven behaviour by the teacher intended to bring about desired learning outcomes in a student, it is then possible to analyse pedagogy as an activity structure. Leont'ev's activity sequence provides a pragmatic means to decompose intentional ICT tool mediated activity into specific actions and operations that occur within the social context of the classroom.

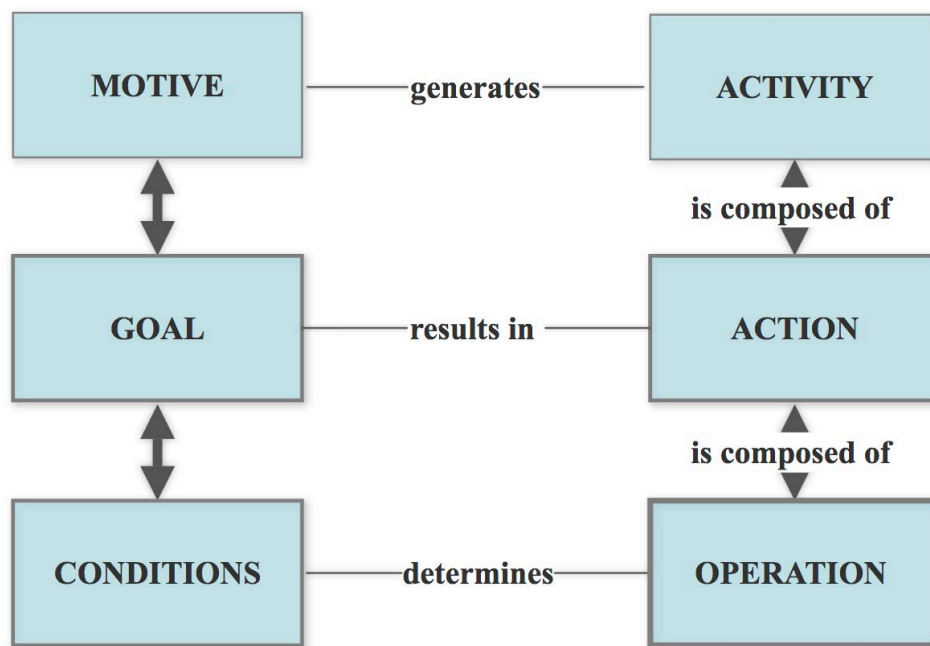


Figure 2.5: An activity structure according to Leont'ev (1978) adapted from Roth and Lee (2010)

2.7.3 *Cultural historical activity theory*

Advancing Leont'ev's (1978) second generation activity theory, another theorist, Engeström (1987) unified and created an expanded and complex triadic model of human activity accounting for the social relationships inherent in tool mediated human actions, now often referred to as cultural historical activity theory (CHAT) (Cole & Engeström, 1993; Engeström, 1987). The CHAT framework includes Leont'ev's collective perspective on the development of the mind, that is to situate learning in context; where culture and history are additional forces to be considered (Barab et al., 2003; Karakus,

2013: 2014). A description of the dimensions of CHAT and its relevance to this research now follows.

Engeström (1987) added three additional social and cultural elements to Vygotsky's (1978) original triadic model of individual tool-mediated action: *rules* that regulate the subject's actions toward an object, as well as with the other participants within the activity system; *community* of people with whom share an interest in the same object (goal); and *division of labour* amongst the participants which includes the roles and responsibilities of the community members. Engeström (1987) referred to this expanded unit as the activity system and depicted the correlation between these additional components using several triadic and dyadic relationships as shown in Figure 2.6.

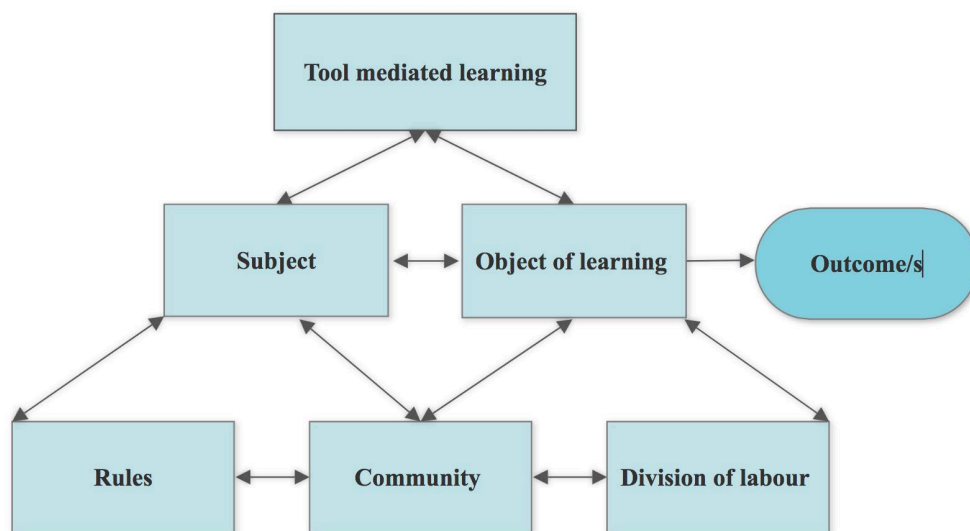


Figure 2.6: Cultural historical activity system according to Engeström (1987) adapted from Engeström (1987, p.78)

According to the CHAT framework at the core of human activity, the *subject* (an individual or group whose viewpoint is adopted) acts on the *object (or goal)* to transform it in some way using the mediating *tools* (or artefacts) arriving at an *outcome*. This outcome can be either concrete or abstract (Karakus, 2013: 2014). It is important to clearly articulate what Engeström (1993) defined as the *object* in this triadic organisational structure: “The object precedes and motivates activity. It refers to the raw material or problem space at which the activity is directed and which is moulded or transformed into outcomes with the help of physical and symbolic and internal tools” (p.

67). Mediating tools can include language, signs, physical or mental models, in the case of this research, the use of ICTs in the classroom (activity system). In relation to this research, according to CHAT, it is the use of these ICT tools within the classroom community that shapes the way the teacher and the students act and think.

Engeström's (1987) studies using CHAT revealed that instability and contradictions can arise between and within each of the individual components (or nodes) of the activity system. Accordingly, an activity system, for example a classroom, is a dynamic entity with the interactions between each of the components shaping possibilities for action (or affordances). These iterative interactions then become the object of collaborative learning, ultimately resulting in the development and change in that activity system (Barab, Evans & Baek, 2003). Although there are many dyadic and triadic relations between these six components, the analytical strength of CHAT is best leveraged when the activity system is utilised as a single/whole unit.

In fact, CHAT is now characterised as a meta-theory or framework, more useful as a methodological lens for analysing goal directed human activity which has been demonstrated in a variety of qualitative ICT educational studies (Barab et al., 2003; Hardman, 2008; Hashim & Jones, 2007; Jonassen & Rohrer-Murphy, 1999; Kuutti, 1996; Lim & Chai, 2004; Stevenson, 2008). It has also been shown to provide both a meta-language to present classroom phenomena, as well as utility as a method for understanding and finding patterns across ICT tool-mediated social interactions (Hardman, 2008; Scanlon & Issroff, 2005).

A brief description of how each of the components of an activity system applies to ICT enabled pedagogical activity for a classroom setting will now follow. This description is largely based on Hardman's (2008), and Stevenson's (2008) conceptualisation of pedagogy using CHAT as the unit of analysis:

1. *Subject*: refers to the main actor in the activity system, in this study this is the teacher. The teachers' beliefs about learning, pedagogical content knowledge, pedagogical reasons, and motivation for using ICT for instruction and ICT skills all influence the subject's actions in this activity system.
2. *Tools or Mediating artefacts*: the ICT tools and non-ICT tools utilised by the teacher and students during the learning activity

3. *Object*: the object represents the learning activity or problem that the students are working on, or the goal of using ICT in the learning activity that is directed at transforming the learning outcomes.
4. *Rules*: the implicit and explicit rules operating in the classroom; the norms, social order conventions in the classroom, instructional rules of the teacher; rules and policies of the school in relation to digital infrastructure and of the wider education system; and curriculum and assessment requirements.
5. *Community*: the teacher and the students working together or ‘acting’ on the shared ‘object’, the human context of the setting. It can also include technical support staff or educational assistants who may also feature as part of that community in some instances.
6. *Division of labour*: the negotiation of the roles and responsibilities of the students and teacher (vertical and horizontal division of labour)
7. *Outcome*: the ‘sense making’ of the activity by the students in terms of factual science knowledge, conceptual understanding and /or skills

The use of CHAT as a lens in this study makes it suitable for the analysis of the participants’ pedagogical practices and may serve to illuminate why they act as they do use ICT.

2.8 Conceptual framework of this study

This review has demonstrated that learning activities that take advantage of the more transformational aspects of ICT in science teaching have been shown to be student-centred, constructive, collaborative, focused on the promotion of higher order thinking skills using authentic or real-world contexts. The conceptual framework to emerge from this literature review also suggests a socio-cultural perspective will be most useful for analysing the learning activities and learning environments of technology rich classrooms. This appraisal also suggests that meaningful pedagogical approaches using ICT requires sophisticated decision making and reflection drawing upon a synthesis of several teacher knowledge bases including technology, pedagogical and content knowledge.

The literature also revealed that the affordances in relation to both the contextual setting and of ICT tools themselves provides the potential for action towards meaningful ICT enabled science learning (outcome). Fundamentally, careful evaluation of the educational affordance, or relative advantage of the selected technology/s in meeting the intended learning goal is of prime consideration in the pedagogical reasoning process. The literature also suggested that these learning goals are likely to be curricular oriented in action. In tandem with this pedagogical decision, designing meaningful learning activities for technology rich environments requires thoughtful reasoning with regards to the instructional learning environment for which the activity is set, necessitating a rethinking of the role of the teacher to that of an orchestrator of the learning environment or learning designer, the student as a learning partner or collaborator and where ICT is positioned as a cognitive learning tool.

The literature also suggests that successful teaching with technology marries competency in TK with PCK, in other words teachers develop a new form of professional knowledge known as TPACK. Teachers who use technology successfully can thus marry pedagogy, content, and technology to realise specific learning goals. Planning learning activities with ICT then requires deliberate purposeful pedagogical design. The literature reviewed also suggests that teacher beliefs serve to act as filters for teacher's decision making.

Much of what has been revealed in the literature with regards to meaningful ICT integration still suggests alignment to Shulman's original PRA (1987) construct, therefore, Shulmans' (1987) PRA model, along with Engeström's' CHAT (1987) models together have been advocated as conceptual lenses for this study for generating knowledge about ICT pedagogical reasoning and ICT pedagogical practices. CHAT encapsulates both the social-cultural and socio-historical contexts embedded in the dynamic nature of a classroom. The application of the PRA model in this study will also serve as an initial referent to codify the judgments and decisions the participants make in relation to the processes of planning, teaching, assessing, and evaluating, and the knowledge needed for these thinking processes.

An illustration of the overarching conceptual lens that will be used to inform this study is shown in Figure (2.7).

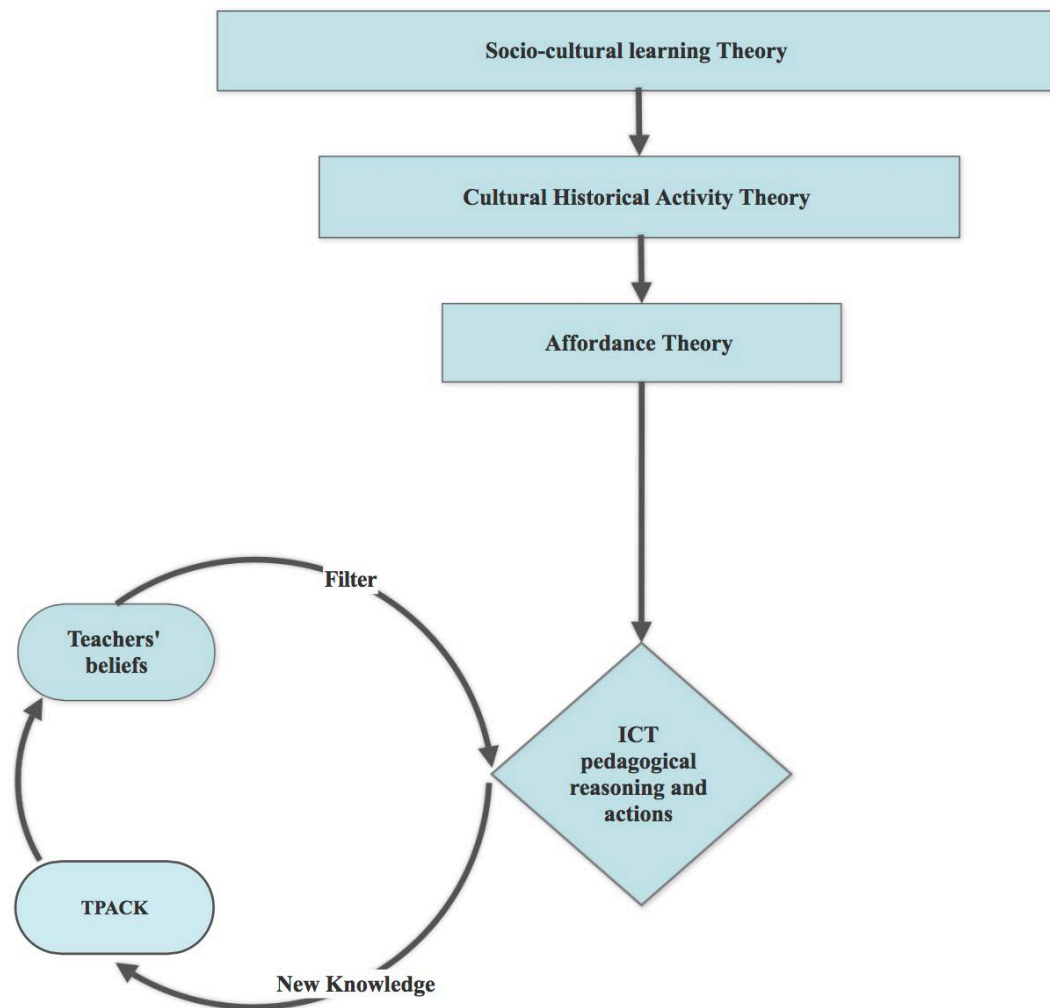


Figure 2.7: Conceptual framework informing this study

CHAPTER THREE: Methodology

The overall research design used in this study was a naturalistic multiple-case study within an interpretivist paradigm. Details of the research approach, selection of participants, data sources, collection phases, and analysis of data are revealed in the narrative that follows. This Chapter also explains the key decisions that were made with regards to the issues of trustworthiness and ethics surrounding this social research study. A methodological account establishing the rigour and quality of this research study's qualitative findings is provided in this Chapter.

3.1 Overall research approach

Overall this research adopted a naturalistic case study approach (Yin, 2014) using purposive sampling (Patton, 2002) to collect qualitative data from the participants. The data were analysed inductively to form three case studies along with a cross-case analysis. In the highly influential and much cited work of Lincoln and Guba (1985), *Naturalistic Inquiry*, the concept of naturalistic inquiry refers to an investigative approach about the social world that involves the researcher collecting in-depth information in the natural setting. Naturalistic inquiry is an approach where the researcher sets out to investigate 'the day-day reality, making no attempt to manipulate, control or eliminate situational variables' (Lincoln & Guba, 1985, p. 42). In this instance, the Researcher captured a range of data in the science classroom, from knowledgeable participants, which in this instance were three expert science teachers. The main advantage of multiple lines of evidence is the opportunity to triangulate the data which helps to ensure the trustworthiness of the findings (Stake, 1995, 2010; Yin, 2014).

Naturalistic research draws upon a range of data, generally interviews, observations and other descriptive qualitative data as part of its methods (Patton, 2002). This descriptive data set is then used to create rich detailed accounts of the lived experience and actions of a specific group or individual/s (Creswell, 2007). Naturalistic inquiry is not used to generalise findings, in fact it is careful to avoid generalised abstractions, instead it aims to present deep insights into the socially constructed world (Lincoln & Guba, 1985; Merriam, 2009). A significant aim of this study was to present rich field case studies of

highly experienced teachers renowned for their expertise in utilising ICT for learning science.

3.1.1 Theoretical perspective informing this study

The inquiry paradigm adopted by a researcher, or worldview, is grounded in a set of beliefs and theoretical perspectives. In turn, this paradigm or worldview informs the methodology, providing the context for its logic and criteria (Guba & Lincoln, 1994). Furthermore, the inquiry perspective taken by the researcher, according to Patton (2002) “is part of the context of the findings” (p. 64) and must therefore be clearly articulated. An account of the theoretical assumptions and methodological decisions informing the research design of this study will now be made explicit.

3.1.2 Epistemological perspective

Ultimately the inquiry approach adopted for a given study is based upon the epistemological and ontological assumptions the researcher has. As Crotty (1998) points out, a complementary relationship exists between epistemology and ontology, implying that an epistemological stance implies an ontological stance. The Researchers’ own epistemological perspective is grounded in a worldview based on the socially constructed nature of knowledge, along with a relativist ontological perspective on the nature of reality.

3.1.3 Interpretivist methodologies

According to Denzin and Lincoln (2008) the interpretivist or constructivist perspective is relativist, transactional and subjectivist, or more simply put a human construction. Assumptions inherent in this philosophical stance include meanings are constructed and transacted by humans as they engage with the world they are interpreting; and, that humans make sense of this world or reality based on their social, cultural historical and political perspective (Avenier & Thomas, 2015; Creswell, 2007; Crotty, 1998; Guba & Lincoln, 1994). Interpretive research is premised on the ontological

assumption that the reality by which an individual makes sense of the external world is socially constructed (Guba & Lincoln, 1994). Knowledge of how individuals come to know this reality (epistemology) are transacted through shared language and the meanings individuals assign to documents, artefacts and tools (Klein & Myers, 1999). Thus, knowledge construction is inextricably related to the lived experience. It follows then, the rules governing teacher behaviour are highly likely to be dependent upon the context. The implications for this study were therefore to capture as many pertinent details about the setting in which each of the case study teachers were situated; and, to recognize that the Researchers' own beliefs and history will influence the interpretation that will be made of the data.

From the interpretivist perspective attempting to establish the truth propositions of other individual's minds has methodological implications (Gillespie & Cornish, 2010). Lincoln and Guba (1985) state that adopting this research inquiry approach means that the "investigator and the object of investigation are ... interactively linked so that the 'findings' are literally created as the investigation proceeds" (p. 207), in other words reality is inter-subjective. The Researcher acknowledges the mutual interplay in terms of theory building between the knower and the known regarding the phenomenon of pedagogical reasoning processes and ICT practices. From this theoretical perspective, the methodological decisions have subsequently shaped the research design and methods selected in this study. To this effect, reflexivity was applied by revisiting the research assumptions and theoretical lenses as the research evolved, along with re-interrogating the participants' responses.

For this research, I was the sole investigator who interacted with all participants. I was able to holistically study the participants' classrooms, community of practice and the teachers' pedagogical models of teaching and learning by interpreting the observations that were made. My interpretations were shared with each of the participants at various times throughout the study for reflection and comment, sometimes via email, occasionally via phone conversations; however, mostly during the observational visits. This member checking was used to validate my original analysis considering clarifications and new insights including those expressed by my participants. As the sole Researcher, I acknowledge my participation in the construction of the reality that is presented, in other words a socially constructed reality.

3.1.3.1 The Researcher

Prior to embarking on an academic role that primarily involves the preparation of secondary science teachers, the Researcher was a high school science teacher, and later Acting Head of Learning Area (HOLA) of a Science Department, originally having qualified with a Bachelor of Science (Biochemistry) and Graduate Diploma of Education. The Researcher was also a Level 3 Classroom Teacher, a Department of Education of Western Australia (DoE) qualification that recognises exemplary teaching practices. The Researcher was also the recipient of some significant teaching awards including Premier's Teacher of the Year, Western Australian Education Awards (2009) and a National Excellence in Teaching Award (NeiTA) for Western Australia (2009). This science teaching background and middle management experience offered the Researcher rich insight into the historical, cultural, and political context of ICT integration enabling valid interpretations of the observations made. The Researcher is a science education specialist at an Australian university and is involved in the initial and post teacher education of teachers.

3.2 Research questions

The precise wording of the research questions also has methodological implications as they frame the content of the research to be undertaken, help organise the project, keep the researcher focused, as well as provide the framework for the write up (Punch & Oancea, 2014). The genesis of this study was borne out of the Researchers' own questions and interest in how to prepare pre-service science teachers suitably for a world where technology rich classrooms are now the norm and one where the current educational policy perspectives mandate this integration. The purpose and research questions framing this study were as follows:

3.2.1 Overarching research purpose

The overall purpose of this research study was to investigate the ICT pedagogical reasoning processes and ICT teaching practices of exemplary secondary science teachers in classrooms with one-to-one laptop access.

3.2.1.1 Research questions

1. What are the pedagogical beliefs of teachers who are effective users of ICT in teaching and learning? (i.e., why teachers act as they do?)
2. What pedagogical reasoning do these teachers employ in creating meaningful ICT based learning experiences? (i.e., how do teachers decide what strategies and representations and tasks to employ?)
3. How do these teachers create a learning environment conducive to student learning with ICT? (i.e., what do they do to create a conducive environment?)
4. What pedagogical repertoire do these teachers use to engage students in learning science using ICT? (i.e., how do they implement their instructional plan?)

Case studies are selected as a research strategy to investigate the ‘how’ and why’ questions of complex and context sensitive social phenomenon (Stake, 2010; Yin, 2014). In this instance, a case study design enabled the Researcher to examine in-depth, real-world practice for each of these participants, and to take account of their specific contextual factors, to investigate how the role of one-to-one laptop availability impacts upon their pedagogical reasoning and their teaching practice.

Sometimes cases are chosen for their distinct differences (Yin, 2014); however, in this multiple case study design the participants were purposefully selected because of their known interest and expertise in using ICT in the science classroom (see details of participant selection in section 3.3.1). This purposive sampling strategy was chosen to help support the credibility of the study’s findings (Patton, 2002).

3.3 Methods, instruments, and data collection phases

The data collection involved five separate phases. Data collection commenced once University and the Department of Education, Western Australia ethics clearances were granted. Data was expected to be collected over one or two school terms; however, unanticipated circumstances arose in one of the case study schools due to a major upgrade on their internal server system. This involved moving the school’s existing network environment to a new wireless network which subsequently resulted in significant down

time. This new wireless network did not become functional until late in the final term of that year. The types of data collected during each phase of research is described below.

3.3.1 Phase One: Selecting the participants of the study

The participants informing this study were purposefully selected so that they all had considerable experience and expertise in providing ICT-enabled science learning experiences. This targeted sampling approach allowed the Researcher access to in-depth information on the phenomenon recorded from the perspective of a specific group of participants (Creswell, 2007); in this instance, secondary school science teachers where the students had one-to-one access to portable *Mac Air* 13-inch laptops with wireless connectivity.

3.3.1.1 Learning Outcomes and Pedagogy Attributes instrument (LOPA)

The science teachers in this study (n=3) were previously known to the Researcher from having worked with one of the participants, from science network district meetings, as well as recommendations from academic colleagues who were aware of these participants' interests and innovative uses of ICT in the classroom and their *Level 3 classroom teacher* status, a Western Australian Department of Education qualification recognising their exemplary teaching practices. A summary of these teachers' backgrounds and their school contexts is shown in Table 3.1.

To verify their suitability to inform this study the participants' Principals and/or their HOLAs were asked to rate these individuals using an adapted version of the LOPA instrument elaborated in Chapter 2 and is shown in Appendix A (Newhouse & Clarkson, 2008). Each teacher was rated independently by their Principal and/or HOLA as performing at a *routine to comprehensive* rating for the use of ICT to provide constructivist-learning environments. The LOPA instrument was particularly useful in this selection process given its coherence to the ICT requirements of *Australian Curriculum: Science*, as well as the obligations of the *National Professional Standards for Teachers* (Australian Institute for Teaching and School Leadership (AITSL), 2011, 2014). These teachers have been given pseudonyms to retain their anonymity and are instead referred to as Michael, Ruby and Patricia throughout this study.

Table 3.1: Summary of teacher backgrounds and context

Teacher context	Michael	Ruby	Patricia
School sector	WA Department of Education (metropolitan)	WA Department of Education (metropolitan)	WA Department of Education (metropolitan)
ICSEA value (mean = 1000)	>1000 but less than 1100	>1000 but less than 1100	>1000 but less than 1100
Teaching experience	>25 years	>12 years	>25 years
Other teaching qualifications	Level 3 status	Level 3 status	Level 3 status
Length of service at the research site	>20 years	>1 year	>20 years
Teaching role at the research site	Senior ATAR Physics and Chemistry and Year 10 Academic Extension	Year 8 & 9 Middle School Science	Senior ATAR Chemistry and Biology; Year 8 and 9 Academic Extension
The context of lesson observations	Year 10 Academic Extension	Year 8	Year 9 Academic Extension
Classroom technology approach	One-to-one (take home)	One-to-one (take home)	One-to-one (booking system)
Student technology	Apple Macintosh Air 13-inch laptop	Apple Macintosh Air 13-inch laptop	Apple Macintosh Air 13-inch laptop
LOPA rating	Routine to Comprehensive	Routine to Comprehensive	Routine to Comprehensive

Overall, a *routine to comprehensive* LOPA rating indicates that each of these participants have the pre-requisite digital literacy skills to critically support students learning science in technology enhanced or 21st century learning environments. The participants ratings are shown in Table 3.2.

Table 3.2: Teacher ratings using the LOPA (2008) instrument

Learning environment component	Michael	Ruby	Patricia
Investigation of reality	Routine	Routine	Routine
Knowledge building	Comprehensive	Comprehensive	Comprehensive
Active learning	Comprehensive	Comprehensive	Comprehensive
Authentic assessment	Comprehensive	Routine	Comprehensive
Engagement, motivation, and challenge	Comprehensive	Comprehensive	Comprehensive
Student productivity	Comprehensive	Comprehensive	Comprehensive
Higher level thinking	Comprehensive	Comprehensive	Comprehensive
Learner independence	Comprehensive	Comprehensive	Comprehensive
Collaboration and cooperation	Comprehensive	Comprehensive	Comprehensive
Learning Styles	Comprehensive	Comprehensive	Comprehensive

3.3.2 Phase Two: Initial sequence interview

The interview remains a hallmark of sociological qualitative data methods producing rich data which facilitates depth of understanding for both the researcher and the participant. However, a mutual interplay occurs between the subject and the researcher which requires the researcher to account for their influence on the data collection and subsequent analysis through being reflexive (Stake, 2010). The

Researchers' journal was vital to this process of reflexivity which documented the Researchers' impressions and insights following interviews and formal observations, as well as during the analytical process leading to the comparison of each of the cases (Patton, 2002; Yin, 2014). The Researchers' journal also included ongoing commentary from other professional sources.

Given the theoretical framework underpinning this research, a semistructured interviewing technique was adopted as this approach allowed the Researcher the flexibility to clarify and probe the respondent's beliefs, motivations, perceptions, and opinions (Patton, 2002). Furthermore, semistructured interviews tend to uncover rich or thick data, a technique essential to the descriptive nature of case studies (Yin, 2014). The semistructured nature of the interviews throughout this study strategically allowed the Researcher to probe deeper into any ambiguous responses, although care was taken not to lead the interviewee down a particular pathway (Partington, 2001). Paraphrasing was also adopted as an interviewing tactic as this helped both the Researcher and the participant reach a consensus of meaning. Dates, times, and venues were always pre-arranged to suit the participant's schedule and held at the participant's work place. Several days before each interview took place the participants received an emailed set of interview questions. After the interviews the participants were advised upon subsequent self-reflection that material could be added or withdrawn.

The first interview took place prior to any lesson observations. This initial interview served as the primary data set to elicit information in relation to the following research question: What are the pedagogical beliefs of teachers who are effective users of ICT in teaching and learning (in other words, why teachers act as they do?). This first semistructured interview took approximately one hour and occurred on site at the teacher's school in a private room. The construction of the questions to stimulate this initial interview was largely adapted from the data collection instruments as developed by the C-SaLT team, arising from a study in Western Australian government schools surrounding teacher ICT professional attributes as they related to the meaningful integration of ICT (Newhouse et al., 2002). These instruments had been informed by Bransford et al. (2000) *How People Learn* framework described in Chapter Two (see Table 2.1). In this first interview, questions were posed like:

- What beliefs do you hold about how students should learn science?

- What are the main purposes you want to use ICT for with your students?
- What is the value in having your students use ICT in the classroom?
- How does ICT fit into your teaching overall?
- What potential do you see for ICT to support learning and teaching processes with your class?

This interview, as with all interviews captured in this study was transcribed in full by the Researcher for analysis. Off topic and social conversation text was removed from this transcription before data analysis commenced. The interviews were audio recorded using an *Olympus VN- 8500 PC* digital voice recorder and transcribed verbatim aided using a software tool called *Inscribe™*. Audio recording the interviews served the Researcher several advantages, which firstly included helping to review the interview technique and finesse this over the period of the study. However, ultimately the rationale for this data collection strategy was that audio-recorded interviews represent the actual event, rather than relying upon shorthand notes. Furthermore, audio recordings can be subsequently and repeatedly replayed during data analysis. Secure data files (audio recorded interviews, transcriptions, video, images, lesson artefacts etc.) identifying each separate participant by a pseudonym were created at the commencement of the study.

3.3.3 Phase three: Pre-lesson interviews and artefact collection

A 15-20-minute pre-lesson semi-structured and audio-recorded interview was conducted on site. In this pre-lesson interview, questions were posed like:

- What are the intended learning outcomes for this lesson?
- What prior knowledge was necessary for this lesson?
- What tasks or activities will the students work on during this lesson?
- What ICT tools will you/students use during this lesson? What will you use them for? Why did you select them?
- What role will the ICT tools play in achieving the learning outcomes?

This pre-lesson interview served to elicit information in relation to two of the research questions: What pedagogical reasoning do these teachers employ in creating meaningful ICT based learning experiences (in other words, how do teachers decide what strategies and representations and tasks to employ?). Also, how do these teachers create a learning

environment conducive to student learning with ICT (in other words, what do they do to create this environment?).

3.3.3.1 Teaching documents/ artefacts including digital resources

The teachers each made a significant amount of teacher artefacts, mostly digital as related to the study, the lessons that were captured. These lesson artefacts, were used as a secondary data set to cross-reference the pre-and post-lesson interviews and lesson observations (primary data set). In most instances, the participants gave the Researcher task briefs they had created to guide their students in the ICT enabled lessons that were captured, which included assessment rubrics.

A corpus of digital teaching and learning resources was generously made available to the Researcher and was subsequently used as a secondary pedagogical reasoning data set. All teacher artefacts were catalogued into a data base. Two of the teachers had created their own classroom websites and had hosted these digital platforms outside of the school's own IT infrastructure. The Researcher was encouraged to view these websites which did not require any special password protected log ins. Again, this additional data served to triangulate the pre-and post-lesson interviews and lesson observations. The Researcher was kindly granted access to view the other teacher's password protected virtual classroom platform. In addition, this participant also granted access to a plethora of animated physics and chemistry podcasts he had created, held on an *iTunesU* account. The teachers also granted access to their *YouTube* channels which they were using to share student projects.

None of the teachers created specific traditional lesson plans for any of the observations captured as part of this study, nor where they expected given the teaching experience of these participants. The teachers were assured by the Researcher that this study was centered around how they naturally went about planning for everyday ICT enabled lessons, with no expectation of specially created lesson plans whatsoever.

3.3.4 Phase Four: Lesson observations and post lesson debriefing session

3.3.4.1 Video based lesson observations

Due to the theoretical framing of this study video was used to capture these classroom observations. This afforded a rich 'moment by moment' account of the

complex social interactions (Erickson, 2006) typically experienced in classrooms and, importantly enabled the Researcher to preserve the features of an entire lesson event. Importantly, this strategy allowed the repeated replaying of the event for a series of analyses from a naturalistic perspective (Luckmann, 2012; 2013). Fitzgerald, Hackling and Dawson (2013) whose research in science classrooms noted that using video “seems an ideal way of capturing the complexities inherent in teaching and learning” (p. 53). Given I was the sole Researcher in this study these salient features of video were most useful for preserving a rich corpus of classroom activity data for subsequent analysis. Three lessons from each of the teachers, were captured; however, in one instance, a corruption in the data left one lesson observation unrenderable. These videos served as the primary data set for ICT pedagogical practices.

Another part of the rationale for the adoption of video as a data collection tool was that this method of collection offers the researcher a fine-grained record which can be easily manipulated and shared (Jewitt, 2012). Vignettes of quality practice arising from this research are intended for use in pre-service training and other professional learning events. A key affordance of this tool for the Researcher in this study was the flexibility to easily manipulate the data in terms of speed of replay and repeated viewing (Erickson, 2006) which was required given the micro-analysis performed on each video recorded lesson, outlined in section 3.4.1. It is important to note that the lessons captured in this research were not sequential. Furthermore, Leung and Hawkins (2011) caution that whilst video records offer tangible evidence with a “higher degree of fidelity in their records of the flow of action and interactions being studied “ (p. 345) that researchers must still be mindful that video evidence of practice taken on a day represents a snapshot and does not reveal the entire context (Leung & Hawkins, 2011). For example, video as a data collection method still does not capture the lesson before or after such an event.

3.3.4.2 Video recording equipment

All video recordings were captured using a consumer quality digital pan-tilt-zoom (PTZ) *Sony Handycam Camcorder*®, with a primary focus on the teacher’s actions and the way the teacher used the ICT. Various video based researchers (Hall, 2007) recommend the use of Lavalier microphones (discreet lapel microphones) to ensure high resolution of the primary source of audio. The teachers in this study wore a discreet

wireless Bluetooth audio transmitter device compatible with the *Sony Handycam Camcorder* ®. As a precaution, a second re-chargeable battery was always taken out on each data collection field trip. The camera was always attached to a quality tripod, which helped the Researcher pan smoothly and tilt when necessary, again the focus being on the teacher. The video recording equipment was contained within a robust camera bag ensuring ease, as well as safety of transportation to and from each site.

3.3.4.3 *Sampling the phenomenon using video*

The key observational foci of the video data were the teacher's actions and interactions with the students, as well as documenting the type of ICT used and the role that it played during the lesson. Scoping each classroom site beforehand for best recording vantage points, as well as, undertaking several short practice video recording attempts was undertaken due to the problematic nature of only one researcher in this study (Goldman, Erickson, Lemke, & Derry, 2007). This tactic also helped to accustom both the teacher and students to the Researchers' presence. During recording the Researcher chose to use panning sparingly; instead following the teacher and using zoom to keep their interactions and activities within the visual frame. In each instance, the recording commenced several minutes prior to the official start of the lesson, and again several minutes after the lesson finished in case any other salient conversations or activities occurred.

Immediately following a lesson observation, the video data was imported using a video file converting tool called *iMedia* by *iSKYSoft* which allowed the initial video file format (MPEG-2) to be processed into a readable format for other digital devices. In this instance, the popular MP4 video file format was chosen to archive these videos. The Researcher then began the process of indexing these MP4s using *iMovie*, a MAC video editing tool. This software application enabled ease of cataloguing the corpus of video data collected; however, *iMovie* was primarily chosen for its simple to use editing functions such as replay, time stamping, and labeling, which were necessary to commence the data reduction phase of the study. Critical analytical elements attended to when reviewing the lesson included:

- How did the lesson commence?

- How were the students organised?
- How was the physical environment organised to assist the learning?
- What were the key teaching and learning activities observed?
- What ICT tools did the teacher use?
- How were the students grouped?
- What ICT tools did the students use?
- How did the teacher monitor the students during the lesson?
- How was the lesson concluded?

After each lesson the Researcher used an analytical memo to review these observations at a macro level (see Appendix B). In addition, the LOPA instrument was used as part of the lesson observation analysis protocol for each lesson observation. A fuller description of the data analysis strategy is provided later in this Chapter.

3.3.4.4 Lesson debriefing session

As pedagogical reasoning is largely tacit and ongoing, immediately after each observation a 15-20-minute post-lesson debrief took place. Again, this was audio-recorded to enable full transcription. This debriefing interview included questions like:

- How well did your students engage with the learning tasks/activities?
- How effective were the ICT tools that you used?
- How effective were the ICT tools that the students used?
- Were the intended learning outcomes for this lesson achieved?

The lesson observations, along with the debriefing session served as a primary data set to respond to two of the study's research questions: How do these teachers create a learning environment conducive to student learning with ICT (in other words, what do they do to create this environment?); What pedagogical repertoire do these teachers use to engage students in learning science using ICT? (in other words, how do they implement their instructional plan)? This data set also served to corroborate the pre-lesson interview data.

3.3.5 Phase Five: Final sequence interview

The overall data analysis strategy was recursive and ongoing which enabled prolonged engagement with the data (Merriam, 2009). Several themes emerged from the

corpus of data collected in each case and were used to construct a final semistructured interview. This final interview lasted around 60 minutes and served as a member checking process to clarify and corroborate the emergent themes from the analysis of the data. Fundamentally, this strategy was employed to help establish the credibility of the emergent themes (Creswell, 2009) in relation to the pedagogical reasoning and practices uncovered by the Researcher.

Given the time between lesson observations and the final interviews, the participants were provided with copies of their recorded lessons to review. Again, this final interview took place at each participant's school site. Several video clips were used as prompts and for points of clarification of the emergent themes during this interview, a useful affordance of using video in the data collection. The participants were again asked to classify key features of their classroom learning environment around: role as a teacher; role of the student; role of ICT in classroom; overall approach to teaching and learning; and, to assessment. The participants also sketched out, in the form of a diagram or flow chart, the pedagogical reasoning process they followed to plan, deliver, and evaluate those lessons that were enabled by ICT. Appendix C reveals the full suite of final member checking interview questions.

3.4 Overall approach to data analysis

In a multiple case study design each case is inductively analysed as a separate bounded system, followed by a further step of analysing the similarities and differences between the cases, known as a cross-case analysis (Yin, 2014). The intent of the cross-case analysis phase in this overall research design was to develop working hypotheses, or explanatory theory (Creswell, 2007) about the complex phenomenon of ICT pedagogical reasoning and to explore the impact of teachers' pedagogical beliefs on why they act as they do with ICT; how these teachers create learning environments conducive to learning science with ICT; and, the pedagogical repertoire used to engage students learning science using ICT.

Given the social constructivist epistemological framework of this research, data collection was combined overall with simultaneous recursive thematic analysis (Merriam, 2009). In this research a theme has been taken to mean something that is important in

relation to the overall research question (Fereday & Muir-Cochrane, 2006). To strengthen the credibility of the emergent findings each case presented in this study was compiled from multiple data sources including:

- Documenting the participants' professional profile.
- Documenting the school context, school ICT environment and the curriculum context and where each of the lesson activities took place.
- Interviewing each participant regarding their pedagogical beliefs, values, and outlook.
- Pre- and post-lesson interviews about the lesson aims, its preparation and whether it achieved its intended outcomes were asked.
- Video recording the lesson, considering the activities sequence, and the role of the teacher and pupils as they used ICT throughout the activities.
- Collection of teaching and student documents and other artefacts associated with each of the lesson activities observed.

Finally a cross-case analysis was undertaken to determine any emergent patterns or themes across the cases (Yin, 2014). Specifics of the interview and video data reduction and analysis strategy are elaborated in the next two sections.

3.4.1 Interview data reduction and analysis strategy

The conceptual framework articulated in Figure 2.7 provided the theoretical logic to guide the initial analyses of the interview data by identifying the variables to attend to (Bassey, 1999; Stake, 1995; Thomas, 2006; Yin, 2014). In this instance Shulman's (1987) PRA model and Engeström's (1987) CHAT were the primary theoretical lenses determined the most useful to guide the initial analysis of the interview data. A coding matrix, developed from the literature, largely adapted from Hardman's (2007) and Stevenson's (2008) CHAT protocol elaborated earlier in Chapter 2 was applied. The coding matrix is shown in Figure 3.3. These *a priori* codes were useful to attend to the large corpus of textual data in this research, however, care was taken to remain flexible in comprehensively analysing the data set for emergent themes (Patton, 2002).

The overall analytical approach firstly involved careful preparation of the raw data transcription of interviews. A manual coding analysis method involving tagging this data

displayed on Excel spreadsheets. Descriptive themes or patterns as related to the research questions were used to develop open codes, albeit initially guided by the matrix shown in Table 3.3. Subsequent cycles of manual coding were undertaken, each time removing overlapping descriptions until the textual data was reduced to inferential themes pertaining to the studies research questions (Thomas, 2006). The first cycle of interview transcript coding produced many representative phrases describing the participants' thinking and representing their actions. These phrases were then reduced into fewer codes, for example; what key learning outcomes were being addressed; what key skills were being addressed; how the physical learning environment was organised; student organisation; student prior knowledge; what ICT tools were used and by whom; and how the teacher monitored the students learning. The analysis was further refined over several iterations, again reducing the inferential codes into more inclusive categories to reveal the key decisions most strongly influencing pedagogical reasoning processes and practices. Data that did not fit directly into these predetermined themes was analysed separately to determine if this represented a new category or sub category (Boyatzis, 1998).

Table 3.3: ICT pedagogical reasoning and action data coding analysis matrix adapted from Hardman (2007); Stevenson (2008) and Newhouse et al (2002)

	ICT pedagogical reasoning	Use of technology in pedagogical practice
Data sources	<ul style="list-style-type: none"> • Pre-sequence interview (audio recorded) • Pre-and post-lesson semistructured teacher interview (audio recorded) • Teacher planning documents/artefacts pertaining to the observed lesson • Student lesson artefacts • Member checking semistructured interview (audio recorded) 	<ul style="list-style-type: none"> • Classroom lesson observation (video recorded) • Audio enhanced recording of teacher during classroom lesson
Theoretical concepts (PRA & CHAT)	Questions to ask when analysing pedagogical reasoning	Questions to ask when analysing pedagogical practices
PRA: Comprehension (Knowledge of the content to be taught)	What views/beliefs are held about how students should learn science?	What pedagogical practices were observed during the lesson that was consistent with these views/beliefs?
CHAT: Subject (Epistemic assumptions held by the teacher)	What is the role of technology in teaching and learning?	What pedagogical practices were observed during the lessons that were not consistent with these views/beliefs?

Theoretical concepts (PRA & CHAT)	Questions to ask when analysing pedagogical reasoning	Questions to ask when analysing pedagogical practices
<p>PRA: Evaluation (Assessment of student learning; assessment of teaching)</p> <p>CHAT: Outcomes (Lesson outcomes)</p> <p>PRA: Transformation (Preparation, re-representation, adaptation, tailoring and instructional selection)</p> <p>PRA: Instruction (Lesson mode and classroom management)</p> <p>CHAT: Tools (ICT tools and non-ICT tools including linguistic tools)</p>	<p>What is the intended outcome proposed for the lesson activity?</p> <p>What ICT tool/s are intended for use during this activity? By the teacher? By the student?</p> <p>What non-ICT tools will be used? By the teacher? By the student?</p>	<p>What outcome resulted from this ICT-enabled science activity?</p> <p>Did any unintended outcomes occur from this ICT-enabled science activity?</p> <p>What ICT tool/s were used during this activity?</p> <p>What non-ICT tool/s were used during this activity?</p>

Theoretical concepts (PRA & CHAT)	Questions to ask when analysing pedagogical reasoning	Questions to ask when analysing pedagogical practices
PRA: Transformation	What is the object/focus of the lesson?	How was the object/focus of the lesson
PRA: Evaluation	What is the role of ICT in meeting the purpose of	moulded/transformed into an outcome using the
CHAT: Object	the activity of the lesson?	ICT tools?
(ICT Lesson goal activity directed at Outcome)		
PRA: Transformation	How will the work be divided during this lesson?	What roles did each member of the community
PRA: Instruction	Who will do what during this lesson?	play during the lesson?
CHAT: Division of labour	What is the intended role of the teacher planned for	
(Vertical and horizontal task and	this lesson?	
power relations between the	What are the intended roles of the students planned	
teacher and the student)	for this lesson?	
PRA: Transformation	What group of people will work together on the	Which group of people worked together on the
PRA: Instruction	object/focus of the lesson?	object/focus of the lesson?
CHAT: Community		
(Teacher and students in the		
science classroom working on		
the Object)		

Theoretical concepts (PRA & CHAT)	Questions to ask when analysing pedagogical reasoning	Questions to ask when analysing pedagogical practices
PRA: Evaluation CHAT: Rules (Social order rules & Instructional rules)	What are the evaluation criteria for the instructional task that has been set? What kind of social rules will operate during this lesson: disciplinary rules? communication rules? ICT rules? What curriculum requirements are imposed upon this activity?	What rules operated during the lesson that regulated the actions during this activity?

3.4.2 Video analysis strategy

Using video to capture naturalistic episodes often results in a corpus of data that can be overwhelming to the researcher (Goldman et al., 2007) as was the case for this Researcher. Video recordings *per se* are not data, rather they are an information source and instead must be transformed by systematic analysis for data to emerge (Barron & Engle, 2007). After converting the initial video data using *iMedia* by *iSKYSoft*™ into MP4 video format the Researcher then indexed and catalogued this video data using *iMovie*™, a MAC video editing tool.

As advocated by Erickson (2006), the data reduction phase involved a whole-to-part recursive analysis strategy. A micro-ethnographic approach to the video data analysis also applied that involved repeated viewing. The editing functions of iMovie including; replay, time stamping, and labeling were useful in this regard. Re-exposure to the whole lesson and then again to specific parts of lesson activity enabled the Researcher to probe specific pedagogical actions for new insights emerge. This analysis was guided by a specific micro-level pedagogical activity matrix tactic, originally devised by the OECD, and will now be outlined.

Analysis of video data is known to be problematic due to the multi-modal nature of video as a data source (Hackling, 2013; Hadfield & Haw, 2012). Given the purpose was to analyse pedagogical practices during ICT-mediated activity, a minute-by-minute pedagogical activity matrix was applied to reduce the lesson observation data. This matrix was originally developed and validated by Centre for Educational Research and Innovation (CERI) (CERI/OECD (Centre for Research and Innovation), 1999). This instrument was later revised and used in a large scale study in on the role of ICT in supporting attainment in UK classrooms (Stevenson, 2004, 2008). A description and rationale for using this pedagogical matrix is offered.

Stevenson's conceptualisation of pedagogical activity drew upon both Leont'ev's (1978) construct of human activity and Engeström's (1987) CHAT as the basis to characterise the individual and socio-cultural relating entities of the pedagogy used by teachers in ICT rich classrooms. Stevenson (2004) used this analytical tool first in a large UK study known as ImpaCT2 to measure the attainment of curricular knowledge, ICT skills, student motivation and collaboration using ICT; then later refining it to develop a

model of digitally based pedagogy (Stevenson, 2008). This analytical tool uses three key facets of pedagogical actions to characterise ICT-based activity and includes; teaching and learning organisation, discursive roles, and ICT usage. Statements in the classroom organisation category pertain mainly to the relationship between how the *Division of Labour* is distributed amongst the classroom *Community*, and include possibilities such as whole class work, team work or individual work. Statements in the conversational role category relate to who directs the conversation in each phase of the activity, that is the discursive relationship between the *Subject* and the *Community*, ranging along a spectrum of possibilities from the teacher directing the conversation through to students directing the talk amongst their peers. Finally statements in the ICT usage category refer to who is controlling the ICT resources during an activity, ranging from the teacher being the sole user through to students being the sole users. In using a CHAT lens ICT usage then relates to the actions between the *Subject* and the *Tool*.

This matrix allows the researcher to then code each minute into a triplet form to describe pedagogical activity and is shown in Table 3.4. For example, a sample pedagogical structure built from the statement categories as shown in Table 3.4 where the teacher gave information about the lesson's requirements to the whole class using a data projector and a PowerPoint presentation would be coded as (D1, S1, T1). To offer another example; a teacher interacting with a small group of students working collaboratively on a science project, using ICT resources as provided by the teacher, and where now being offered critical feedback would be coded as (D2, S4, T2). This coding strategy enabled the Researcher to more easily identify how the teacher's (*Subject*) actions affected the ICT-mediated learning task (*Object*) to obtain the lessons specific goals (*Outcome*). Importantly this analysis also served to triangulate the data arising from the pre-and post-lesson interview, as well as corroborate the teachers stated pedagogical beliefs. In this Research it is important to reiterate that the key foci of the video sampling were on the teacher and not focused on the students *per se*.

Table 3.4: Action and operation descriptors used to code each minute of lesson activity. Adapted from Stevenson’s (2004; 2008) study (pp. 14-15 & p. 841), originally based upon a framework validated by CERI/OECD (1999)

Classroom organisation mode	Conversational roles	ICT usage
Teacher working with whole group (D1)	Teachers giving information to whole class (S1)	Teacher using ICT (T1)
Teachers working with small groups of students (D2)	Teachers directing questions and answers to reproduce facts (S2)	Learners using ICT in collaborative tasks as initiated by teacher (T2)
Learners working in small groups (D3)	Teachers directing conversation (S3)	Learners using ICT in collaborative tasks as initiated by themselves (T3)
Learners working individually (D4)	Teacher stimulating reflections or other critical analysis (S4)	Learners interacting via ICT as initiated by teacher (T4)
Learners reporting or presenting own material to whole group (D5)	Learners directing conversations with peers (S5)	Learners interacting via ICT as initiated by themselves (T5)
		Learners creating using ICT (T6)

It is important to note that the lessons captured as part of this study were not sequential rather they were snapshots of these teacher’s ICT-mediated practice. To determine possible inferences and to compare pedagogical activity within and between the cases, a graphical presentation of these three pedagogical structures has been presented as part of each case study. This has then been used in the cross-case comparison to determine any similarities and differences. Shown in Figure 3.1 is an overall summary of the approach to data analysis undertaken in this study.

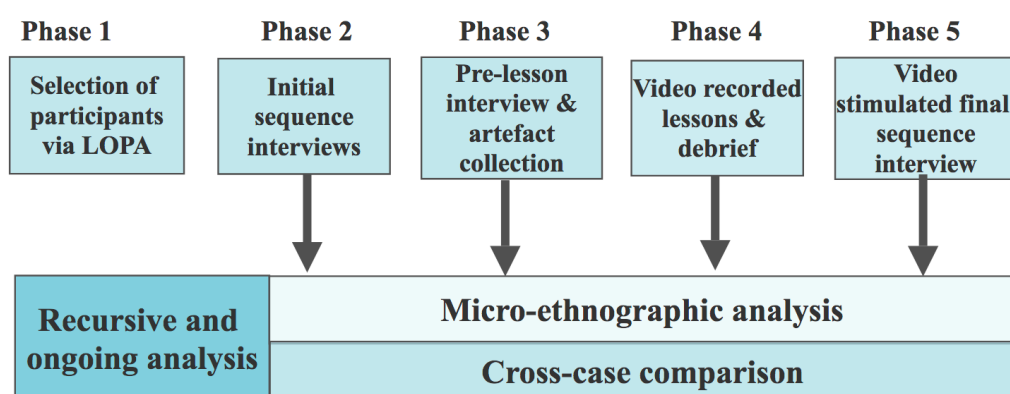


Figure 3.1: Overall approach to data analysis

3.5 Issues of rigour and ethics

This next section discusses the treatments applied to mitigate issues surrounding the rigour, in other words integrity in which this study was conducted to ensure the trustworthiness of the study's findings. This section also discusses the ethical issues in relation to working with human participants as suggested in the literature. Concepts such as reliability, validity and generalisability are typically associated with quantitative research. Instead alternative terminology drawing from the seminal qualitative research methodology literature as applied to this study will now be outlined. Qualitative inquiry researchers have demonstrated a variety of measures to deal with the notion of quality or trustworthiness of the research process; however, in this instance four constructs of trustworthiness, that is credibility, transferability, dependability and confirmability (Guba, 1981) as they were applied to this research will now be examined.

3.5.1 *Credibility*

A significant body of peer reviewed literature surrounding the credibility of qualitative studies suggests rich evidence must be documented that allows the reader to follow the logic of the data analysis, along with the resultant conclusions (Merriam, 2009). Data collection and analysis were undertaken by the same researcher, experienced as a science teacher, and now science teacher educator, facilitating a consistent and

credible approach throughout the data collection (Patton, 2002). The Researcher was highly familiar with working in Department of Education science classroom settings which enabled a natural flow of communication.

A convergence of multiple sources of data and collection strategies, as well as, method triangulation was applied to this research to enhance the credibility of the emergent findings (Merriam, 2009; Patton, 2002; Punch & Oancea, 2014). The techniques applied to demonstrate the credibility of the present research is now outlined.

3.5.2 *Method triangulation*

Method triangulation was undertaken in this study, as data were collected from multiple sources including, in-depth participant interviews, both pre- and post-lesson debriefing interviews, artefact analysis and including videoed evidence of classroom practice. Method triangulation were also achieved through comparison of the participants' interviews and lesson observation data with the instructional material curated on their personal teaching websites and/or other type of virtual classroom environments. Data triangulation also occurred as the data were collected across several participants in different settings and at different times (Twining, 2017). Theoretical triangulation also occurred as the data were interpreted using two theoretical frameworks; Shulmans PRA model (1987) and Engeström's CHAT (1987).

3.5.2.1 *Reflexivity*

A rigorous reflexive stance is advocated in the qualitative methods literature which is best described by Charmaz (2006) who states that reflexivity is:

The Researcher's scrutiny of his or her research experience, decisions and interpretations in ways that bring the researcher into the process and allow the reader to assess how and to what extent the Researcher's interest, position and assumptions influenced inquiry. A reflexive stance informs how the researcher conducts his or her research, relates to the research participants and represents them in written reports (pp. 188-189)

The positional reflexivity (Punch & Oancea, 2014) or the lens through which the researcher positions the research from has been acknowledged and elaborated both in the

conceptual framework (see Figure 2.9) along with the articulation of the interpretivist epistemological stance and subsequent data analysis strategy as discussed earlier in this Chapter. The Researcher compiled written field notes into a journal during and immediately following each interview and classroom observation. Analytic memos, often in the form of concept maps and tables were also noted in the Researchers' journal. The Researchers' interpretations were checked for accuracy by asking the participants to confirm these interpretations and to provide clarification when necessary throughout the duration of the study.

With any ethnographically oriented study the researcher must remain vigilant and set aside assumptions (Denscombe, 2007); however, the Researcher acknowledges that any attempt at explanation of the social phenomena presented in this study is based on my own values and interests. It is strongly advocated in ethnographically oriented studies to adopt a 'fly-on-the-wall' stance during each observation. The Researcher tried to remain as unobtrusive as possible during filming. Whilst the Researcher aimed to cultivate an empathic relationship and build rapport with each of the participants for the duration of the study, the aim each visit was not to suggest or lead the participant towards any outcomes. In other words a non-directive interview and video recording technique was adopted (Twining, 2017).

3.5.2.2 *Member checking*

As strongly advocated in the literature, a critical strategy serving to enhance the credibility of the findings is allowing the participants to comment and assess the interpretations of the data in which they have participated (Creswell, 2009; Merriam, 2009; Patton, 2002). This is known as member checking. A final member-checking interview was undertaken with each participant to verify the interpretations and emerging theories that were made.

Other credibility enhancing tactics employed included debriefing sessions between the Researcher and the highly experienced supervisors of this study to widen the vision and bring their experiences and perceptions to bear. The supervisors were able to critique and verify the Researchers' interpretations, providing an element of analyst triangulation (Patton, 2002). Furthermore, guidance from these experienced researchers ensured rigorous qualitative research procedures were followed. Other opportunities for

scrutiny of this project involved presenting the findings at several university research colloquiums. This afforded the Researcher chances to explain, defend and review the research design considering the comments made.

3.5.3 *Transferability*

The construct of transferability of the findings is akin to the concept of external validity or generalisability as applied in quantitative studies and refers to the extent to which the findings can be applied to another situation (Stake, 2010). Transferability is enhanced by offering detailed or thick descriptions of the contextual and situational information under which the study's findings operate. This enables the reader to make judgments or comparisons so that they may then be able to relate the findings to their own situations or other contexts. As used in this research, another technique used to improve the transferability of the study's emergent findings is to include multiple cases along with a cross-case comparison (Lincoln & Guba, 1985; Stake, 2010; Yin, 2014). Additionally, the situational context for each case is clearly outlined, allowing the reader to appreciate the boundaries of each setting.

3.5.4 *Dependability*

Trustworthiness of a study also involves establishing the dependability of its findings. In quantitative practice this concept is referred to as reliability and is taken to mean that the findings could be repeated and would be consistent if the same research methods were re-employed (Denzin & Lincoln, 2008). Demonstration of credibility generally reinforces the dependability of the study's findings. However, addressing dependability in qualitative practice, given the unique contextual nature of the data collected, means that if the study were repeated, the results would not necessarily be the same. Dependability as a validation strategy is then taken to mean describing the research design and its implementation in vivid detail (Shenton, 2004). Dependability of this present research was assured through the articulation of clear procedures before commencing data collection, along with the active and reflexive documentation of the

Researchers' actions throughout data analysis that clearly articulates the method of interpretation (Creswell, 2009).

3.5.5 *Confirmability*

Finally, conformability is provided through the objectivity of the research data itself (Lincoln & Guba, 1985), in other words, the degree of neutrality in the research findings. In an empiricist sense this was taken to mean that the researcher, makes a considered attempt to distance themselves from the phenomenon being studied or from a qualitative perspective this means explicating one's own predispositions (Miles, Huberman, & Saldana, 2014). Already established earlier in this Chapter is the Researchers' stance on the interpretivist nature of knowledge and reality. The Researcher has already methodologically accounted for her influence on the inter-subjective basis of the researcher-participant interaction (Gillespie & Cornish, 2010) and the interpretations of human activity, text and artifacts undertaken throughout this study, otherwise known as reflexivity (Yin, 2014).

In synopsis, the exploratory nature of this research implied that the truth was not a permanent reality, but rather relevant to the lived experience of the members in this study and the discoveries were an agreement between the Researcher and each members of this research (Denscombe, 2007).

3.6 Ethics: informed consent

All aspects of the study strictly adhered to the Edith Cowan University's (ECU) Policy for the Conduct of Ethical Human Research. The University's Human Research Ethics Committee approved the research procedures. Each participant engaged in this study (teachers and students) supplied informed consent (see Appendix D) including respective parents/guardians, principals and the teachers' employer, the Department of Education, Western Australia (DoE). Furthermore, participation by all individuals was on a voluntary basis, where withdrawal of consent from this study could occur at any time during this research without prejudice, although none chose to do so. Before data collection, a meeting with each Principal discussed the salient features of the project. This

meeting also provided an opportunity to reiterate the confidential treatment applied to the arising data. Each Principal provided written informed consent that included the ongoing use of suitable video vignettes of classroom practice primarily for use in pre-service science teacher education (see Appendix E).

3.6.1 Considerations of anonymity and confidentiality

Using video in an educational setting to capture data presents challenging ethical considerations, in particular those surrounding access and sharing to be negotiated (Derry, Hickey, & Koschmann, 2007). According to Fitzgerald, Hackling and Dawson (2013) capturing classroom video by researchers is “a major disincentive for participants involved in video research is the fear of potential embarrassment” (p. 58). To mitigate against this, all teacher participants viewed the video footage, and could erase embarrassing footage and even have their faces blurred (using video-editing software); however, none of the participants chose to do this. In this study, participating teacher’s identity was protected using a pseudonym and any identifying features such as school names or student names on any of the artefacts that have been presented in the subsequent chapters have been anonymised.

In this study, due to the use of video as data collection tool negotiating research access warrants special mention as this required initial consultation and consent from the DoE. A range of usage conditions were applied to this study by DoE along with respect to privacy and anonymity. In summary, these conditions included:

- Students whose parents or themselves did not consent will be avoided or have their faces blurred
- If a teacher required filming to stop for whatever reason this would occur
- The videos would only be viewed by the participants and the research team during the collection and analysis phase
- The videos would always be stored on password protected computers and kept in accordance with ECU’s policy for the Conduct of Ethical Human Research
- Copies of the videos would be supplied to each participant for their own reflection, commentary, and professional development

- Additional approval for the use vignettes or still images in conferences or for teaching purposes and only with the proviso that the school's identity would be completely anonymised

Whilst the intent of this research was to capture the teachers' practices permission also had to be granted from each of the students participating in these classrooms. There were only two instances of students that did not wish to be filmed across all the participants' classrooms. Great care was taken to ensure that video recordings did not include these students and that they were edited from any of the final video footage.

3.7 Chapter summary

The purpose of this study was to investigate the pedagogical reasoning of three highly effective science teachers known for providing quality ICT-enabled learning environments. Specifically, to investigate why they act as they do in secondary classroom environments where students had one-to-one access to laptops and connectivity to the Internet. Overall a case study approach was used that employed qualitative methods. The data generated were sourced from teacher interviews, teacher and student artefacts and videos of classroom teaching. This Chapter outlined the rationale for these choices which provides the reader a methodological audit trail (Twining, 2017) and therefore an opportunity for judgement in regards to the quality of this research.

Three case studies were developed from this data and are presented in the following chapters. The teachers that are the focus of these case studies have been given pseudonyms to retain their confidentiality. Key findings and assertions have been used in the following chapters to signpost the salient features with respect to answering the studies research questions. The next chapter presents Michael's case study.

CHAPTER FOUR: The case of Michael

This Chapter presents the first of three case studies that provides a descriptive and interpretive account of this participant's pedagogical beliefs in relation to ICT, his reasoning surrounding the use of ICT and how he creates a learning environment that provides meaningful technology enabled learning experiences. The Chapter begins by presenting the contextual factors pertinent to this teacher, including an account of his professional profile, beliefs and pedagogical outlook followed by an analysis of two lessons. This case study has been compiled from a range of data including face-to-face interviews, video-recorded observations, school documents, teacher-planning artefacts, student artefacts and includes the array of software and digital learning artefacts both the teacher and students accessed during these observations.

The contextual information presented at the beginning of this case study were mostly solicited from the participant during the initial teacher interview conducted at the commencement of this study. Background data pertinent to the School context presented in this case study was garnered from the school's public website and from the MySchool.edu.au website. The case study teacher presented in this Chapter is referred to by the pseudonym Michael to protect and respect his identity.

4.1 Data sources and analysis

Before the observations began an initial interview lasting around 60 minutes was conducted on site to elicit Michael's professional teaching background, pedagogical orientations, beliefs, and practices surrounding his approach to using ICT in the classroom. Michael was emailed a set of semistructured interview questions approximately one week prior to the interview. Michael's interview was transcribed verbatim. Analysis of the interview data adopted an inductive analytic process to determine any possible insights into this teacher's pedagogical beliefs that may potentially shed light on his ICT pedagogical reasoning and pedagogical repertoire. Transcripts of the Researchers' field notes were also analysed to offer additional insights into this analysis. A final member checking interview, lasting around 60 minutes was

conducted to confirm the emerging themes in Michael's ICT pedagogical reasoning and practices.

To illuminate the pedagogical reasoning process employed by this teacher in planning for and reflecting upon the lessons observed, pre- and post-lesson interviews were conducted on site. Artefacts associated with the observation such as the assessment rubrics, task briefs, including the software that was used in the classroom was also captured to shed light on how Michael designed successful ICT mediated activity. Michael also re-represented his reasoning process in the form of a flow diagram during the final member checking interview. Shulman's (1987) PRA model was used as an overarching lens to analyse these data sources. Data were initially coded using the theoretical components as shown in Table 3.1, and then the analysis was further refined over several iterations to reveal the key decisions most strongly influencing Michael's pedagogical reasoning processes and practices.

Three entire lessons were video recorded; however, the audio on the first lesson captured was inaudible. Because of this technical failure a Bluetooth lavalier microphone was subsequently used for all subsequent video data captured in this study. The analysis of Michael's lessons utilised an actions and operations activity matrix based on an overarching CHAT lens, as presented in Table 3.2, to illuminate the pedagogical practices observed that were related to the Outcome (s) of the lesson using the ICT (Tools). Of importance was the types of learning communities that were formed, the roles of the participants (both teacher and students), norms and conventions of behaviour, technical rules, and evidence of student learning to characterise the entire lesson activity. In other words, how did the teacher create or transform the lesson into an outcome using the ICT tools? Attention was directed to the role of the teacher, including analysis of the instructional methods and other support materials used to promote active participation in the learning process.

4.2 Professional profile and context

4.2.1 Professional experience

Michael has been teaching secondary science for 33 years. He is an Upper School Chemistry and Physics specialist teacher currently in a government metropolitan

secondary school in Perth, Western Australia. He has taught at this site for over 20 years. According to Michael: *“I tend to stay in the one place. And it is nice because you get to teach families...And you get known in the community which is good and I know the community, which I really enjoy”* (Initial teacher interview: 05/09/13). In addition to being an upper school physical science specialist Michael teaches general science to Year 10 Academic Extension students. Michael has been a qualified *Level 3 Classroom Teacher* since 2006, a status that recognises his exemplary teaching practices here in Western Australia.

Michael is renowned for his innovation in using technology to enhance student learning pointing out that he has been experimenting with different instructional approaches using ICT for over 20 Years:

I have been using technology a lot longer than anyone I know. My first modem was a 300 Board modem, a handset that I dialed the number and you connected directly to a bulletin board, wherever it was, and I paid STD rates! Later on, I would bring my Commodore to School because they could plug into a TV, but there wasn't much educationally really, it was more because the kids enjoyed it, so I would just share a few things with them. I then used an Apple portable that I would take home and bring to school. I would find virtual microscopes ...I would create all my tests and worksheets electronically, so I was kind of a pioneer (Initial teacher interview: 05/09/13).

In 2009 Michael became an Apple Distinguished Educator (ADE), one of 2000 ADEs worldwide recognised by Apple for his innovation and willingness to initiate new learning opportunities using Apple based technology in the classroom. Michael has previously initiated and run after school astronomy science clubs in his own time offering interested students an opportunity to investigate the local skies around Perth using ICT. He explained that:

I control my telescope with my iPad. I get the kids to hold it up to an object through the telescope and see it. It's way better than in the old days... I

mean its cheating Astronomy but it helps the person who is a novice (Initial teacher interview: 05/09/13).

A few years ago, Michael's astronomy club collaborated with a local university on a real-world science project to help identify transient objects using a powerful radio telescope called Spirit. In this project, the students were able to remotely log into the Spirit telescope from school and control its range to take photographs for further analysis. The work of Michael and his students in this project helped this University based astronomy research centre gain accreditation as a Minor Planet Observatory. A plaque honouring the work of Michael and his students features now at the University's astronomy centre.


Michael's skills in integrating ICT in the classroom were recognised resulting in his appointment to the role of *e-Learning Coordinator* for the School in 2012. For this he receives an allocation of 0.1 full-time-equivalent (FTE) to assist teachers across the school community in regards to ICT integration. By invitation, Michael assists individual staff members to enhance their ICT integration practices, aiming to create a community of practice. Michael felt that at this present time:

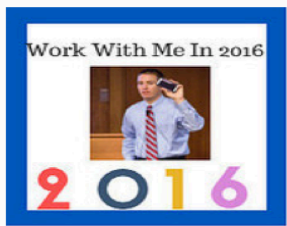
I am just plugging holes, stopping, just trouble shooting...I am starting to realise that if I was out of the classroom...and got around to more classrooms I could have more impact. But I've got a feeling with the current climate that it's not going to happen...I would like to have a plan that I could implement but I don't have time for it. You see a lot of time is taken up with plugging holes or kids forgetting passwords, or you know that sort of stuff (Initial teacher interview: 05/09/13).

To support a community of practice Michael established a *Scoop.it*TM site, a type of online content curation platform, so that he could regularly update teachers across the school with articles and exemplars of how to meaningfully infuse ICT in the classroom. This online magazine style catalogue provides staff with subject specific examples of ICT uses, general pedagogical considerations, as well as reviews of ICT tools. Michael

carefully selects articles leaving insightful and practical comments such as that shown in the exemplar shown in Figure 4.1.

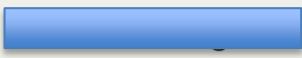

Free Technology for Teachers: 5 Things We Can do to Prepare Students to Work Independently





From www.freotech4teachers.com - February 24, 11:19 PM

Nearly ten years ago Karl Fisch and Scott McLeod's Did You Know/ Shift Happens (<http://shifthappens.wikispaces.com/>) videos made many of us aware of the fact that the nature of learning and the nature of work has irreversibly changed. Yet in many schools we continue to we still teach as if we are preparing students to work and learn in the 80's and 90's (you can pick the century). While there is value in some of the traditional methods we must strive to incorporate new perspectives and instructional strategies.



insight:

1. Acknowledge What's New in the Classroom and the Workplace
2. What's it mean to be an "expert."
3. Create Wise Consumers of Information
4. Encourage and Support Publishing Online
5. Working independently sometimes means working with others.

Figure 4.1: An example of a scooped article by Michael for the e-learning school community site

When queried about the rationale behind the chosen articles for his *Scoop.it*TM site Michael explained that he based his selection using the SAMR model of technology integration. In other words, promoting the use of choosing ICT more consistent with the facilitation of higher order thinking in the classroom, stating: *"The substitution, augmentation, you're just doing stuff you've always done, just a little better. But the modification and redefinition, that's the stuff you can't do without ICT"* (Final interview: 05/12/15).

Key finding 4.1 Professional teaching experience

Michael's professional teaching experience is expansive. Michael considers himself an early adopter of ICT being an active user in the classroom for over 20 years. He is renowned for his ability to integrate ICT both from a technological and pedagogical perspective. Michael is a Level 3 Classroom Teacher, a status that recognises his exemplary teaching practice across all three domains of the AITSL Professional Standards for Teachers. Michael is also recognised as an Apple distinguished Educator (ADE) for his prowess in integrating technology. As such, Michael was appointed the e-Learning Coordinator at his school where he takes an active role mentoring other teachers to promote the more transformational uses of technology in the classroom. Michael also created an online community of practice site using a digital curation tool called *Scoop.it* to disseminate resources to support the meaningful integration of ICT amongst the entire school faculty.

4.2.2 School Context

Michael teaches at a secular co-educational government school established some 50 years ago, which has over 1300 students in attendance across Years 7-12. This School has a current Index of Community Socio-Educational Advantage (ICSEA) value one standard deviation above the mean of 1000. ICSEA values, calculated and reported by the Australian Curriculum, Assessment and Reporting Authority (ACARA) are used as a standardised measure of socio-educational advantage. This ICSEA value places Michael's school in the top 15% of all schools in Australia for socio-educational advantage.

This school was ratified as an Independent Public School (IPS) several years prior to the commencement of this study. An IPS refers to a public school where the principal has greater autonomy to make operational and educational decisions relevant to the benefit of the local school context. Notably by determining the governance, curriculum, and staffing recruitment to support this delivery. Along with this level of flexibility IPS schools are supported by a school board to oversee the strategic planning of the school. As part of the School's business plan, staff learning currently emphasises the development of professional learning communities and enhancing teacher skills in using

technology to improve student learning. At the time of writing, this School ranked highly as a top public school for its overall academic performance based on the Australian Tertiary Academic Ranking (ATAR) system.

4.2.3 Curriculum context

Students spend five years at this senior high school, entering a middle school environment for Year 7, 8 and 9. Middle school students are housed in separate wings of this School, timetabled separately from the senior school, and are taught by middle school specialist. This School also offers a Gifted and Talented Education (GATE) language program, along with specialist programs in both Visual Art and Music. Students selection for the GATE program is based on an achievement test, administered locally by the Department of Education. Middle school students are streamed into either academic extension programs (AEP) or general pathways for Mathematics, Science, English and/or Humanities and Social Studies.

This streaming continues in Year 10 when the students then enter the senior school. The science curriculum adopted by this school is aligned to the Western Australian School Curriculum and Standards Authority K-10 Science Curriculum (SCASA), as drawn from the (ACARA). Michael teaches one class of Year 10 AEP students, with whom all the lesson observations took place. He describes his cohort of students as, *“probably a bit more academic and a bit more driven...they will take things and run with them”* (Initial teacher interview: 05/09/13). Michael offers his Year 10 AEP class a more academically rigorous science curriculum with the expectation they will enroll in the ATAR university bound science courses including, Biological Sciences, Chemistry, Human Biological Sciences, and or Physics for Year 11 and 12.

4.2.4 School ICT environment

In 2008, funding from the National Secondary Schools Computer Fund was used to purchase individual *MacBook Air 13”* laptop computers for those students in Year 10-12 on a one-to-one basis. Michael revealed that he tells all, *“the kids to leave their wood at home and bring the electronic to school. And that’s the way we function with Macs”*

(Initial teacher interview: 05/09/13). At the time of data collection for this study these same *Mac* laptops are also purchased for the middle school; albeit in middle school these computers are housed on lockable trolleys. This necessitated that all middle school teachers utilised a booking system to gain access to these devices. The federally funded National Secondary Computer Fund expired in June 2013 leaving this School to investigate and then initiate a new computer-funding model. According to Michael:

Now that it's gone, I think (Manager of ICT) is looking at a parent-funded model. I would rather them have a tablet, as they all have computers at home anyway and I believe you can do a lot more with an iPad in the classroom than the computer. Because in the classroom you are not doing big number crunching, you are not writing huge reports. You want to be mobile, you want to get up from your desks and walk around, go out into the yard, have a look at the environment, and you want your computing to come with you. Laptops are portable but they are not like a tablet (Initial teacher interview: 05/09/13).

At the beginning of 2014 the School subsumed all one-to-one laptops given out to students, re-housing them inside dedicated ICT laboratories and on lockable portable trolleys, thereby necessitating teachers return to using a booking system to access computers. The School then subsequently initiated a voluntary parent owned notebook program implementing this across the School in 2015, asking parents to purchase a specified notebook from a prescriptive list. This 'bring your own device' (BYOD) model has now seen the parents become responsible for the cost of this notebook, insurance, external hard drives as well as the ongoing maintenance of the device; however, the School provides and maintains all the essential software for free. The School is committed to equitable access and offers students the ability to borrow notebooks via the library, as well as offering computer laboratories.

As part of the School's strategic plan towards the adoption of the BYOD model Michael presented at various parent workshops to help explain the rationale for purchasing ICT devices for use at school. To support this strategy Michael created a graphic to reveal to parents the potential transformative uses of ICT in the classroom. In

this graphic (shown in Figure 4.2) Michael mapped Bloom's Taxonomy (Masia, Krathwohl, & Bloom, 1956) to Puentendra's SAMR model (2006) indicating these models, "*marry very well together*" (Final interview: 07/12/15).

During the final interview Michael considered that he has been operating at the 'Redefinition' stage of the SAMR model for some time. In other words, he uses the affordances of ICT to carry out tasks that could not be achieved otherwise; that is to transform the learning environment. He stated that he was now strongly advocating for this level of ICT transformation to other teachers at his School so that students could, "*be able to move up into those higher order levels in Bloom's, up to analyse the world around them and create stuff and solve problems*" (Final interview: 07/12/15). However, in supporting other staff members to integrate ICT he was keen to point out that he advises teachers to: "*Dip your feet in, just have a go*" (Final interview: 07/12/15).

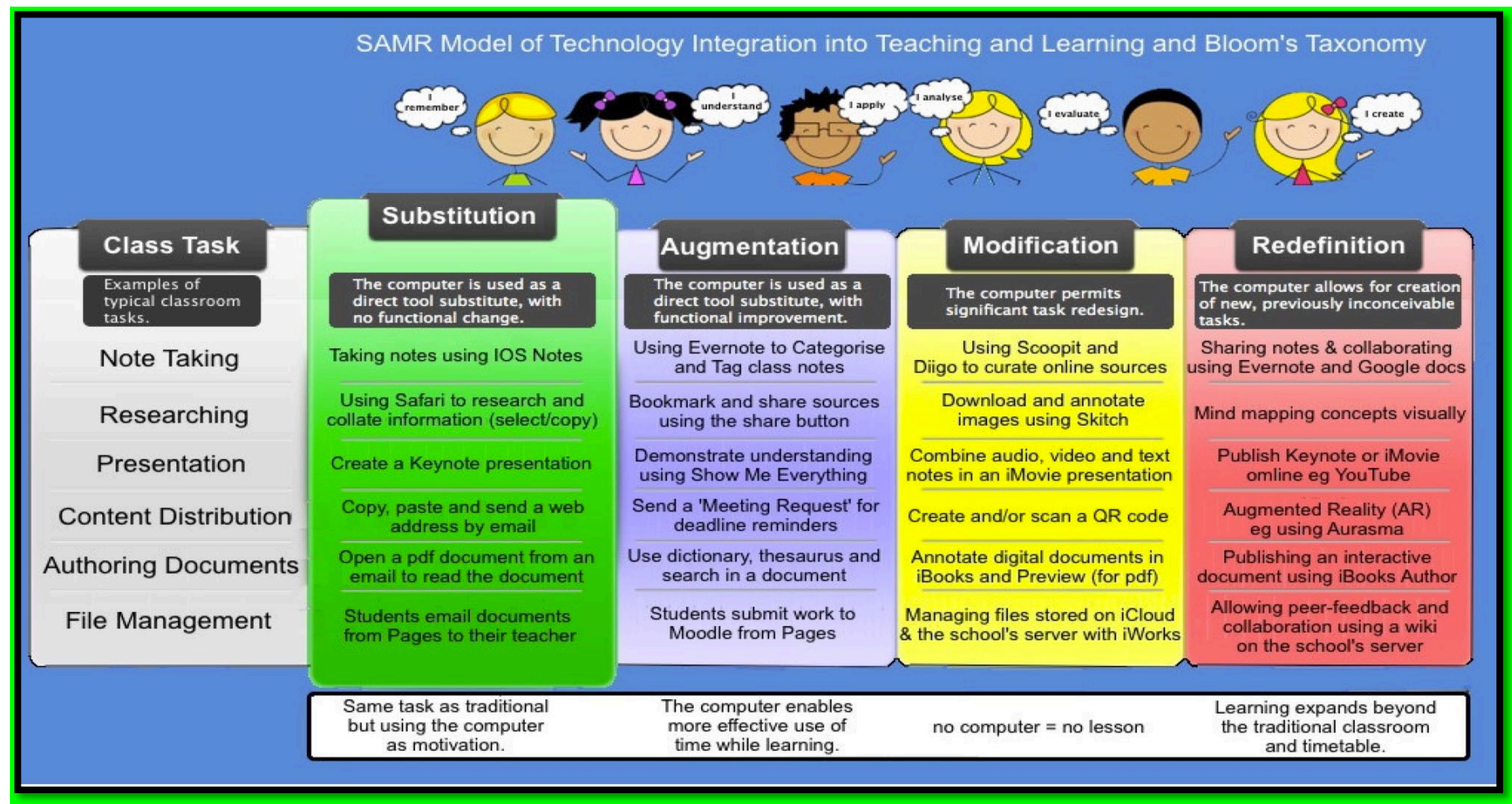


Figure 4.2: Graphic created by Michael demonstrating Bloom's framework linked to the SAMR integration model

The School operates an intranet and a Learning Management System (LMS) also known as a Virtual Learning Environment (VLE) delivered via a modular object-oriented dynamic learning environment or *Moodle*, as it is commonly known. This *Moodle* was essentially an extension of the school intranet system enabling the provision of curriculum resource materials (content). *Moodle* is a popular LMS in Western Australian secondary schools and was adopted by Michael's school because of its simple user interface. This allowed Michael to customise his own classroom ICT environment including the upload of his course materials, ICT learning resources, customise classroom homepages and make class announcements etc. Furthermore, this LMS allowed students to access it at any time and from any device. At this School, students also have access to a centrally controlled Department of Education portal called *Student Connect*, which enables students to access their individual assessment items. According to Michael *Student Connect*, "*is a bonus for students, as I will mark an assessment at home, put it in the portal, the kids at home can see their results immediately that night. That is fantastic! Then the next day we will go through it*" (Initial teacher interview: 05/09/13).

The School has two main policies governing the use of ICT: *Computer and Internet usage policy* and the *Mobile Phone policy*. School computing facilities, including the one-to-one laptop provision, was given on the condition that ICT would be used for legitimate school-related activities and reserved the right to monitor any individual laptop for internet usage. All students and staff were required to authenticate their log in with a user ID and password. All staff and students were expected to abide by an explicit code of conduct in regards to the safe and ethical use of computers and failure to do so may invoke withdrawal of computer privileges. The School acknowledges the ubiquity of mobile phones in students' lives; however, at the time of data collection banned students from using them in class under all circumstances. This is in keeping with the Director General of Education for public school's edict that mobile telephones are not to be used by students in classrooms.

Michael spoke about his students out of school experience with technology where smart phones are the natural communication tools of choice indicating that clear majority of his students owned smart phones. He feels strongly that smart phone use could enhance the learning environment stating that: "*These tools are data collection devices, as well as for consumption, they are for creation, these are tools that if Galileo had...where would*

be now?” (Initial teacher interview: 05/09/13). Michael elaborated upon the affordances of smart mobile devices for classroom use asserting that:

I think my god! They have a computer in their pocket and you won't let them use it. But that's what you have to work with...they are supremely accurate timepieces; I mean they are great little cameras for videos, high definition videos; they are just remarkable (Initial teacher interview: 05/09/13).

Key finding 4.2 School ICT context

The ICT infrastructure at the time of data collection offered reliable networked technologies available on a one-to-one laptop basis for students. The school was presently moving towards a parent owned BYOD framework. The school operated a Moodle based LMS. The School's ICT policy and culture is promotive and fully supportive of ICT integration. Michael actively helps to promote the transformative uses of ICT for learning at various parent and community events and amongst his fellow teachers. Most students in Michael's classes owned smart devices.

4.3 Michael's beliefs, values, and pedagogical outlook

During the initial and final member checking interview Michael was keen to point out that effective science teaching and learning involves helping students to develop lifelong skills of critical thinking, problem solving and collaboration using relevant contexts, and that central to this cognitive development was the belief that:

“The key important thing though, is relationships” (Final interview: 07/12/15). Michael explained that an educated person, *“is not people with knowledge of facts or just factoids. I want students to be engaged, lifelong independent learners...so sometimes the content is not my focus. It's more how they get there and how they'll do it later on* “(Final interview: 07/12/15).

Michael espouses a science education where students are helped to develop lifelong critical and creative thinking skills, importantly using relevant and real-world contexts. For Michael student learning must primarily consider:

Like anything, it's got to be relevant, it's got to have meaning. We have a curriculum we have to get through but always the learning is, only ever when it is part of their world, then they start to see the relevance for it, otherwise there's no point...Creativity is what I keep telling the kids is what we want in science, we don't want to keep going down in a straight line that everyone has always done. You see a problem and think about it creatively and come up with multiple solutions (Initial teacher interview: 05/09/13)

Michael revealed a desire to use ICT in the classroom to offer students opportunities to express themselves as individuals, using the vast range of free multimedia tools now available rather than using traditional text formats. According to Michael, learning must involve students creating knowledge and then afforded an opportunity to showcase their understandings, where possible to real world audiences. As an example, he described a whole class project where groups of students collaborated to produce a multimodal representation of a recently learnt physics concept using a free online tool called *iBook Author*. Ultimately each representation would form a chapter of an eBook with the aim being the eBook would become a legacy for younger students at the school. Michael explained his rationale for this learning activity:

I always tell the kids that I have learnt way more science than I ever did sitting in a lecture theatre because I have to think about how do I explain that? How does this other person understand? What are different ways I can get this concept across? ...In these collaborative groups the students are doing the instructing as well...because they are thinking of different ways of explaining it to your peer, who may not have understood. So, when you are thinking of alternative ways of explaining things, it gives you a deeper understanding of its meaning (Initial teacher interview: 05/09/13)

Michael reiterated several times during this study that working collaboratively is, “*modelling how science is done*” (Final interview: 07/12/15). Depending upon the learning objectives and the nature of his students he stated that:

Some kids just don't, they work better solitary. If they are using a computer and happier to work solitary, that's fine, they are probably solitary with their computer at home...I don't know but I'm not going to force the issue and make them uncomfortable for what I would see as not much of a benefit. Although group skills are important, I do appreciate that, but that will happen in other parts of the classroom work (Initial teacher interview: 05/09/13)

Michael cares deeply about the quality of his teaching and as part of his usual practice conducts student surveys to evaluate and reflect on his teaching. This student feedback and his subsequent reflection helps to inform his plans. Michael recalled a ICT activity he had designed requiring the students to create an eBook reflecting that:

What was good about it was that they had to really understand it because they knew someone else was going to read it. So, when they were researching there was a purpose, it was authentic because they knew next year's group of Year 10s will look at this book or their parents, so it wasn't just a bit of paper for the teacher to mark and then I give it back and put it in my bag and then forget about it (Initial teacher interview: 05/09/13).

Michael did express a primacy of the content or disciplinary knowledge he is required to cover as part of the Year 10 science curriculum, however, he emphasised that he uses the mandated curriculum as the context for the development of lifelong learning skills, stating:

I have the syllabus to get through...that is my context, doing what I want to achieve, which is to develop learning skills. Sometimes I will look at a science understanding or investigation skill or science as a human

endeavour and do some research on how are other people using ICTs to do this (Final interview: 07/12/15).

On several occasions throughout the study Michael also elaborated upon the formal assessment demands that drive classroom activities, indicating that he would much prefer to centre his classroom activities around problem-based learning as:

It would work perfectly if my hands were not tied with the assessments that have to be done. By the time they get into Year 12, they've got to sit that examination at the end. I know that if students went through Senior School Chemistry and Physics doing challenge or problem-based learning, they'd probably come out better chemists or physicist, but they wouldn't score so well on that examination (Final interview: 07/12/15).

Michael explained that his approach to assessment is more about formative feedback, stating: *"I like feedback and feed forward...so guiding them for the next assessment, then they've hopefully learnt from and they don't keep repeating the same mistakes over and over again"* (Final interview:07/12/15). When asked to justify the main reason behind why he uses ICT so often in his classroom Michael claimed that: *"The use of ICT is as natural for myself as breathing. It is integral to my day-to-day existence and without it I would feel shackled in my teaching... It's because it's real life. It's a tool I use every day and the students use every day"* (Final interview: 07/12/15). Michael was keen to point out that he does not position ICT as innovation *per se*, reiterating this point several times throughout the study claiming:

Maybe its innovation to bring it into the classroom but it shouldn't be. It should be in the classroom...and that's the relevance that kids need. It's their world...I say the pen and paper is technology, and that's the way I see an iPad or a computer, it's just a part of what we use to communicate...it's a great way for them to go and get information, collect it, condense it, conceptualise it, in a format that they know (Final interview:07/12/15).

Key finding 4.3 Views on teaching and learning science

Michael views on learning align with a social constructivist perspective, where students are positioned as active participants. He supports a learning environment where critical and creative thinking, and collaborative skills facilitate the design of his ICT enabled learning activities; albeit where these activities are aligned to the key content in the mandated science curriculum. Michael indicated that formal assessment regimes of the upper secondary school science curriculum somewhat constrain the meaningful integration of ICT.

Michael explained that until the arrival of the one-to-one laptop program in 2009 he made the decision to utilise a data projector and his DoE leased laptop in the classroom, rather than booking students into the school computer laboratories, encouraging students instead to access the Internet at home. Michael suggested that since the advent of one-to-one availability of laptops his teaching has improved dramatically stating:

My teaching has just gone, whooooaa, like that. Honestly when we had machines in banks I just couldn't be bothered, the booking of them was a nightmare, people didn't plug them in to charge them...they didn't have mice, there were bits missing in the classroom (Initial teacher interview: 05/09/13).

Michael claims that one-to-one access to ICT in his classroom is now an indispensable tool, a means by which he can provide his students with simulations, animations, videos, virtual experiments, games, mind mapping tools, and communication tools. Michael claimed that the use of animations greatly assisted his ability to facilitate understanding of abstract science concepts: *"I just did polymers. I think simulations are vital for explaining difficult concepts... I can't teach without them!"* (Final interview: 07/12/15). He was careful to point out that learning has always involved tools and positions ICT as a ubiquitous structural part of his classroom learning environment stating:

I think a lot of people think technology is different, I don't see it as much different to anything else, it is just a tool, and if it just a tool then uses it, and don't worry, don't let it get in the way of the learning... It's just what you use... I would either be displaying something on the screen, which might be a video or an animation or a presentation or whatever, or I will be saying open your laptops and go to our Moodle page, there is an interactive I have got for you, or there is a document I have got for you, or whatever... In fact, a lot of my kids do not bring paper, they don't even write on paper (Final interview: 07/012/15).

Michael positions ICT as an invaluable mediational tool enabling real word connections stating: “*You’re getting out of the classroom, you are getting into the real world*” (Final interview: 07/12/15). As an example, he shared a recent activity with his Year 12 Physics class where he was able to stream a 3-dimensional X-ray image of his wife’s broken foot via a data projector. He was then able to rotate this image in real time to the class for them to locate the fracture. At the time, the students were learning about X-rays as part of the Year 12 Physics syllabus. According to Michael, a key affordance of technology is: “*It allows me to do things that I couldn't do otherwise...what I really want to do is break down time and walls...learning is everywhere and always*” (Initial teacher interview: 05/09/13). Michael talks about the importance of knowing when not to use ICT and foremost considering how the ICT will support or enhance the learning stating: “*I never want to artificially utilise anything, it’s got to be authentic. It’s got to be realistic, it’s got to be useful, there’s no point just doing it for the sake of it*” (Initial teacher interview: 05/09/13). Michael was also keen to point out that practical science activities are still an important part of his classroom environment revealing:

I have even heard of some people doing virtual Bunsen Burner licenses and I think, what is the point of that? They haven’t struck a match...science can’t all be done virtually...you need to get out of your chair sometimes and move around and do stuff (Initial teacher interview: 05/09/13).

Throughout this interview Michael referred to specific examples of software applications that he finds useful to support teaching and learning. In illuminating the perceived educational affordances of these applications Michael mentioned the current array of intuitive multimedia presentation tools that: *“You don't have to teach the software. You just say here is a tool”*. Again, he referred to the *iBook Author* tool used by the class to create the Physics eBook, revealing that in instructing his students on how to use this tool simply involved a 10-minute overview stating:

Then I said go for it, any questions let me know and I will come around and assist. But they know, they will collaborate and they will sort out their own problems, and if not, they ask, so it doesn't really involve teaching the software, they just get on with the job. It doesn't get in the way of learning. I mean it's nice to learn the software but that's not the purpose of the eBook (Initial teacher: 05/09/13).

According to Michael another useful mediational aspect of students having personal laptops is that they can annotate PDFs from online books, *“so that makes that textbook their own personal textbook”* (Initial teacher interview: 05/09/13). Michael also discussed using ICT to access virtual science experiments. For example, in his Year 12 Chemistry class after having carried out physical acid/base/redox titrations he directs the students to virtual titrations explaining: *“So once they know how it is done, rather than having to do it over and over again to get the same data, they have the opportunity to try it with different chemicals and see what it looks like”* (Initial teacher interview: 05/09/13). Currency of scientific information and instant access to data, according to Michael are other appealing affordances of one-to-one laptop access in the classroom. Michael revealed that he rarely uses hard copy textbooks in the classroom now: *“There are too many sources to be reliant on one I believe...I mean information is current online, why would you get something printed that was written three or four years ago?”* (Initial teacher interview: 05/09/13). Michael also uses the affordances of ICT to provide students access to contemporary science issues, particularly for students to explore science as a human endeavour. He organises a class wide subscription to an online science magazine called *Cosmos*. According to Michael an important benefit of this e-

Magazine subscription is the facilitation of breaking down the stereotypes that science is: “*Not all grey-haired people, it’s young males and females and it’s for everyone* (Initial teacher interview: 05/09/13). For Michael, another key educational affordance of ICT is the ability for students to connect with like-minded individuals anywhere in the world. Declaring that access to the Internet enables social interactions that would otherwise not be possible, where students can hear ideas from other students as well as scientific experts. Michael claimed that, “*the Internet, is great because kids are finding like-minded individuals in the globe, where as they don’t always find them in the classroom*” (Initial teacher interview: 05/09/13).

When asked to elaborate on the perceived usefulness of one-to-one laptop access Michael identified the significant opportunities afforded by ICT to participate in solving authentic problems, such as accessing or collecting real scientific data. Citizen science projects are those that use technology, usually involving the download of some free field software to a mobile device to capture some specific data. Citizen science projects aim to harness the collective efforts of many individuals in society to facilitate data collection on a range of scientific endeavours, such as biodiversity data. At various moments in this interview Michael stressed the notion of student relevance, ideally where an authentic purpose for doing science is offered stating:

Citizen science, is another use of ICT, things like the Atlas of Living Australia. Kids go out and take an image of a bird in this tree here, its GPS located and that puts some information, it forms a living atlas of Australia and it’s all done by citizens and it’s marvelous (Initial teacher interview 05/09/13).

Key finding 4.4 Views on the role of ICT for learning science

Michael reasons that without the one-to-one Internet access he would not be able to provide such a diverse range of authentic contemporary and authoritative science resources. Michael positions ICT as a fundamental aspect of student research, constructing science knowledge and for communicating this understanding, however, sees its real power as a learning tool to connect curriculum to real world examples. Michael leverages the affordances of ICT to provide students with rich multimodal


learning opportunities, such as videos, simulations, and virtual experiments. He also reasons that these digital resources enable students to obtain repeated practice of a range of science skills e.g. titrations. Michael offers his students agency in choosing their own preferred multimedia tools from the vast array of free online tools so they can create and communicate their scientific understandings, indicating this offers a more personalised approach. Furthermore, the array of user-friendly publishing platforms enables students to easily publish their digital creations to diverse audiences. In addition, a significant learning affordance of ICT for Michael is the ability for students to connect on a global scale with like-minded individuals and participant in activities such as citizen science projects.

Michael explained that he utilises the facilities of the school based LMS *Moodle* extensively as means to catalogue almost his entire curriculum claiming: “*I tell my students leave your wood at home...all my courses are on Moodle*” (Initial teacher interview: 05/09/13). According to Michael the *Moodle* LMS platform at the school allows his students to access his curriculum material anytime and from anywhere using any device, if the students have an Internet connection. Michael offers his Year 10 science students a plethora of digital instructional resources to access outside of the classroom walls. Past test papers, revision sheets, terminology banks, an index of suggested authoritative and reliable hyperlinks, a catalogue of all learning task briefs and assessment rubrics, including all of Michael's Keynote (PowerPoint) classroom presentations are curated here. He explains that he continually expands his reservoir of learning materials or as he calls these: “*Teaching and learning opportunities*” (Final interview: 07/12/15).

Michael felt that the sheer volume of freely available Internet accessible resources and tools meant that he spent considerable time preparing and strategically selecting these resources prior to classroom use, or as he calls it, “*lurking the Internet*” (Initial teacher interview: 05/09/13). Michael indicated that he also preferred to source his own materials and create bespoke tasks rather than utilising popular teaching Australian digital teaching repositories like *Scootle*. As an example, Michael revealed he has taught many English as a Second Language (ESL) students whom would often request additional instructional support, particularly for the more abstract concepts e.g. equilibrium graphs as prescribed

in the senior school syllabi. This activity often consumed his lunchbreak or after school preparatory time. As an Apple Distinguished Educator, Michael was given a free *iTunes* account (an Apple tool for curating educational resources). In 2007, Michael then began to create his own podcasts for these abstracts science concepts and publish these on his *iTunes* channel. Indicating that his students could then listen to these explanations at the point of need, or repeatedly if necessary. Michael claims that learning from experts both in and across settings, particularly from resources made freely available via the web has enabled him to become more inclusive of ESL students..

At the time of this study Michael has created over 50 animated science podcasts, which he freely shares with anyone via his *iTunesU* repository, as well as another online channel he utilises called *Podomatic* (a web platform that allows users to create podcasts and then freely share this content online). These physics, chemistry and general science animated podcasts range from one minute to approximately seven minutes in length, revealing that even a lecturer of Physics from a French University sent him an email to compliment him on these useful podcasts. An example of an animated podcast related to graphing chemical equilibrium is shown in Figure 4.3, a challenging concept prescribed in the senior school syllabi he is required to teach.



chemistry - classes

chemistry video podcasts for high school

Equilibrium Graphs

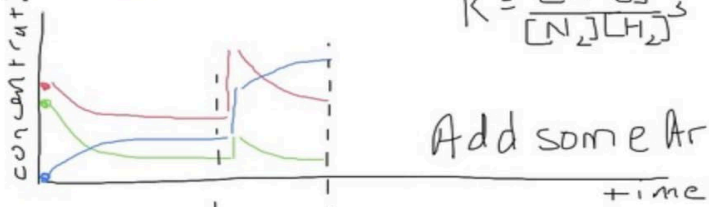
October 21, 2016 05:24 AM PDT

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

Temp 400-450°C Pressure ~20 atm

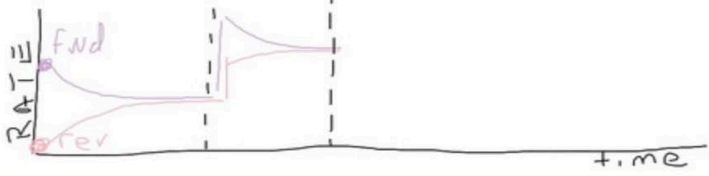
$$K = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

concentration




time

RATE



time

We look at graphs of concentration vs time and rate vs time for the Haber process. Consideration of the value of the equilibrium constant as changes are made to the system at equilibrium are included.



Play

[Send to Friends](#) | [Leave a Comment](#) | [Download](#) | [Permalink](#)

[View Profile](#)

Podcast Summary

These chemistry video podcasts are high school chemistry snippets, from [redacted]

To help make these resources more useful your feedback would be appreciated.

You may also want to check out my physics video podcasts at [redacted]

Thanks,

[redacted]

[redacted]

[redacted]




Figure 4.3: An exemplar animated podcast from Michael’s open source *Podomatic* channel

In lurking the Internet, Michael mentioned that he often must filter and adapt the digital resources he comes across for classroom use requiring a huge investment of his time. Although he claims his own personal interest in technology helps to offset the amount of time these at home planning activities demand stating: *“At home I will say to my wife, I just have to go and check my emails and then four hours later I have done lots of other stuff...but I enjoy it and in fact I enjoy sitting in front of technology and curating”* (Initial teacher interview: 05/09/13). Michael pointed out his students are still learning how to learn, and therefore still cognitively developing, consequently he provides scaffolds of how to approach learning tasks in the form of task briefs, as well as providing assessment rubrics to guide the work that is to be submitted. Indicating that these scaffolds help students focus on producing quality work, ultimately helping students to become independent problem solvers:

They’re still developing at this stage and I think you need to give structure, models.... If they’ve got a purpose, if that’s clear, that’s out of the way, then they get on with the job. So, I’m hoping that by constantly modelling, here is what we are doing etc....here are the steps...here is what I’m looking for. Eventually by seeing that many times, they will start to develop that themselves (Final interview: 07/12/15).

Michael also uses his *Moodle* page to operate a question and answer forum to help augment knowledge construction by his students. Students are encouraged to post scientific problems to this forum. However, for members of the class to see the responses they must first contribute a response, thereby encouraging personal accountability in this collaborative conceptual knowledge building activity. He explained that another affordance of technology enables absent students to catch up on classroom activities and assignments. Again, Michael houses his classroom learning task briefs and assessment rubrics inside his *Moodle* page.

Michael reported that his personal digital literacy and ICT self-efficacy is strong, having had a keen interest in technology for over 20 years. As early as the mid 1990s Michael began constructing worksheets and tests that incorporated images using his own personal *Commodore* computer that he would transport to and from school daily. These

worksheets were created using a software program called *Graphic Environment Operating System*, or *GEOS*, a *DOS* based software. Since the early 1990s Michael has used ICT to communicate and collaborate outside of his classroom revealing:

I remember my first computers were Commodores...I would always use them to interact with kids. I remember when my first websites were way back on bulletin boarding with my Commodore and communicating with people over in Germany... I have used it to communicate and collaborate for a long time. A lot longer than anyone I know actually (Initial teacher interview: 05/09/13).

To date Michael has not participated in any professional learning surrounding the meaningful integration of ICT initiated by the Department of Education, nor could recall any that has been recently offered. Instead he has always sought his own professional development, much of which has been self-taught via the Internet. However, as an Apple Distinguished Educator Michael occasionally attends *Apple* community events and learns about creative and innovative uses of *Apple* based ICT for the classroom. His role as the School's eLearning coordinator also helps to maintain the currency of his digital capability and affords an opportunity to disseminate useful ICT resources and guides for staff members via his community *Scoop.it* site.

As early as 2007 Michael created a personal *YouTube* channel as a teaching and learning repository but had only just recently began to utilise this video file sharing facility to house his growing catalogue of instructional videos. Michael reasoned that *YouTube* can be accessed via any Internet connected device at any time, thereby increasing the flexibility of the learning environments he offers. Recently Michael had begun utilising a screen-casting whiteboard tool called *ExplainEverything* that allows him to create annotated animated science explanations. These representations are created on his iPad and then later placed onto his *YouTube* channel to support knowledge construction in the classroom. An example of an *ExplainEverything* teaching episode created by Michael is shown in Figure 4.4.

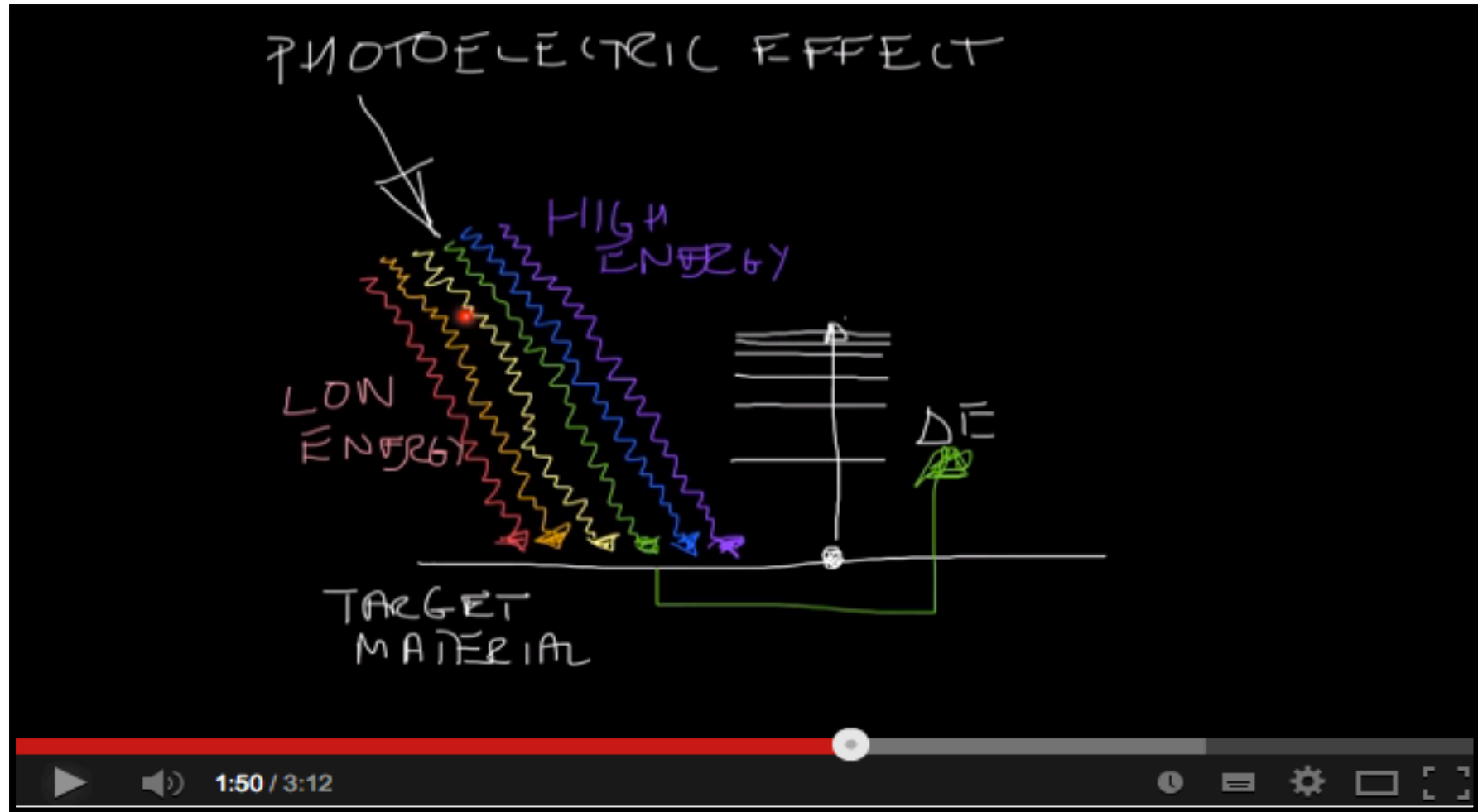


Figure 4.4: An exemplar *Explain Everything* episode held on Michael's *YouTube* channel.

Key finding 4.5 The curating and scaffolding of digital curriculum resources on to school facilitated LMS

One-to-one laptop availability enables flexible access to a wide range of educationally beneficial contemporary science curriculum resources, which Michael reasons is a critical factor driving his ICT integration efforts and student use of ICT in his classroom. To facilitate the meaningful use of ICT Michael curates a plethora of digital curriculum resources which he sources mostly from the Internet, housing these in a school based LMS platform known as *Moodle*. This allows students to flexibly access Michael's curriculum material at any time. Michael continually curates' new resources and maintains the currency of hyperlinked ICT resources. Michael also designs a range of inquiry-based learning tasks and assessment rubrics to guide the quality of students work using many of these curated resources. These instructional resources are aligned to the mandated science curriculum.

Michael alluded several times throughout this study to the speed at which new information is uploaded to the Internet and then made available by technology, making traditional knowledge dissemination in the classroom seem redundant. He claimed that before the one-to-one provision he saw himself as more of a lecturer. By comparison, he used the terms 'model' and 'facilitator' as metaphors to describe his current role in the classroom saying: *"As with all teaching and learning that occurs in a classroom, my role is a facilitator...then I guide them on that journey"* (Final interview: 07/12/15). However, as will be shown in the subsequent lesson observations Michael played an integral role in the classroom as both a knowledge broker and orchestrator of the learning.

Key finding 4.6 Technological pedagogical content knowledge

Michael's interest and use of ICT in the classroom originated over 20 years ago. Michael's digital capability is expansive having been largely self-taught. His skills have been self-initiated and continue to be self-taught. Michael spends a significant proportion of his personal time searching for and selecting meaningful applications of ICT in his classroom referring to this as *'lurking the Internet'*. He selects those ICT tools that are free and do not have complicated extensive registration requirements or

passwords. This consumes a considerable amount of Michael's time, albeit he indicated he enjoys this curation activity. This preparation time is offset by his keen interest in using technology for learning. Michael uses a sophisticated variety of courseware authoring tools to create bespoke digital learning objects for use in his classroom e.g. *ExplainEverything*. Michael has created a rich reservoir of multimodal digital resources and shares these on open access video and audio and file sharing sites such as *iTunesU*, *Podomatic* and *YouTube*, thereby offering his students flexible access to this curriculum material. Michael also shares his vast ICT integration expertise and these resources with the School community via an online community of practice website called *Scoop.it*.

4.4 Lesson observations

Shulman's (1987) PRA model and the CHAT (1987) model were used as lenses to analyse Michael's pedagogical practices. These data are supported by an analysis of the lesson's pedagogical activity structure using the action and operation descriptors outlined in Table 3.3. An analysis of the key decisions, as well as the teaching and learning practices for each of the lessons observed is now presented. Each lesson is presented separately using data derived from the pre-lesson interview, teaching artefacts, the lesson observation, including the post-lesson debriefing session.

4.4.1 Lesson one: Theme Year 10 'Project Moon Base'

4.4.1.1 Pre-lesson interview

Michael explained that traditionally during Year 10 Physics his students were required to design and conduct a laboratory investigation in relation to Newton's Second Law, one that normally involved using dynamic trolleys and ticker tapes. Michael revealed that he wanted to do something more contemporary and relevant stating: "*Nowhere in the world, but in a science, class are ticker tapes used, so this is more of a web-based investigation design research task*" (Pre-lesson interview: 25/09/13). He explained that the rationale of this lesson, part of a planned series of four, was for students to work collaboratively in small groups of their choosing to produce a possible solution to the research problem of will large forklifts be needed to move fuel tanks on the Moon, or will small forklifts do?

Michael indicated that his students had previously covered several lessons on Newton's Laws of Motion and now recognised that a stationary object or a moving object with constant motion has balanced forces acting upon it. To prepare for this lesson Michael had created a learning task brief, called Project Moon Base which outlines the requirements of this experimental design challenge and is shown in Figure 4.5. This challenge required the students to research and then analyse web-sourced information, thereby mimicking authentic scientific inquiry, to then design a possible experimental solution to the problem, as stated earlier.

Michael's intentions were for each group to create a digital product which was to demonstrate their chosen experimental design using any of the freely available multimedia online tools such as *Glogstar*, *Prezi*, *iMovie*, or *iBook Author*. However, Michael indicated that it was more important that the students had ownership over the final product stating: "*The actual product is open-ended. I always do that because they are all different*" (Pre-lesson interview: 25/09/13). Finally, he expected each group to pitch their scientifically based argument to a panel of judges which he intended to be made up of a real-world audience, including the Head of Science, another science teacher as well as the School's laboratory technician. Michael reasoned that this afforded student an important opportunity to develop argumentation skills and practice public speaking.

Michael explained that the origin of this task was something similar he had seen on a science teaching online repository he had found whilst lurking the Internet; however, he indicated that he needed to adapt the original version to ensure the assessment requirements met those for a Year 10 academic extension group and so had modified the original version. Michael was most keen to emphasise that the overarching decision driving the use of ICT in this lesson was to mimic authentic scientific inquiry and promote collaboration amongst the students. Michael's extensive knowledge of the mandated curriculum is demonstrated in the construction of this learning task. It is clear that this lesson maps directly to Year 10 Physics curriculum where students are expected to understand, "*The motion of objects can be described and predicted using the laws of physics and using Newton's Second Law to predict how a force affects the movement of an object*" (ACARA, 2015a.). Furthermore, as evidenced by the assessment criteria detailed on the rubric associated with Michael's learning task (see Figure 4.5), the

learning task maps directly to the Year 10 achievement standards, again mandated by these mandated curriculum documents.

Michael stated that working in teams to design this experiment was the primary aim for this project, hoping that his students would, *“Realise that everyone in the group has to contribute, everyone has some input, and diversity of groups are important”* (Pre-lesson interview: 25/09/13). In structuring the task this way, it is evident that Michael was aiming to promote interdependence and accountability during this collaborative task. Considerations of instructional design, in this instance role-based collaboration, were clearly apparent in the preparation of this investigation task. For this activity, the students were offered the choice of working as either an Astronaut, a Theoretical person or as the Experimental Team member for the duration of the project. As a precaution, in preparing for this lesson Michael had preselected and, *“downloaded some useful videos from online and stored them just in case...you’ve got to have back up”* (Pre-lesson interview: 25/09/13). These digital resources were uploaded onto the class Moodle page prior to the lesson: *“I don’t give out hard copies...a lot of them now just go straight to the Moodle page...that’s just the way the lessons begin”* (Pre-lesson interview: 25/09/13). Furthermore, in preparing for the lesson Michael had also ensured that any hyperlinks listed on the learning task brief were active. These freely available web-based resources included a range of interactive simulations, audio, and video resources, as well as current text based informational sources (see Figure 4.5).

Whilst Michael expected the students to utilise these pre-selected digital resources as a springboard, he explained: *“I would rather they find it themselves...but if they can’t find anything they can start by looking at those”* (Pre-lesson interview: 25/09/13). Again, this resonates with his belief that students themselves need to become autonomous and critical users of the vast array of Internet resources. It also echoes with his rationale for students using ICT to connect with contemporary and engaging sources, rather than be restricted to resources located within the confines of the classroom walls.

Selecting, storing, and curating these high-quality instructional materials reflect Michael’s significant science discipline expertise, as well as evidence of his TPACK. Michael’s personal ICT capability is expansive, for example in preparing for this lesson he explained that, *“on the Moodle page it would normally open up the video on the page, I actually change the settings to force it to download to the student’s machine so that if*

they come back and the network is down, they've at least got a copy of the resources" (Pre-lesson interview: 25/09/13).

Extensive transformational lesson preparation is clear for this activity to have taken place. First, Michael had modified an existing digital resource to suit the characteristics of his academic extension students and re-framed it around a problem-based challenge. He then curated a range of instructional videos and websites related to this concept area and pre-tested these to ensure the links were active before uploading these to the class *Moodle* page. In addition, Michael had produced an assessment rubric that clearly outlined the final product expectations (see Figure 4.6). Almost 75% of the available marks for this task show direct alignment to Year 10 mandated scientific curriculum including content understandings and higher order inquiry skills. Michael indicated that creating a criterion-referenced rubric such as this one enabled his students to remain focused on the task at hand, as well as evaluate their work in progress stating: *"I don't care how they do it, as long as they meet the criteria"* (Pre-lesson interview: 25/09/13). These instructional resources all helped to ensure the focus of the lesson was on the key learning objectives, as well as to ensure the flow of this lesson. Clearly this lesson had been meticulously planned yet Michael modestly claimed this was simply something he did.

Newton's Second Law Investigation

Introduction:

The National Space Foundation has decided to construct a base on the moon. A lot of material will need to be moved while constructing the lunar station. The question is, will large forklifts be needed to move fuel tanks or will small forklifts do?

You are part of a Science Research Team to investigate this question by proposing an experiment that will be done during a preliminary visit to the moon.

Task:

In the preliminary visit you cannot take forklifts, but can take simple equipment. Your proposed experiment will basically see if Newton's second law applies on the moon.

As a member of the Science Research Team you have to complete the following tasks:

- **Member 1 (Experimental):**

You will need to think about the equipment and how the experiment will be done.

- **Member 2 (Theoretical):**

You will need to think about the variables and relationship.

- **Member 3 (Astronaut):**

You will need to think about how the experiment will be done given that the moon is different to earth.

Your team will describe your proposed experiment.

Some links that may be useful starting points:

NEWTON'S 2ND LAW

<http://www.williamsclass.com/EighthScienceWork/NewtonsThreeLaws.htm>

<http://teachertech.rice.edu/Participants/louviere/Newton/law2.html>

<http://library.thinkquest.org/11902/physics/newton2.html>

<http://zonalandeducation.com/mstm/physics/mechanics/forces/newton/newtonLaw2.html>

EXPERIMENTS

Newton's Second Law rubric: Basic Elements					
Title, names, and roles	0	1	2	3	NA
A statement of aim	0	1	2	3	NA
A clear explanation of the variables	0	1	2	3	NA
A list of the equipment	0	1	2	3	NA
Explanation of how the experiment will be done with diagrams and pictures	0	1	2	3	NA
Comparison of the situation on the moon with that of the earth	0	1	2	3	NA
Diagrams and pictures	0	1	2	3	NA
Scientific Aspect					
Explain Newton's second law using words	0	1	2	3	NA
Identify changes that take place when forces are acting	0	1	2	3	NA
Describe the relationship between force, mass, and acceleration	0	1	2	3	NA
Relate qualitatively acceleration to a change in speed and/or direction because of a net force	0	1	2	3	NA
Know what the force is	0	1	2	3	NA
Know what the acceleration is	0	1	2	3	NA
General					
Clarity and flows easily	0	1	2	3	NA
Creativity	0	1	2	3	NA
Readability	0	1	2	3	NA
Overall visual appeal	0	1	2	3	NA
Total points					

Figure 4.5: Newton's Second Law student investigation task guide and assessment rubric

Michael also indicated that he normally asks his students to view the class *Moodle* page to preview the learning task brief beforehand, although he expected that many students might not do this. In further preparation for this lesson Michael had also made a *Keynote* presentation (a type of presentation tool like *PowerPoint*) to assist with explaining the requirements of the learning task. This explanatory presentation was also uploaded to the class *Moodle* page. Michael stated that he always did this as it helped to

pre-empt many of the questions he expected surrounding the task requirements, rationalising that providing these extra instructions saved him class time.

Key finding 4.7 Extensive lesson preparation and the curating of resources

Michael carried out extensive transformational preparation for this ICT mediated lesson, which firstly involved determining a clear learning purpose. This context was derived from the mandated Year 10 *Australian Curriculum: Physical Sciences* curriculum requirements and achievement standards. Given the academic nature of his students, Michael framed the activity using a problem-based approach where students were expected to work in teams of three to create a solution. Michael had diligently selected relevant, reliable, and multi-modal ICT based stimulus resources and curated these digital resources onto his *Moodle* page enabling flexible access to these curriculum resources both inside and outside of the classroom. Michael also undertook to pre-test ICT tools and hyperlinks. A clear instructional learning task, along with a criterion-based assessment rubric was also created by Michael to guide students thinking and final scientific representations in this learning activity.

4.4.1.2 Lesson one observation

Michael's Year 10 AEP students are all greeted at the door upon arrival and begin to chat to him about the recent weekend football results. Some of the students tease him about his team's performance. Lots of laughter ensues. Before the session commenced Michael had already entered the room to set up his *MacBook Air (13 inch)* and connected it to the interactive whiteboard (IWB), in this instance a *MimioTeach* portable interactive whiteboard or MMIO. There was a fixed position data projector located centrally at the front of the classroom. Michael carries a personal wireless presenter, as well as an *iPhone* that he uses to start recording student attendance as students enter the classroom.

Laboratory benching lines the perimeter of this science classroom featuring sinks, taps and gas outlets, as well as a range of typical science lab equipment. Michael has arranged his classroom desks and chairs in groups of four and six, all with front facing foci stating: "*I want them to come into the room and just straight away know that we're working together. There's not one front of the room*" (Final interview: 7/12/16).

As Michael stated: “*They soon learn that they will miss out if they don’t bring it...I find that if I use it every lesson they bring it every lesson*” (Pre-lesson interview: 25/09/13). Michael does not make concessions for forgotten laptops, instead students must go without.

Key finding 4.8 Classroom architecture and norms

The physical learning environment of Michael’s classroom is arranged so that students sit in groups of four or six with scientific lab benches lining the perimeter. Michael’s classroom routine involves pre-loading his digital instructional materials prior to the students entering the room and projecting these onto the *MMIO* whiteboard. Students log on to the class *Moodle* page immediately upon sitting down awaiting further instructions.

This lesson was the first of a planned sequence of four around the context of Newtons Second Law. Michael began the lesson by inquiring as to whether the students had read Project Moon base learning task, and as he suspected, many had not. He then opened the pre-prepared *Keynote* presentation (directly from the class *Moodle* page), and in doing so modelled how to locate this document. He then spent approximately 10 minutes introducing the objectives of this learning task to the class using his prepared *Keynote* presentation to emphasise the key task points. During this introductory phase Michael explained the range of Internet based stimulus material he had pre-selected, yet emphasised: “*You are free to roam*” (Lesson one observation: 25/09/13).

During this phase of the lesson the students were receivers of information, albeit exchanges of questions regarding the task ensued. In describing the task requirements Michael prompted the students to consider incorporating factors into their experimental design such as: “*A description of scientific principles in words and mathematics, a list of equipment, it’s mass, volume and cost, how will the experiment be performed, a statement of aim, and a catchy project name*” (Lesson one observation: 25/09/13).

Michael also explained that teams of three were to form and that each team would ultimately pitch their design solution to an audience of other teachers, using whatever multimedia format they wished. In order to make them more thoughtful and targeted about this presentation Michael reviewed the RAFT writing principle with the class

(NCTE org, 2016) where; ‘R’ refers to the role or purpose of the writer, ‘A’ refers to considerations of the audience the communication is intended for, ‘F’ refers to the format style of the presentation and ‘T’ for the topic that is being written about. Michael rationalised that including cognitive tools like the RAFT principle as part of his initial lesson set up helped to set higher standards for the project work that is to be submitted.

After some excited discussion about what role each member of the team would play the students then commenced navigating the various suggested web-based sources offered by Michael. In this lesson, the students were primarily positioned to act as explorers and collators of relevant science information using their laptops as the meditational tool. Michael allowed the students to determine their own ‘Science Research Team’, stressing several times that each group was to consist of no more than three people. After excitedly determining the composition of the teams each group then worked collaboratively for almost 40 minutes of this 60-minute lesson to begin distilling information from the Internet based on Michael’s suggested resource list.

The task was open-ended in nature, including the ability to choose an ICT media tool for the final product, allowing students to creatively construct their own representations. This resulted in much excited conversation amongst the teams. In fact, at one-point Michael needed to draw his students’ attention away from these initial discussions and re-focus the students back to exploring the relevant information about Newton’s Second Law, telling one group: *“You can’t design your experiment until you really know the physics”* (Lesson one observation: 25/09/13).

During Michael’s interactions with the students he followed many dialogic teaching principles. Continually weaving his way around the room Michael interacted to find out what the students were thinking, inquiring as to who had chosen what role and why. Occasionally teams would beckon Michael to their desks wanting to check or clarify their emerging ideas. Michael was seen to offer lots of formative feedback to each group and seemed careful not to direct students thinking down a pathway, instead probing their ideas and asking them for clarification;

ST1: So, there is no gravity on the Moon right and no air?

Teacher: That’s right, so what might that mean for the weight of the science equipment you might take?

ST2: Maybe it has to be light?

Teacher: Sounds like you are thinking on the right track

ST1: the Second Law is $F=ma$ -correct?

Teacher: Yes. So, you need to think about, if the Moon has no air and very little gravity how might this effect your experimental design? Maybe you two need to do some more research. Might be good to look at some videos of how astronauts did work on the Moon.

ST 1: Maybe we should also find out about the type of soil or rock on the Moon?

How will we stabilise the forklift?

Teacher: Excellent thinking! I hadn't considered that, great idea!

(Lesson one observation: 25/09/13).

The students remained on-task throughout the entire duration of this lesson, clearly engaged with the problem-based challenge set for them. The overall instructional sequence of this lesson followed a pattern of informing his students of the task objectives, presenting the students with the digital based stimulus materials, students exploring the digital resources whilst Michael continually probed student ideas and provided formative feedback. Finally, Michael drew the whole class into a short plenary session, drawing out the lesson's outcomes, as well as a reminder of the key task requirements for the following sessions.

As a further means of triangulating and characterising the data arising from this ICT mediated lesson, Michaels actions and operations were decomposed using Stevenson's CHAT analytical tool (2008), as previously elaborated in Table 3.3. This involved categorising Michaels *classroom organisation* of the students, the *use* of ICT, (e.g. the functionality of the tool use) and the *conversational roles* that shape the relationships between the teacher and the student (e.g. lecture, questioning, summarising). This allowed Michaels instructional practice to be scrutinised on a minute-by-minute basis. Each facet has been expressed as a percentage of the total lesson and presented in tabular form as shown in Table 4.1.

This data revealed that Michael spent 47% of this lesson engaging in dialogic teaching whilst working with small groups: his questioning engaged students in critical reflection and analysis. Whilst Michael did consume 28% of the lesson time setting up

Project Moon Base and conducting a short plenary at the end of the lesson, he personally used ICT only 9 % of the time during the lesson. The remaining lesson time the students were using their laptops to carry out the lesson activity. The students were positioned in teams of three to conduct this learning activity. Given that this was the first in a planned sequence of four lessons, Michael spent 60 % of the lesson time working with individual teams engaging in mostly dialogic teaching. Closer analysis of the ICT activities being conducted by the students revealed that 72 % of the use of ICT by the students involved exploration of the suggested Internet based resources as offered by Michael rather than initiating their own ICT explorations as he had hoped for.

Table 4.1: Pedagogical activity structure of lesson one using Stevenson’s (2008) activity matrix

Classroom organisation mode	Percentage of lesson observed	Conversational roles	Percentage of lesson observed	ICT usage	Percentage of lesson observed
Teacher working with whole group (D1)	28	Teachers giving information to whole class (S1)	37	Teacher using ICT (T1)	9
Teachers working with small group (D2)	60	Teachers directing questions and answers to reproduce facts (S2)	2	Learners using ICT in a collaborative task as initiated by (T2)	19
Learners working in small groups (D3)	12	Teachers directing conversation (S3)	14	Learners using ICT in a collaborative task as initiated by themselves (T3)	0
Learners working individually (D4)	0	Teacher stimulating reflections or other critical analysis (S4)	47	Learners interacting via ICT as initiated by teacher (T4)	72
Learners reporting or presenting own material to whole group (D5)	0	Learners directing conversations with peers (S5)	0	Learners interacting via ICT as initiated by themselves (T5)	0
				Learners creating using ICT (T6)	0

Key finding 4.9 Pedagogical repertoire

The students worked in role-based teams each using their own laptops for almost three quarters of this lesson. Students were free to assign themselves to a specific role in this problem-based research investigation. After a comprehensive introduction to the task Michael engaged in dialogic teaching with these small teams, prompting and guiding the student's exploration of web-based resources which they accessed via his *Moodle* page. The meticulous explication of the instructional and assessment objectives, the pre-selection of ICT based stimulus Internet based materials, dialogic teaching, and patient, attentive and friendly pupil-teacher interaction, were the hallmarks driving the success of this observed lesson.

4.4.1.3 Post lesson debriefing

At no single point during this lesson did Michael sit down. When presented with this observation Michael revealed that he had always managed his classroom in this way. Michael moved mostly from the outside perimeter, indicating that in this way he could view what was on the student's laptops. When asked as to account for why he was observed to continually roam the classroom, Michael suggested that:

I don't want to be standing over them because they're in their small chairs and I'd be leaning over them so yeah, I like to get down to eye level...I think that when you're teaching you've got to be with the person you are teaching...you know, not sitting up the front at a desk and stuff. So at least me coming around I can see what is going on...even if they weren't using computers I would still be going around looking at their work (Post-lesson debrief: 25/09/13).

In Michael's humble evaluation of the lesson he thought that his students were; *"On task most of the time. Some were focused too much on creation rather than planning the experiment...but I thought they were motivated by the task"* (Post lesson interview: 25/09/13). He recalled a particular group of girls who choose to use *iBook Author* for their final Project Moon Base presentation: *"They are going to give everyone on the panel*

an iPad...I really like the way they come up with different ideas for presenting things”
(Post lesson interview: 25/09/13).

Clearly Michael has a rapport with each of students, as evidenced by the smiling, appreciative nodding and on task behaviour witnessed throughout the entire lesson. Michael is delighted when the students reveal more divergent ideas excitedly recalling: *“One student was looking at the soil, the base, Engineering is what he wants to do and so he’s thinking about the foundation for this design on the Moon, no-one else was thinking that!” He’s considering the atmosphere and the soil and stuff I hadn’t even thought of that!”* (Post lesson interview: 25/09/13). However, he was also keen to point out that he felt that at times during this lesson he was overly directing the students: *“I noticed a few times I did say things and thought I shouldn’t have said that, they should have been able to work that out for themselves”* (Post-lesson debrief: 25/09/13).

Michael felt that instant access to a vast array of informative sources helped students to think more creatively. However, he was keen to point out: *“I had links, if they were stuck...but I would rather them find stuff, it’s an adventure...otherwise they all turn out the same sort of stuff from that”* (Post lesson interview: 25/09/13). When queried about the amount of time this must consume Michael was keen to point out that in preparing for this lesson the value of the *Moodle* page is that it serves as an ongoing adaptable repository of instructional materials:

The way I look at it is that I can re-do this same lesson some other time with slight modifications, so yeah there is preparation initially, but down the track it saves time and makes it more interesting...what is so great is you get to organise stuff...put it in somewhere in a labelled folder so I can pull it out whenever I want to do it again (Post lesson interview: 25/09/13).

Key finding 4.10 Alignment of lesson intentions to outcomes

The overall design of this lesson was in keeping with Michael’s stated beliefs of student-centered construction of science knowledge, where each group of students were to collaborate to derive a possible solution to a problem. Michael afforded his student’s freedom of choice in the final product design, which clearly created excitement amongst his students. Each student utilised his or her own laptop for almost

90 % of the lesson, engaging in collaborative inquiry for almost three quarter of this lesson, again in keeping with his views on active student uses of ICT. No ICT related issues, such as network failure or broken hyperlinks disrupted the flow of the lesson. Michael had curated all digital curriculum resources into his classroom *Moodle* page prior to this lesson enabling flexible student access to these curriculum resources.

4.4.2 Lesson two: Theme Year 10 science examination preparation

4.4.2.1 Pre-lesson interview

Michael explained that officially the Year 10s were winding up for the year and were about to undertake a two-hour Year 10 Science examination, so this lesson was part of a series of three revision lessons of the semester's content. Michael indicated that the key intention of this lesson was for the students to appreciate the need to revise for an upcoming exam. He wanted to demonstrate to students how to construct concept maps as a means of a revision strategy. Michael wanted the students to work collaboratively to produce a concept map of the key physics content to be tested in this examination claiming: *"In the real world you collaborate, you're not the sole expert. So, I'm trying to get them ready for the real world and the topic"* (Pre-lesson interview: 02/12/13). Again, his justification of the instructional organisation, i.e. group work, resonates with his social constructivist beliefs.

Firstly, Michael explained that the lesson would involve outlining the format and content requirements of the Year 10 science exam, for which he had also prepared a document and placed this already on the *Moodle page* for the students. He explained he would then follow this by modelling with the whole class how to create a chemistry mind map: *"I'm then going to capture it using my MIMIO and then I'll put the final product up on the Moodle page so they can access that later"* (Pre-lesson interview: 02/12/13). The key focus of this lesson was to involve the students working in small groups to create a physics mind map using a new software application called *Twiddla* (a free web based real-time collaborative whiteboard tool that enables co-browsing, file sharing and text mark up of documents).

Michael had found *Twiddla* whilst lurking the Internet over the weekend. His decision to choose this tool was mainly because it was freely available over the Internet and justified its use by explaining:

I wanted to try out this one because it was more collaborative, it's not designed for brainstorming, it's designed for collaboration. I wanted something simple. I didn't want them having to sign up for it... and get an account...they just log on...one person in the group starts the whiteboard...and then they have a web link, which is very simple, as they just give it to the other members, they put that in and then they can all log on. I just don't want them to have accounts and that. I want to keep it simple. Unfortunately, because it's free they don't have the save option but they can screen capture it...I don't want them mucking around with the technology, that's not the point (Pre-lesson interview: 02/12/13)

In choosing *Twiddla* over other digital tools Michael explained he did not want the technology itself to be the focus of the lesson, instead to focus on creating a useful mind or concept map as a revision tool. Michael also prepared several drill and practice video games relevant to the chemistry and physics concepts applicable to the Year 10 science examinations as a back-up (see Figure 4.8) using a free video game creation tool called *Class.tools.com*. Michael's extensive knowledge of the mandated curriculum again was demonstrated in the construction of these video games. Each game maps directly to the mandated Year 10 physics and chemistry curriculum learning outcomes where students are expected to understand “*the motion of objects using the laws of physics as they apply relationships between force, mass and acceleration to predict changes in the motion of objects*” and “*different types of chemical reactions are used to produce a range of products that can occur at different rates*” (ACARA: *Physical and Chemical Science*, 2015b). Furthermore, a range of other examination revision resources found on Michael's Moodle page also reveal direct alignment to the achievement standards as mandated by these curriculum documents. Again, further evidence supporting that curriculum requirements frame the selection of Michael's digital resources.

4.4.2.2 Lesson observation

Again, Michael had set up his laptop and connected this to the data projector and *MMIO* interactive whiteboard before the students had entered the classroom. Shortly after the students arrived they immediately begin to open their laptops logging onto the class

Moodle page. After gaining the students attention Michael directed the classroom discussion to the upcoming examinations. After realising many of the students were still navigating the *Moodle* page Michael politely requested, “*shut your laptops folks*” (Lesson two observation: 02/12/13) which they did immediately.

Michael explained that the next few lessons will involve revising intensely for this important Year 10 exam. As part of the student’s preparation he explained he wanted to introduce a revision technique called concept or mind mapping: “*The purpose of mind maps is to get your thoughts together, to have concepts linked to each other... not to just study things as isolated things but to see how they all relate to each other*” (Lesson two observation: 02/12/13). He explained that firstly, the whole class will attempt a chemistry mind map and then later in the lesson they will work in small groups to produce a physics mind map using a free online tool called *Twiddla*.

Michael then explained the key features of a mind map. He demonstrated a mind map on the *MMIO* using the context of the impending science examination to explain how to construct this mind map explaining:

It starts with a central idea, which is basically how our brains work, you take a central idea and then other ideas come off it...ideas branch out radiating from this central theme...it’s not about straight lines and dot points...but its more pictorial to enable you to see the links...then maybe you start to see other links...maybe you start to dot lines in to other ideas on your map (Lesson two observation: 02/12/13)

He then directed the whole class to a prepared document available via the *Moodle* page that summarised the key focus areas of the examinations well as its format. Calling the class to attention Michael requested at this point:

I don’t want anyone to have their laptops out at this stage, I don’t want anyone to have a pen in their hand, I want you to have your brains in gear so we can get this thing sorted out. The reason I don’t want you to write anything down is that we’ll capture whatever is on the board and I’ll put it on Moodle for you (Lesson two observation: 02 12/13).

Using the *MMIO* pen Michael wrote the word ‘chemistry’ on the white board and without much hesitation the students begin to call out key chemistry terms and concepts. However, the *MMIO* pen tool did not work, so without hesitation he changes to an ordinary white board marker telling the students he will use his *iPhone* to take a photo of the finished product. Michael then gently probed the students’ ideas as they called them out:

ST 1: Moles

ST 2: Ionic equations

ST 3: Reduction and oxidation

Teacher: I’m just writing this down onto the mind map then we are going to start putting in the links...anything else that we have covered?

ST 4: Atomic weight

ST 5: Reactivity of metals

Teacher: Yes. Ok, so what do you think is the central concept here?

ST 5: Redox reactions?

Teacher: Yes, ok (and then draws a bold branch from the central ‘chemistry’ term to redox reactions and then links this to metal reactions as well as ionic equations)

Teacher: Is there anything else related we could write up here?

ST 6: Number of moles equals mass divided by molar mass

Teacher: This is exactly what I was looking for! (He then draws a link on the mind map from Moles to Molar mass and writes the formula $n=m/M$)

Teacher: When we discussed chemical reactions, we used chemical equations. What can you tell me about that?

ST 7: Stoichiometry?

Teacher: Beautiful! That’s the word to do with relative amounts of reactants and products. In a chemical equation you have reactants on the left and products on the right?

ST 8: Mass is conserved.

Teacher: That's right! Remember Lavoisier, the guy whose wife did all the work and he took credit for it? So, recapping you've said stoichiometry, chemical reactions, conservation of mass, these terms are going to come up as well. (Michael then writes these terms onto the mind map and draws a branch linking this back to the central theme).

Teacher: Can you guys remember something that I said at every lesson about what must be the very first step of any calculation?

ST 7: Work out the number of moles of whatever you can

ST 9: Then ratios

Teacher: Brilliant! Thanks. After you have determined the ratio what's the next step?

ST 9: Then answer the question (Michael then summarises these three key points on the mind map) (Lesson two observation: 02/12/13)

After completing the class chemistry mind map shown in Figure 4.6. He then requested the students to open the class *Moodle* page to locate a link to a web tool called *Twiddla*. He explained that *Twiddla* is a free collaborative white boarding tool that can capture ideas, allowing you to add or erase anything you wish. Michael then logged on to the *Moodle* page opening the *Twiddla* hyperlink, projecting these steps onto the *MMIO* for the class to follow.

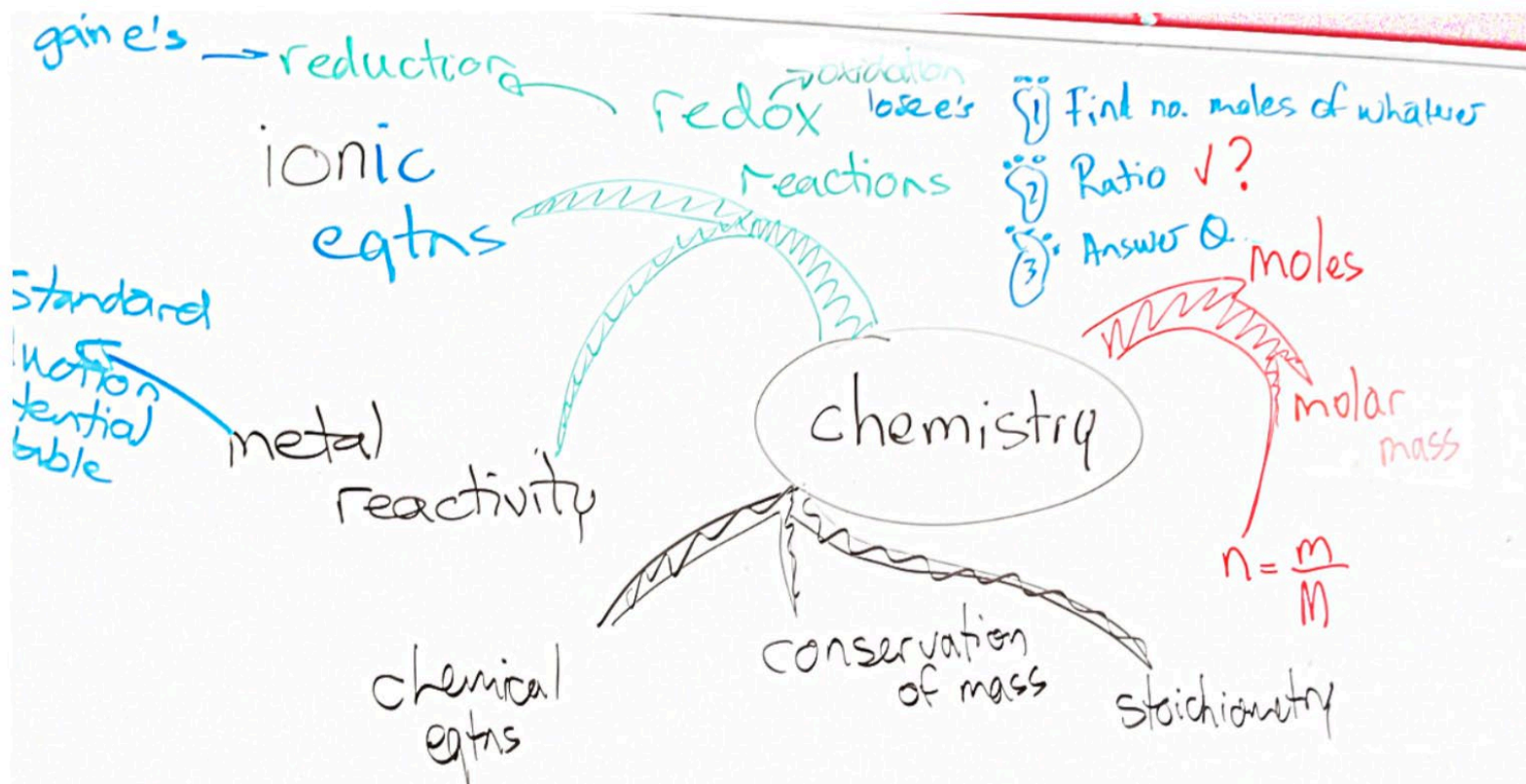


Figure 4.6: Chemistry mind map constructed by the whole class

Michael began to offer some tips on how to use *Twiddla*; however, most students at this time began to open the hyperlink and commence using *Twiddla* anyway. Michael sensed this and instead began to move in and out of each group ensuring they had launched the *Twiddla* tool. He noticed a group of students using different colours to describe their ideas and interrupted the class and called out some advice: “*Guys, this group is using a different coloured pen so each person can see immediately who has added something*” (Lesson two observation:02/12/13). However, after another five minutes students had begun to complain that *Twiddla* is not working for them, indicating that not everyone in the group could connect to the shared whiteboard canvas. He continued to circulate for another five minutes and noticed that several other groups were also having difficulty connecting to *Twiddla*. He then made the decision to abandon this activity switching instead to a whole class discussion of the key physics concepts,

Teacher: It was a good idea but I don't know that it's actually productive so if you want to capture what you've done use the screen capture...What I'm going to ask you to do is close your laptops and then were going to do a whole group exercise. I think the software was hindering what we were trying to do

ST1: It might have been better with pen and paper?

Teacher: I agree. We might have got a better product. So, well try something else. When I was walking around I did see Newtons Three Laws, I did see Scalars and Vectors, these are the main concepts. But nobody put down the Equations of Motion. Can you describe Newtons 1st Law?

ST2: Lazy – Inertia

Teacher: I agree, with a simple word like that, or you could have gone into a full-blown explanation term, either way would have done. What's a simple way you could describe Newtons 2nd Law

ST3: Force equals mass times acceleration = ma ?

Teacher: That's great. What about a way to describe his 3rd Law

ST4: Every action has an equal and opposite reaction

Teacher: That's correct, so these are very quick descriptions of these three laws. When we look at the equations of motion I would probably list them

all down. But even that is probably not enough for your revision and I think you would have to define each of those symbols and what they represent so I would show for example that S represents displacement. (Lesson two observation: 07/12/13)

In the remaining 15 minutes of this lesson Michael directed the students back to the class Moodle page where he suggested they now play the physics and chemistry revision video games (see Figure 4.7). Without being asked the students worked in pairs to play these games. In the last remaining five minutes of the lesson Michael drew the attention of the whole class by explaining some useful preparatory and revision advice, saying:

Now these weren't the most engaging games but I have said that when you are preparing for a test or examination the best thing to do is to do test or examination questions. I'll put some revisions sheets up on Moodle and I'll show you where these are in a sec. But the other thing that you do when you're preparing to develop any skill is you repeat it. If you are going to play a piece of music and you are performing it you will practice over and over, you won't just play it once and go that's good. The guy who won the golf on the weekend he didn't just play 18 holes of golf and that's it. He played 1000's of holes of golf to get his strokes down just right. Because what happens is you get this body memory where the muscles know what to do...muscle memory. The same thing happens in doing an examination or a test. If you're preparing for that and you practice and you repeat you'll get these skills built in. You'll sit down look at the question and know oh it's that type of question and this is how I answer it. You won't be under stress because you will be well prepared. What those little games, whilst not at a high level, showed that if you repeat over and over you can have that engraved into your brain so that you can remember it. One thing that people find with this repetition that if you just did it the night before the test you might remember it just for the test and that's it but if you keep repeating it over and over, and we've got a couple of weeks before the exam, and if

you keep doing a little bit every night it's going to stay in your memory. He refers to the student who answered very quickly on the subject of mass and says that is an example of someone repeating over and over and now it stays in your memory. So, you will need a lot of this stuff for Physics and Chem next Year so it's not just for this exam. (Lesson two observation:07/12/13)



Figure 4.7: Drill and practice examination game created by Michael

Using Stevenson's CHAT analytical tool (2008) to characterise the pedagogical activity structure of this ICT enabled lesson revealed that Michael spent 58% of this lesson engaging in dialogic teaching. However, this was largely done whilst working with the whole cohort by stimulating critical discussion to promote thinking around the key chemistry concepts learned over the semester. Michael spent 33% of this lesson using ICT himself, again directed at the whole class to co-construct a chemistry mind map. Unfortunately, the *MMIO* board failed to capture this class constructed mind map,

however, Michael took a photo using his *iPhone* and promised to upload this later to the *Moodle* site.

For 49% of this lesson the students worked collaboratively in small groups, using ICT where they were able to interact with one another both during the construction of a physics mind map using *Twiddla*, and then again when they played the online revision games. It should be noted that almost 18% of the ICT usage was consumed by the students attempts to co-create a physics conceptual map, however, this ICT tool failed to work. As a result, Michael abandoned its use and effortlessly moved his students on to some pre-prepared Chemistry and Physics revision games. Analysis of the remaining ICT usage revealed that 44% of the lesson time was consumed by the students exploring the suggested Internet games created by Michael. The remainder of ICT usage was directed by Michael himself (33%) where he worked with the whole class to co-construct a chemistry mind map using his *MMIO* whiteboard. This data is summarised in Table 4.2.

Table 4.2: Pedagogical activity structure of lesson two using Stevenson’s (2008) activity matrix

Classroom organisation mode	Percentage of lesson observed	Conversational roles	Percentage of lesson observed	ICT usage	Percentage of lesson observed
Teacher working with whole group (D1)	56	Teachers giving information to whole class (S1)	30	Teacher using ICT (T1)	33
Teachers working with small groups (D2)	0	Teachers directing questions and answers to reproduce facts (S2)	3	Learners using ICT in a collaborative task as initiated by teacher (T2)	49
Learners working in small groups (D3)	44	Teachers directing conversation (S3)	9	Learners using ICT in a collaborative task as initiated by themselves (T3)	0
Learners working individually (D4)	0	Teacher stimulating reflections or other critical analysis (S4)	58	Learners interacting via ICT as initiated by teacher (T4)	18*
Learners reporting or presenting own material to whole group (D5)	0	Learners directing conversations with peers (S5)	0	Learners interacting via ICT as initiated by themselves (T5)	0
				Learners creating using ICT (T6)	0

4.4.2.3 Post lesson debrief

Michael felt disappointed that *Twiddla* had not worked despite him testing it over the weekend: “*I tested it (MMIO & Twiddla) this morning and it was fine!*” (Post lesson interview: 02/12/13). Michael indicated that having his classroom *Moodle* page “*Was a bonus*” as it meant he always had contingency ICT activities prepared and even “*Well, sometimes you just go back to way we always did it-without ICT*” (Post lesson interview: 02/12/13). Michael felt that preparing his students for this examination had to be given a priority due the current importance of assessments in the overall ATAR ranking system: “*Unfortunately it’s going backwards, everyone now does the same syllabus, you can teach them differently...but the students want to get a percentage at the end, so they get a rank...I have to do four common assessments now with my Year 10s!*” (Post lesson interview: 02/12/13)

Clearly in this instance the goal of using ICT to co-construct mind maps as a revision tool failed; however, the lesson was far from a failure stating to the class, “*the software was hindering what we wanted to happen...we might have even got a better product with pen and paper*” (Lesson observation: 02/12/13). Michael effortlessly re-oriented the students to working on the prepared video revision games which had been preloaded onto the class *Moodle* page. Despite Michael’s extensive transformational preparation for this lesson Michael indicated that sometimes free online tools crash, hence having back up plans such as the video drill and practice games is always useful.

Key finding 4.11 Back up plans for technical failure

	Michael made extensive lesson preparation for this lesson, which included curating all the ICT materials and resources onto his <i>Moodle</i> page prior to the lesson commencement. Whilst the <i>MMIO</i> screen capturing tool and the <i>Twiddla</i> application failed to work, Michael’s extensive back up plans resulted in another smooth lesson where the students were on task. Michael’s willingness to abandon the use of ICT and switch to a more traditional whiteboard and pen method resonates with Michael’s views that ICT should not be the focus or goal of the lesson <i>per se</i> , instead ICT is to serve as a tool to get work done.
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As evidenced by the lesson observations detailed here, along with Michael's plethora of digital resources curated and personally created as shown on his *Moodle* page, *iTunesU* and *Podomatic* repositories demonstrates that the mandated curriculum plays the primary role in determining the rationale for the selection of ICT resources in these activities.

Meeting the curriculum learning goals is Michael's overarching goal stating:

So, there's a number of different ways I would approach it. Sometimes I will look at a science understanding or investigation skill and do some research on how are other people using ICTs to do this? So, I'll do some research around. So, in that case, it is the syllabus that drives me that allows me to select the ICT, which I'm going to use, which I think is going to be the most efficient mechanism for getting there. But then on other occasions... it will be I'll see a new tool and think, wow that is fantastic. What content area or investigations theory can I utilise this in? (Final interview:07/12/15)

Michael insists he enjoys lurking the Internet for new classroom digital innovations, which after investigation at home readily tries out in the classroom. Useful tools, along with tips on ICT integration are then freely shared with his colleagues via a school community *Scoop.it* site. During the final member checking interview Michael was asked to verify the key findings emerging from this analysis, including being asked to represent the key reasoning steps involved in creating the lessons that were observed. Michael found this somewhat challenging to do. To assist in representing his general reasoning process Michael was asked to draw a flow diagram for these ICT mediated activities. A re-representation of Michael's ICT pedagogical reasoning process is shown in Figure 4.7

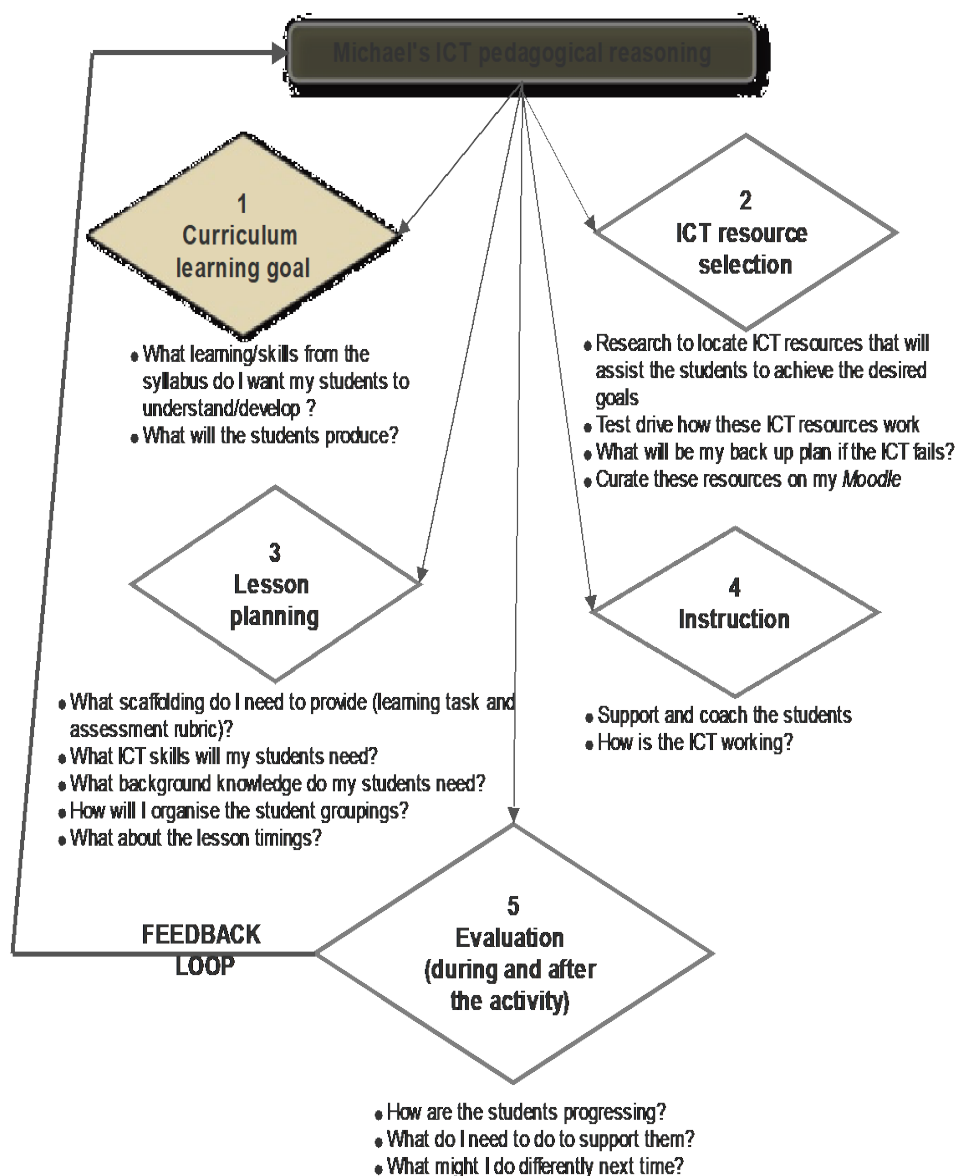


Figure 4.8: Michael's ICT pedagogical reasoning process and actions

4.5 Chapter summary

An overall whole-to-part recursive analysis of Michael's data sources revealed several key emerging themes of Michael's pedagogical decision-making process for the purposes for which ICT was used to engage students' interest, choice of teaching strategies and ways by which students demonstrate their learning. Michael espouses an

overall social constructivist approach to science teaching and learning (see Key Findings (KF) 4.3, 4.4) where the ultimate learning goals include fostering lifelong critical and creative thinking and collaboration skills; however, this is framed using the mandated science curriculum as the context to drive these lifelong skills. In other words, the curriculum becomes the context that drives the use for ICT in Michael's classroom (see KF 4.5). ICT is used primarily to mimic the technology rich environment of the students' lives. Furthermore, Michael positions ICT as a tool for student exploration of concepts and communication of understandings (see KF 4.3 & 4.4).

In preparing for his lessons Michael spends lots of his personal time to filter, curate and create a huge array of digital learning resources for his students placing these onto his *Moodle* page as well as onto his other social media repositories such as *Podomatic*, *iTunesU* and *YouTube* (see KF 4.5, 4.6 & 4.7). Michael practices demonstrate that he uses ICT to offer learning activities that transform the learning environment (see KF 4.9). His ICT resources include a rich array of multimodal learning opportunities, such as videos, games, simulations, and virtual experiments many of which have been custom made for his student cohort (see KF 4.5, 4.6). He reasons that as the students have one-to-one access they can flexibly engage with these curriculum materials at any time from any place (see KF 4.5, 4.7).

In preparing for his lessons Michael also creates learning task briefs and assessment rubrics, or learning scaffolds to guide the quality of student work in these activities (see KF 4.5). Michael only selects those ICT tools that are free and do not have complicated extensive registration requirements or passwords (See KF 4.7). If ICT is used, it is chosen because fundamentally because it allows the students relative advantage over traditional non-ICT resources (see KF 4.5 & 4.6). Again, these learning scaffolds are placed on Michael's classroom *Moodle* page enabling re-use (see KF 4.7 & 4.10).

As was observed, the extensive transformational lesson preparation left Michael ample lesson time to guide his students and to engage in dialogic teaching to promote discussion and higher order thinking about the work that is to be done (see KF 4.9). Michael engages in dynamic, or in the moment evaluation of how the lesson is proceeding and will abandon the use of ICT if this impedes the flow of the activity (see KF 4.11). Students in Michael's classroom are free to work in groups to create various ICT products where Michael's *Moodle* page was the initial launch pad for each learning activity observed (see KF 4.7 & 4.9). Whilst Michael offers a wide array of pre-selected

tools his practices indicate he encourages students to explore the Internet further. Michael perceives his role in the classroom as a knowledge broker and orchestrator of the learning environment. Students are the key users of ICT in the classroom not Michael (see KF 4.3, 4.9 & 4.10).

CHAPTER FIVE: The case of Ruby

This Chapter presents the second of three case studies. The case study teacher presented in this Chapter is referred to by the pseudonym Ruby to maintain anonymity. Ruby teaches at the same school as Michael; however, she teaches in the middle school (Years 8-9). Overall this Chapter provides a descriptive and interpretive account of Ruby's beliefs in relation to ICT, and how she pedagogically reasons and creates the learning environment to provide meaningful technology enabled learning experiences in a one-to-one student laptop environment. The Chapter begins by presenting the contextual factors pertinent to Ruby, as well as an account of her professional profile, beliefs and pedagogical outlook which is followed by an analysis of observations from three lessons. A range of data was gathered to address the study's key research foci, that is:

- Why does Ruby act as she does with ICT in her classroom?
- How does Ruby decide what instructional strategies and representations and learning tasks to employ when students have one-to-one laptop access in her classroom?
- What does Ruby do to create a learning environment conducive to student learning with ICT?
- How did Ruby implement her instructional plan during the lessons that were observed?

The data included: face-to-face interviews; video-recorded lesson observations; school planning documents; teacher planning artefacts; lesson observation notes; email exchanges, as well as a record of the array of software and digital learning resources that Ruby and her students accessed during the lesson observations. The contextual information presented at the beginning of this case study is relevant to the middle school and was mostly solicited from the participant during the initial teacher interview conducted at the commencement of this study.

5.1 Data sources and analysis

An initial informal meeting lasting around 40-minutes took place at the University campus and used to get acquainted, build rapport and discuss the key purpose of the

study. This meeting was followed by an onsite school scoping visit to determine the best possible video viewing position during the study. A few weeks later a semistructured audio recorded interview lasting around 60 minutes, was conducted at Ruby's school to elicit information regarding her teaching background, pedagogical orientations, beliefs, and practices surrounding ICT for teaching and learning science.

To illuminate the pedagogical reasoning process employed by this teacher in planning for and reflecting upon the lessons observed, pre- and post-lesson interviews were conducted on site. For all interviews conducted with Ruby, sets of semistructured interview questions were emailed approximately one-week prior and as with all interviews conducted in this study, the interviews were transcribed verbatim. A final member checking interview, lasting around 60-minutes was used to corroborate the emerging themes in Ruby's ICT pedagogical reasoning and practices. During this final interview Ruby was asked to represent her general reasoning process graphically to illustrate her reasoning process and delivery of meaningful technology enabled learning experiences.

Ongoing and iterative inductive analysis commenced in parallel with data collection. The Researchers' extensive field notes and memos were also analysed to enhance the internal validity of the analysis. The analysis of the interview data was initially guided by the theoretical components shown in Table 3.1 using a whole-to-part recursive micro-ethnographic analysis strategy to characterise the pedagogical activity for each of the recorded lessons. At a holistic level, importance was given to the types of communities that were formed, the roles of the participants (teacher, student) and the role of ICT during the lesson, norms, and conventions of interaction, technical rules, and evidence of student activity to characterise the entire lesson activity. Attention was directed to the role of the teacher during these lessons, in other words, how did the teacher create or transform the lesson into an outcome using ICT?

At the micro level, each lesson was systematically coded on a minute by minute basis using a pedagogical activity matrix which has already been articulated in Chapter 3 and summarised in Table 3.3. This data analysis strategy enabled the Researcher to decompose the actions and operations observed in each lesson to assist in the identification of how Ruby organised her students (e.g. whole group, group work, paired work, individual), the functionality of the ICT tool used, as well as help to characterise

the role of the relationships that were observed between the teacher and the student (e.g. lecture, questioning, summarising) that shaped the activity of the lesson.

5.2 Professional profile and context

5.2.1 Professional experience

At the time of this study Ruby had been teaching middle school general science for six years having qualified 14 years ago with a Bachelor of Education as a middle school specialist. As she explained: “*Given I qualified with a middle school education degree I am teaching science in a more integrated way...I feel that this perspective informs my science teaching better...I have a more holistic view*” (Pre-lesson sequence interview: 12/09/13). At the time of this study Ruby was teaching Year 8 students in a dedicated middle school environment in a government metropolitan secondary school in Perth, Western Australia; the same school as Michael. This was her second year at this school. Like Michael, Ruby is also a qualified *Level 3 Classroom Teacher*, a status that recognises her exemplary teaching practices across all three domains of the AITSL Professional Standards for Teachers. As part of the 0.1 full time allowance of time allocated to this Level 3 status, Ruby was at the time of this study responsible for developing a brand-new subject for the entire Year 8 middle school cohort called Integrated Studies, a project-based subject.

Key finding 5.1 Professional teaching experience

Ruby is a middle school science specialist with 14 years of experience and is identified as a *Level 3 Classroom Teacher*, a status that recognises her exemplary teaching practice across all three domains of the AITSL Professional Standards for Teachers. As part of her Level 3 Leadership role Ruby was responsible for developing a new curriculum subject for the Middle School where she works called Integrated Studies, a cross-curricula project-based subject.

5.2.2 *School Context*

Ruby teaches at the same school as Michael, in a building dedicated to Year 8-9 middle school students. This building comprises several wings housing the Year 8 and 9 learning communities. In keeping with the middle school philosophy, a team of middle school specialist teachers, led by team leaders for each year group, are responsible for teaching either Year 8 or Year 9. According to Ruby, team teaching and team planning results in, *“a certain level of uniformity and equity”* (Initial teacher interview: 12/09/13). As a dedicated middle school science teacher Ruby is currently responsible for teaching general science to 120 Year 8 students. Ruby believes that the middle school teaching and learning philosophy of integrated and negotiated curriculum, building independence and a sense of identity is something that, *“I actually believe quite passionately that I can meet my students needs more effectively in that model”* (Final interview: 12/09/16).

5.2.3 *Curriculum context*

Ruby uses the mandated science curriculum framework which is set by the School’s Curriculum and Standards Authority for Western Australia (SCASA) as the basis for planning her teaching, learning and assessment materials in middle school which contains only minor variations from *Australian Curriculum: Science* (ACARA, 2015b). This prescribed science curriculum also offers Ruby guiding principles for teaching and learning, as well a range of support materials for ensuring consistency and comparability for the reporting of student achievement.

Ruby was keen to point out that the team planning approach common to the middle school model somewhat constrained her ability to use ICT, pointing out that other teachers in her team were not as keen as herself to explore the affordances of ICT for learning. This was also further constrained by a middle school requirement to conduct several common assessments items explaining:

Everybody sits the same test. I understand that their needs to be some uniformity but I just don’t think we need to have 100% all the time. I quite strongly believe that boys don’t write about things but they will tell you about it in conversations....they know way more than they write....so I get

them to a do vodcast...I get them to film their experiments and talk about it...that way you can actually see who is understanding the concept and who's got a better grasp of it rather than a bit of paper...I really would like to use ICT more as an assessment tool because I think it appeals to that multiple intelligence approach...I mean why can't we get kids to create video blogs?...but you know you are constrained by your environment
(Final interview: 09/12/16).

Science is timetabled as a standalone subject in this middle school and is offered for four periods of one-hour duration per week, much like it is in most traditional secondary schools in WA. Within each learning community, science classes are arranged around whether the student has been selected for one of the specialists Gifted and Talented Education (GATE) Languages, Visual Art, or Music programs. The students are further differentiated in middle school into either academic extension programs (AEP) or mainstream pathways for science. At the time of the study Ruby taught three classes of mainstream science and one class of science to academic extension students. Four of Ruby's students in the mainstream classes required the assistance of an educational support aide, although the lesson observations that were undertaken did not feature any of these students. Furthermore, the lessons that were observed featured Ruby's mainstream classes.

Because of Ruby's *Level 3 classroom status* and her skills with ICT Ruby had recently been tasked with designing a new middle school subject called Integrated Studies. At the time of this study this was its first year of delivery. According to Ruby, the key aim of this new subject was to:

Build a community...develop a common language...and allow students to negotiate their world a little...and the idea is that it brings all four core subjects through a context. So, this term there is a competition focus. The kids get to pick, each competition is worth points based on effort...and they must accrue 15 points, so they can actually work to their strengths, so the arty kids are doing posters for the Water Corporation and we have kids taking photos for the digital photography competition and I'm now trying

to get kids through the 60-second science competition (Initial teacher interview:12/09/13).

Key finding 5.2 Middle school curriculum planning context

Ruby uses the state mandated science curriculum as the basis to plan and design her teaching, learning and assessment resources for her middle school science classes. Middle school team planning requirements necessitated several common assessment tasks were to occur each term. Ruby felt this restricted her use ICT for learning, teaching, especially in regards to assessment. Ruby is however, able to offer her students agency in being able to negotiate curriculum during a new weekly subject called Integrated Studies, a largely project oriented subject.

5.2.4 Middle school ICT environment

The School's ICT environment has been previously described in Michael's case study. However, the key difference in the middle school is that the students did not have one-to-one take home laptop access. Instead 32 *MacBook Air* (13 inch) laptops were available for Year 8 use on a booking system. Ruby indicated that there was rarely an issue with gaining access to these laptops, and that she was in fact the predominant user of them in the middle school; although in booking them Ruby indicated she ensured that the laptops were utilised throughout the entire lesson.

During project-based work Ruby found the in-class borrowing system counterproductive in that some students used different types of software applications at home which were sometimes not available via the school server. In preference, having their own device would mean continuity of project work in and out of the classroom. Ruby's workaround solution was to have students show screen shots of project work conducted at home which then necessitated these students then work on other science related activities during class time. Ruby indicated that most of her students had access to computers at home or owned a smart device.

Each middle school classroom was equipped with a *MMIO* IWB and data projector. Ruby indicated that a robust wireless network was available at the School at the

time of the study. Ruby herself uses a *MacBook Air* (15 inch) laptop which she leases through the Department of Education.

Key finding 5.3 Middle school ICT context

The ICT infrastructure in the middle school at the time of data collection offered reliable networked technologies. *MacBook Air* (13 inch) lap tops were available for student use in the classroom on a one-to-one basis via a booking system. Gaining classroom access to these laptops was unproblematic. For continuity of project-based classwork Ruby's preference would be for one-to-one laptop take home access. Most Ruby's students had access to a computer or smart device outside of the classroom.

5.3 Ruby's beliefs, values, and pedagogical outlook

Ruby explains that if she were to characterise her approach to teaching science it would be:

Teaching science in an integrated way...what is really important to me is the moral implications of science...that kind of focus that allows me to instil in the kids that you need to be making informed choices about your life and you need to see both sides of the argument...my goal is to have my kids make informed decisions about their lives (Initial teacher interview:12/09/13).


The biological metaphor of 'producer' versus 'consumer' came up several times throughout this study with Ruby keen to point out that she encouraged her students to be contributors to the global knowledge base rather than simply downloading information. Ruby believes that effective teaching with technology involves helping students to develop lifelong learning skills:

I don't just mean self-management skills to be able to navigate through a set of learning tasks, but have independence of thought about what they are doing...being a sophisticated consumer of digital media ...skills to decode

what's happening in their life everywhere...I just want my kids to be sophisticated consumers and users of their world and the content that forms that (Final interview: 09/12/16).

According to Ruby, students should learn science by engaging with lots of hand-on as well as virtual inquiry opportunities about the natural world. Enabled by one-to-one laptop access, Ruby explained that she had been getting her students involved in a variety of citizen science projects in the classroom and insists that: *“I would like to think that from kids spending time with me they go with this global perspective We are all citizens”* (Initial teacher interview:12/09/13). Citizen science projects typically involve students collecting data for real world community science projects then uploading this data via ICT to a database. In doing so students gain experience from trained scientists in data collection, inquiry methods and problem solving. The partnership generates vast quantities of data thus accelerating the science project. Ruby actively promotes participation in citizen projects, as evidenced by a flyer she had created as shown in Figure 5.1. Notably Ruby allows her students full agency over the citizen science projects students choose to get involved in.

CITIZEN SCIENCE



WHAT'S IT ALL ABOUT?

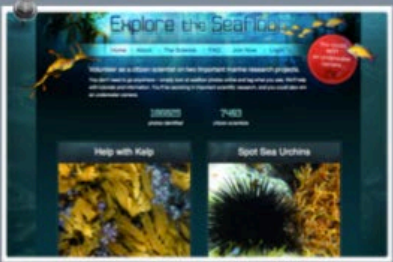
You don't have to work in a **laboratory** or wear a **white coat** to be a **scientist**. In fact, you don't even have to have any **formal training**. You can get involved in the scientific process **every day** by participating in **citizen science**, a movement in which volunteers (like you) are helping **professional scientists** collect and analyse data from all around the globe.

Just think, you could even start a **local** citizen science program to collect and analyse data of particular interest to your community. If it's **important** to you, it's probably important to somebody else. **We can all make a difference** and we can all be citizen scientists!

Take a look at some of the **exciting** projects below:

EXPLORE THE SEAFLOOR


Simply look at seafloor photos online and tag what you see!



<http://exploretheseafloor.net.au>

AGENT EXOPLANET

Study known exoplanets by measuring the brightness of stars!



<http://lcogt.net/agentexoplanet/>

Figure 5.1: An exemplar of a citizen science project brief created by Ruby

Ruby stated that her use of ICT in the science classroom was primarily as an engagement tool, *“to show them that I’m meeting them in their world...this generation of kids have never known what the world was like without the Internet and without technology...it’s about capturing their interest”* (Final interview: 09/12/16). She felt continually motivated to integrate ICT into her curriculum which stemmed from her belief in the need to stay relevant stating: *“You need to stay current with your kids, they need to see that you are invested in their world by being interested in the things that they are interested in, like social media”* (Initial teacher interview: 12/09/13). For Ruby, the role of ICT in her classroom was ultimately:

Front and centre...it’s like the spine or backbone...I don’t think the connections between what they are learning and the meaning the kids are creating for themselves can be as deep...to have them manipulate something online, an interactive...as opposed to getting them to read a book, there’s just no comparison (Final interview: 09/12/16).

Ruby was keen to point out that with one-to-one laptop availability in her classroom meant, *“there is nothing I can talk to them about that they can’t research for themselves or will come up in Google in one fifth of a second”*. (Initial teacher interview: 12/09/13). Given ubiquitous access to information now a leading feature of her classroom environment, remaining relevant in the classroom requires that she forms learning partnerships with her students. Explaining that she maintains her relevance by, *“infusing the human element into what we are doing...having individual conversations about the ethics of what we’re doing...the stuff that sits alongside the content knowledge”* (Final interview: 09/12/16). Ruby also emphasised the value of reciprocity in building learning partnerships with her students.

Ruby suggested that fundamental to cultivating genuine learning partnerships was, *“purposefully trying to create a safe learning environment...where they can ask me random questions about anything...crazy stuff...where they can feel some success and then once you’ve got them to a point... they are happy to take some risks”* (Initial teacher interview: 12/09/13). Reinforcing that notion of learning partnerships, Ruby mentioned several times throughout this study that her own technological skills continue to evolve in partnership with her students, *“often they are tech experts in the room...they drag me*

along for the ride! “(Initial teacher interview: 12/09/13). Ruby described that “*for me its continual on the job training. I’m getting PD on how to master these tools in the way the students use them...it’s that reinforcing on that much deeper level that this is a partnership and it’s not just me being the font of all knowledge*” (Final interview: 09/12/16).

Key finding 5.4 Views on teaching and learning science

Ruby’s views on learning align with a social constructivist perspective, where students are positioned as active producers of scientific understandings rather than consumers of information. Ruby promotes the development of lifelong decision-making skills along with the ethical understandings of how scientific knowledge is appropriated. She provides a learning environment where the discovery of knowledge takes place through the cultivation of learning partnerships. She promotes active citizenship by fostering participation in global citizen science projects.

Ruby was keen to assert that ICT must serve a genuine purpose in her classroom. In using technology for almost every science lesson Ruby was keen to point out she is a considered user of technology in the classroom:

I am passionate about using ICT but not for ICT’s sake, it needs to enhance, it needs to provide scaffolding, it needs to enrich their understanding or be a way to communicate their findings. It must be able to do one of those things and if it can’t, then I don’t use it; and if it can do all of those things, then it’s a brilliant resource. You have to be discerning...at the moment there is not that high level of discernment with the things we use, instead we go ‘pooh’ technology but we need to apply the same high standards to these digital devices and tools...I am very conscious of the fact that the ICT I use can stand up to a range of criticisms (Initial teacher interview: 12/09/13).

Student use of ICT in the classroom is more important than her own, indicating that part of Ruby's rationale for its use is also about, *"personalising the process of learning...the kids will make meaning of things in different ways because of their own experiences...and so for me standing up there manipulating content for them while we are all doing it together...well I don't see that as efficient or an effective way"* (Final teacher interview: 09/12/16). Furthermore, in being able to use networked technologies Ruby believes that students are afforded tremendous opportunities to, *"expand their personal learning networks"* (Final interview: 09/12/16). Ruby prefers to establish a collegial classroom environment explaining that she favours group or paired work as it leads to risk taking, peer tutoring and the potential for innovation. Importantly for her, *"the other students in the room are not in competition, they are people you can draw on, this is about collective knowledge sourcing and you can use their strengths to help you"* (Initial teacher interview: 12/09/13).

To this end Ruby does not define where students sit or with whom they work with insisting that, *"a lot of their day is restricted and defined at school...they are told when to eat and when they can go to the toilet. If they can have some freedom of choice about where they sit and who they work with I think that goes a long way in this partnership"* (Final interview: 09/12/16). Furthermore, Ruby was adamant that:

Innovation comes from more than one person, so a student can have a great idea, you put two things together and you just create this explosion of things...even if it's not a true meeting of the minds, there can be that crystallisation of their own thought processes when you are having to verbalise to someone else...so working in groups is practicing communicating and we know that communicating in science is a big thing (Final interview: 12/12/16).

Ruby had been recently exploring the affordances of vodcasting or vlogging as it is sometimes known, as an alternative to formal written science laboratory reports. Ruby was using this new multimedia approach as a type of assessment strategy to determine students' understanding of science inquiry skills, and as a strategy to be more inclusive of the boys in her classroom. A vodcast enables the creator to add images, graphics, video, and animations over an audio track. Ruby indicated that given her students' age and

developing ICT capability, she produces ICT reference guides when she introduces new ICT tools to her classroom; in this instance, a science vodcasting reference guide. In tandem with promoting vodcasting at the time of this study, Ruby had established a dedicated *YouTube* channel to display her students vodcasting creations. Ruby stated: *“I say to them, you can contribute to this global knowledge data base or you can just keep it for me and my records...I tend to upload kids projects a lot “* (Initial teacher interview: 12/09/13). Ruby indicated that her *YouTube* channel also served as a repository of student work, *“I keep these items for my records so when we go through and moderate I can show people evidence they have done this”* (Final teacher interview: 12/12/16).

Whilst Ruby defines the work to be done she does not distinctly define the type of product that is to be submitted. Instead allowing students, some of whom are Gifted and Talented, to create different types of multimedia products to represent their learning. Ruby believes that students are to be offered agency in how they represent their scientific understandings. She indicated that the vast and evolving array of multimedia tools made possible by ICT helped encouraged an environment of imagination and creativity. Ruby states that, *“there’s a fine line between scaffolding but also being restrictive and I think I find a lot more with Gifted and Talented students that sometimes you can put the reins on them by closing down too many parameters”* (Final interview:12/12/16).

Key finding 5.5 Views on role of ICT for learning science

Ruby sees ICT as a ubiquitous and natural part of a student’s world and this underpins much of the rationale for using ICT in her classroom. Ruby situates one-to-one ICT access as fundamental to her science classroom learning environment. Student use of ICT in Ruby’s classroom is more important than her own. Its role is primarily for engagement and to leverage the educational affordances of ICT to provide students with rich multimodal opportunities, such as videos, simulations, and games. Ruby promotes the use of ICT for students to create and communicate personal understandings encouraging them to be creative in their use of multimedia authoring tools. She uses ICT to extend learning outside of the classroom so students have opportunities to expand connection to other world views and to get involved in solving authentic real-world problems e.g., global citizen science projects. Ruby asserts that

ICT must be purposefully directed in order that its use may serve to support students in personalising their learning experience.

Unlike Michael, Ruby did not utilise the school's VLE or *Moodle*. Instead Ruby was sanctioned by the School's executive to utilise her own classroom website called *Miss.Ruby.com* which she created several years ago, whilst teaching at another school. In keeping with her philosophy that knowledge should be shared, Ruby's website is not password protected. Ruby indicated that she views her website as a virtual classroom, primarily serving as a repository of her classroom curriculum resources. The website is a content management system (CMS) which Ruby indicated she uses as a launching pad for most of her classroom lessons. Ruby's website is not a true learning management system (LMS) *per se* unlike the School's *Moodle*.

Ruby pays for the hosting of this website on a server that sits outside of the school's platform along with the domain registration. Whilst rare, Ruby indicated that this was useful, as if the School server was ever down, students still had the ability to access her website resources, for example from home or from a smartphone. The landing page of Ruby's website serves as a bulletin board for key pertinent classroom information (unit plans, news section, assessment outlines, study skills guides, text book information, competition details etc.) and its design and layout are shown in Figure 5.2. Ruby also willingly reveals her classroom philosophy on this landing page indicating that whilst this landing page serves primarily as a communication tool for her students, her website also serves as a communication tool with parents and the rest of the school community: "*I like them to know what we are doing, they can jump on the web now and see exactly what we are doing in class which for me is worth gold.*" (Initial teacher interview: 12/09/13).

Ruby stated in selecting resources for her website that she, "*constantly casts my net out on the Internet...I consider it like deep sea fishing, it's a labyrinth of things...you come across things and go, oh that's really cool!*" (Initial teacher interview: 12/09/13). However, she was also keen to qualify that:

I can't say anything on my website is completely original, that is why it is not password protected or anything...it goes against anything we do anyway...we are all magpies by nature, teachers pick up bits and pieces everywhere...you know we need to be having open discussions about our

subject...you put things out there. I think the profession will suffer if we start saying this is mine and I think that goes against the scientific philosophy as well, you know we should put things out there, lets contribute to the global thing (Initial teacher interview: 12/09/13).



Figure 5.2: Landing page of *Miss.Ruby.com* classroom website

Ruby's website contains a vast amount of digital teaching and learning resources which have been organised and classified using a navigational menu across the top of the landing page. Ruby has used the four science content areas of the (ACARA, 2015a) as the

primary parent folders to organise these digital resources, that is: Biological, Chemical, Physical and Earth and Space Sciences. There is also a fifth parent menu folder called Robotics, which holds resources pertaining to a new science club she was establishing at the School at the time of this study. In reviewing the resources curated on Ruby's website these correlate to the content and achievement standards stipulated in the mandated science curriculum. This confluence is exemplified using a unit of work Ruby created for the chemistry requirements of the mandated science curriculum and is shown in Figure 5.3. Here the scope of the content in this unit of work shows clear alignment as stipulated in the mandated curriculum for Year 8 chemistry and to the stated learning outcomes shown as follows:

- **Chemical Sciences (ACSSU151):** The properties of the different states of matter can be explained in terms of the motion and arrangement of particles
- **Chemical Sciences (ACSSU225):** Chemical change involves substances reacting to form new substances
- **Chemical Sciences (ACSSU152):** Differences between elements, compounds and mixtures can be described at a particle level (ACARA, 2015a)

Furthermore, Ruby had also integrated science investigation into this unit of work.

Approx. Timing (W)	Curriculum Focus	Skills, Knowledge, Understanding	Suggested Texts/ Resources	Assessment
1	Elements & The Periodic Table ACSSU152 ACSHE134	<ul style="list-style-type: none"> State that matter can be classified into pure and impure substances. Define an element as a pure substance that is made up of one type of particle. Recall that some elements are naturally occurring and others are not. Understand that each element has unique characteristics called properties that can be grouped as either physical properties or chemical properties. Understand that all known elements are displayed in the periodic table. Locate common elements on the periodic table and that groups of elements share the same properties. Correctly write the chemical symbols of the first 20 elements in the periodic table as well as commonly known metals and non-metals i.e. manganese, iron, nickel, copper, zinc, lead, silver, tungsten, gold, mercury, tin, bromine, iodine, barium, uranium. 	PS7.1	Changes of State Lab (10%)
2	Metals & Non-metals ACSSU152	<ul style="list-style-type: none"> Elements can be classified into metallic and non-metallic elements. Given a Periodic table, draw a line to distinguish between metals and non-metals. Describe the main properties of metals – shiny, high melting point, solid at room temperature (except Hg), malleable, good thermal & electrical conductors. Describe the main properties of non-metals – dull, low melting point, most exist as liquids & gases at room temp, brittle, poor conductors of heat & electricity. Recognise that metals are denser than non-metals. Link the property of a metal to its main use. 	PS7.1	
3	Molecules & Compounds ACSSU152	<ul style="list-style-type: none"> Define a molecule as the smallest unit of a substance where two or more particles (atoms) are combined. Recall some elements exist as single particles (atoms) and others as diatomic molecules. Define a compound as a substance where two or more elements are chemically combined in a fixed ratio Know the formula of common substances, including H₂O, NaCl, CO₂, O₂. Using the formula of a compound, identify the number & type of elements in the compound. Understand that compounds have unique properties that are different from the properties of the elements they are formed from. Recognise that compound names are based on the names of the elements they contain. 	PS7.2	
4	Physical changes ACSSU225	<ul style="list-style-type: none"> Define a physical change as a change where no new substances are formed. Understand that physical changes may be a change in state, shape, or mixing of substances together. Physical changes are often reversible. Dissolving and melting are examples of a physical change. 	PS6.2	
5	Chemical changes ACSSU225 ACSI141 ACSI145 ACSI146	<ul style="list-style-type: none"> Describe chemical change in terms of atoms of molecules rearranging to form a different combination of atoms – resulting in the formation of new substance. Chemical changes can be detected by colour change, presence of bubbles, precipitate, & energy in terms of heat/light. Chemical change is associated with production or absorption of energy. Observe different examples of chemical change. 	PS6.4	Chemistry investigation (12.5%)
6	Simple reactions ACSSU225	<ul style="list-style-type: none"> Know examples of chemical changes in everyday life. Produce gases through simple reactions in the lab and use standard tests to identify these gases – hydrogen, oxygen and carbon dioxide. 	PS6.4	
7	Impact of chemical properties on substances ACSSU225	<ul style="list-style-type: none"> Corrosion is a chemical reaction in which a metal reacts with oxygen. Rusting is the name given to the corrosion of iron. List ways in which rusting can be prevented – keep away from moisture; apply oil as an insulating layer & paint metallic surface. Flammability is how easily something will burn or ignite, causing fire or combustion. Flammable substances are those gases, liquids and solids that will ignite and continue to burn in air if exposed to a source of ignition. Substances are grouped, as either flammable or combustible by their flashpoints. Flammable liquids will ignite and burn easily at normal working temperatures. Combustible liquids have the ability to burn at temperatures that are usually above working temperatures. 	PS6.4	

Figure 5.3: Exemplar of Ruby’s Year 8 Chemical Science Unit outline

To assist her students in navigating to the digital resources she had curated on her website Ruby chose to categorise them according to the science topic classifications as shown on her unit of work outlines (see Figure 5.3). Again, using Ruby’s Year 8 chemistry unit of work shown in Figure 5.4, the digital resources curated to her website related directly to the unit’s topic descriptions such as: Elements and Molecules; States of Matter; Compounds; Physical Changes etc. Many of the digital resources that Ruby curates are interactive, including a plethora of simulations, games, tutorials, and revision

tools that would support self-directed learning. Ruby stated that, “*philosophically there is nothing on the website that I can claim to be exclusive intellectual property...these are resources I’ve seen and sometimes modified or I’ve attributed in other places*” (Final interview: 09/12/16). In addition, Ruby also uploads her learning task descriptions, classroom presentations (created in *Keynote*) along with her laboratory activities, assessment rubrics and classroom worksheets. Ruby proudly claimed that at the time of this study her website analytics revealed over 10 000 hits and was being accessed as far away as South Africa and Bangladesh.

Chemical Science Year 8 Chemical Extension

Home Biological Chemical Physical Earth & Space Robotics

Below I have listed all of the resources you will need to study Chemical Science in middle school.

White resources - worksheets.
 Orange resources - keynote presentations.
 Yellow resources - reading materials like textbook chapters.
 Red resources - GATE enrichment activities.
 Other coloured resources - links to interactive websites, games and multimedia sites.

+ Elements & Molecules

- W Elements & compounds ppt.
- W Chemical Science workbook
- W Molecules in motion
- W Element symbols
- W The Gold Dust Kid
- W It's Elemental!
- W Alchemy and chemical symbols
- W Elements revision sheet
- W SpELEMENTS
- W Element Jumbo Crossword
- W Samples of elements practical
- W Element wanted poster
- W Alchemy turning lead into gold
- W Fakebook elements
- W Offline fakebook colouring
- Building blocks of matter Q&A
- Elements Q&A
- Play the new periodic table song
- If molecules were people!

+ The Periodic Table

- W The Periodic Table ppt.
- W The Periodic Table note taking frame

+ States of Matter

- W Chemical science vocabulary list
- W States of matter webquest
- W Particle Theory of Matter ppt.
- W Properties of solids, liquids, gases
- W Particles of matter
- W Phase changes worksheet
- W Dry ice observation experiment
- W Balloon experiment
- W Changes of state experiment
- W Changes of state worksheet
- W Condensation and Evaporation
- W Disordered hyperuniformity
- Solids, liquids & gases Q&A
- Click to access a states of matter interactive
- Chemical mix up revision game

+ Physical Changes

- W Physical & Chemical changes ppt.
- W Analysing physical change
- W Chemistry vocabulary sheet
- W Chemistry revision cut & paste
- W Physical & chemical virtual lab sheet

+ Compounds

- W Compounds ppt.
- W Naming Compounds
- W 50 ways to name compounds
- W Hanging together
- W Drawing compounds
- W Elements and compounds
- W Compounds & mixtures webquest
- W Naming compounds info
- W Making compounds interactive
- Elements & compounds Q&A
- Compounds Q&A
- Play GoREACT to learn about elements
- The first 10 elements song!
- Try fusing or separating elements

+ Chemical Changes

- W Simple chemical reactions ppt
- W Detecting chemical change
- W Energy change in endothermic reactions
- W Reactants & products
- W Chemical reactions
- W Making reactions go faster or slower
- W Production of Hydrogen Investigation

Figure 5.4: Exemplar of *Miss.Ruby.com* Year 8 Chemical Science resources

Ruby indicated that technology is used by her students in almost every lesson. This involves designing task briefs including an assessment rubric using defined criteria for success and uploads these to her classroom website prior to the start of a new task ensuring flexibility of access inside and outside of the classroom. Her rationale for creating these learning scaffolds is twofold, firstly:

It's about workflow-so nobody is just sitting there waiting to have something clarified. I try to give them enough information to troubleshoot any issues they might have...making that learning journey as seamless and efficient as possible ...so then there is no chance for them getting off task.

And Secondly,

It's what I would call the public relations aspect because that's the take home message to parents....so when the kids go home and the parents are going god, what have you been doing on your computer all night? What have you got to show for it? By having those documents there, it allows the student to have that dialogue with the parents, showing them that there is academic rigour (Final interview: 09/12/16).

Ruby assesses her students' work against the rubrics and uses these as points of discussion and feedback during the task. Ruby indicated that these assessment rubrics serve a dual purpose; both formative in that it guides and directs the quality of the work that she wants submitted, as well as for summative purposes stating that: *"I think the kids are able to work more independently, so they get on and do what they need to do because they know exactly what is expected of them"* (Final interview: 09/12/16). Ruby suggested then it was a matter of determining whether a student had met the assessment criteria, and that it was immaterial as to whether a student had created a paper-based submission or had in fact used an ICT format. Ruby believes that the wide array of freely available multimedia tools now freely available via the Internet meant students have more agency in how they choose to demonstrate their scientific understandings; however, she was somewhat frustrated by the School's formal assessment program that limited ICT use.

Ruby described a range of affordances of her classroom website. Primarily she established her password free classroom website so students could access her learning resources from any location at any time. In this way Ruby believes that she can cater more inclusively to a wider range of student abilities, particularly to help students engage with challenging or misunderstood concepts:

I guess its extending my capability by providing remediation for kids that need it, so there's some resources on there that allow them to go 'I don't understand this bit about how chemical reactions happened but I'm going to look at this video that Miss Ruby said was kind of a funny song but its helping me to remember the four changes that you can observe' ...So I feel I can capture a wider range of kids at their point of need (Final interview: 09/12/16).

Another part of her reasoning was more functional and related to classroom management and organisation. To further assist students to navigate to her website resources Ruby uses symbols and colours to indicate the nature of the resource e.g., white to indicate classroom worksheets and yellow for Keynote presentations. Ruby felt that making all her learning resources readily available in one central digital repository helped to facilitate productive classroom routines, enabling students to get on with the learning tasks at hand. Furthermore, these ICT resources were available for use by students at any time outside of the classroom.

Key finding 5.6 Curation of digital curriculum resources into a school sanctioned virtual learning environment

To help facilitate the meaningful use of ICT Ruby curates a plethora of digital curriculum resources and houses these in a school sanctioned website called *Miss.Ruby.com* created using open source software. She curates these resources from the Internet. The aggregation of these resources into her own classroom website serves primarily as a cognitive guide to direct students to quality online resources, and as well to support work flow in and outside of the classroom. This strategy also allows Ruby more time to engage in meaningful dialogue with students rather than classroom talk of

a procedural nature. To facilitate navigation to her website resources she classifies and arranges these according to the mandated science curriculum key learning areas. Ruby's website enables students to flexibly access a vast range of ICT based instructional materials. Whilst serving to direct current classroom and assessment activity, the website also serves to communicate the quality of work to the wider community.

Ruby had learnt how to design her classroom website from scratch several years ago, and whilst she believes the learning benefits of this virtual classroom have been educational enormous she did comment that, "*it was onerous to set up but it's fine now*" (Final teacher interview: 09/12/16). To initially develop the *Miss.Ruby.com* website she had spent most of the school holiday breaks over a period of one year. Essentially this activity required Ruby to understand *HTML*, or *Hypertext Mark-up Language*, a fundamental technology that allows you to build and structure a webpage. Apart from attendance at an Apple Educational conference several years ago, Ruby's revealed that her technological skills have been essentially self-taught by watching *YouTube* videos and by subscribing to a variety of educational technology blogs. Ruby explained that this Apple conference proved to be a catalyst for her interest in the educational affordances of ICT, especially problem and project-based learning.

Key finding 5.7: Technological pedagogical content knowledge

Ruby's technological skills are extensive and self-taught, having created her own classroom website from scratch several years ago. The School's executive approved sanctions Ruby to use her website instead of the school's *Moodle*. Ruby was the only teacher at the time of this study to offer a classroom website. She demonstrates considerable technological skills in designing and maintaining this CMS based website using *HTML* language. Ruby spends a significant proportion of her personal time searching for and curating meaningful applications of ICT and digital resources for her classroom. She continues to remain interested in pursuing her own technological skills for the benefit of her students. Ruby has amassed a huge catalogue of multimodal and interactive resources, which she has organised around the themes of the *Australian Curriculum: Science*. Ruby's website is open source offering her students flexible access

to her curriculum resources independent of the school server. Ruby uses her website landing page as a bulletin board serving to communicate the current classroom activities with her students, parents, and the wider school community.

5.4 Lesson Observations

Shulman's (1987) PRA model and Engeström's (1987) CHAT model were used as lenses to analyse Ruby's pedagogical practices. These data were also supported by a microanalysis of the lesson's pedagogical activity structure using the action and operation descriptors outlined in Table 3.3. An analysis of the key decisions, as well as the teaching and learning practices for each of the lessons observed is now presented. Each lesson is presented separately using data derived from the pre-lesson interview, teaching artefacts, the lesson observation, including the post-lesson debriefing session.

5.4.1 Lesson one: Theme Year 8 Fakebook Chemistry

5.4.1.1 Pre-lesson interview

Ruby explained today's lesson was the third session of an intended sequence of four chemistry lessons focusing on elements of the Periodic Table. Ruby indicated the lesson's purpose related to developing students' understanding of the arrangement of elements within the Periodic Table, specifically why an element belonged to a family of elements. This is a key chemical science conceptual understanding mandated in the Year 8. Students are expected to understand; "Differences between elements, compounds and mixtures can be described at a particle level- locating elements on the Periodic Table" (ACARA, 2015a).

In the preceding two lessons the students had been introduced to this chemistry concept using a didactic approach where she had delivered a digital presentation created using *Keynote*. Primarily Ruby had directed the students through an overview of chemical families and periods using this *Keynote* presentation expecting students to make their own science notes followed by whole class discussions. Ruby then assigned each individual student a specific element to research. During this lesson she was expecting students to conduct a detailed investigation of their elements chemical and physical properties using a range of websites she had curated as the launching pad. The intention was for the students to determine why their element was situated within a family and to communicate

these findings using a freely available web-based authoring tool called *Fakebook Element* by *Class.Tools* in an engaging manner. Whilst this was an individual research project, students were encouraged to discuss their emerging ideas with their peers. Ruby indicated that without one-to-one Internet access rarely did the students get beyond collecting a range of simple facts about elements to create a paper-based brochure or poster. Ruby also reasoned that using the *Fakebook* tool the students would be highly motivated as this ICT tool mimics the functionality of the hugely popular social media platform *Facebook*.

In keeping with her social constructivist beliefs Ruby believed that the ability to personalise each *Fakebook* page, along with the interactive nature of the *Fakebook* application would encourage students to demonstrate their individual creativity. This tool allows students to customise their *Fakebook* element page by importing a range of image files and videos directly from the Internet. Furthermore, Ruby also reasoned the synchronous nature of the tool meant that her students would thoroughly enjoy viewing the other students' online entries, making comments and posting 'likes' to their peers *Fakebook* pages humorously stating:

You don't see another kid writing on another kid's poster- 'Hey yeh, that's a really cool poster!' The Fakebook tool allows them to do that, so they can comment on each other's work and so it's increasing that kind of social aspect of it and I think that science, science is collaborative, you know, by its very nature (Pre-lesson interview: 25/09/13).

The design of the *Fakebook* template required the students to detail key chemical and physical properties of their element which Ruby claimed was within reach of every student in her class (see Figure 5.5). However, the design of this template also meant that after discovering basic chemical and physical properties students could further demonstrate a higher level of understanding by making 'elemental friends' with other species from the same family of the Periodic Table. This web-based tool allowed Ruby to discriminate higher order reasoning amongst her students by the nature of the 'elemental friend' choices imported to each of their *Fakebook* pages, much the same way you can add friends to a *Facebook* group. The discriminatory nature of the *Fakebook* template to gauge student understandings was a key part of Ruby's reasoning for selecting this ICT tool stating:

So, the lower ability kids are going to go 'I'm going to pick all the elements that look the same colour'. And that's ok, as they are showing their understanding, and then you will have kids that will say- 'Well I'm going to pick elements that all have two valence electrons'. And you will hear me say to the kids today- 'Why do you have your friends as your friends? And they say- 'Well because we have something in common'. So- 'What do you have in common?'. Oh "we both like to play sport or we do this or that. So, your element is going to need to have friends... are their elements on the Periodic Table that have something in common with yours? And so, they are going to need to trawl through and research some extra elements to be able to go 'Oh, well I have decided that the friendship for my element will be based on their conductivity, or their melting point or the fact that they sit on the third period which means that they have got 3 shells'...So it's that intimate understanding. So, it provides that scope for everybody to be successful regardless of their ability. And that's actually really important in creating that environment where they feel safe to do those things (Pre-lesson interview: 25/09/13).

Ruby also liked the visual and creative nature of the task indicating she could identify 'over the shoulder' whom amongst her students were applying their knowledge to make 'elemental friends', in other words, the visual nature of the *Fakebook* template would easily help her make an assessment of each student's level of science understanding. Ruby explained that she had prepared an additional *Fakebook* planning template to help scaffold some of the students who she was aware may have some difficulty conceptualising this task. This planning template also included a criterion-based assessment rubric which she had mapped to the achievement standards of the mandated curriculum. As always, Ruby had uploaded these project scaffolding materials, shown in Figure 5.6, to her classroom website prior to project taking place. Creating these planning scaffolds that offered clear task descriptions was part of her normal practice and helped to free valuable lesson time so she could offer more mentoring and work closely with individual students. Additionally, these learning scaffolds were useful when students were absent.

Key finding 5.8 Extensive lesson preparation and curation of resources

Ruby had carried out extensive transformational preparation for this ICT mediated project, which firstly involved determining a clear learning purpose. This context was derived from the mandated science curriculum (chemistry) requirements and achievement standards. Students were expected to interpret, analyse, and synthesise information sourced from the web and had agency to personalise their findings. The structure of the task meant students could demonstrate a high level of scientific understanding. Ruby purposefully selected a web-based tool that enabled interactivity amongst her students. She had produced a clear instructional task guide, a planning template, and a criterion-based assessment rubric to guide student thinking in this activity. All these resources had been curated onto her *Miss.Ruby.com* website enabling flexible access both inside and outside of the classroom.





fakebook

Create a fake profile for a fictional / historical character

Name here

Like any pictures in this page, just click to change it!
 e.g. Search Google for "Facebook cover images"

<http://www.classtools.net/FB/home-page>

Save

Create a fakebook page for your element!

About

1. You need to include a profile picture of your element.
2. When your element was 'born' (discovered)
3. What your element looks like - colour, texture.
4. Where the element "lives" on the Periodic table & where it can be found in the universe.
5. "Occupation" - whether your element conducts heat and/or electricity.
6. Include information about at least 2 uses of your element.
7. State of matter at room temperature.
8. Boiling point and melting point of your element.
9. Include at least 5 "friends" that your element has. (Be sure to include a reason why each element is considered a friend)
10. Include the "family members" of your element.
11. At least 8 posts that your element might write on their wall.
12. At least 3 other interesting facts about your element

Check out the example: <http://www.classtools.net/FB/1068-36aX6G>




Marking Guide

	Excellent (5 points)	Good (4 points)	OK (2 points)	Needs Work (1 point)
Overall Profile	Imaginative profile that provides a detailed overview of the element.	A good profile which shows a general overview of the element in a creative way.	An attempt to complete the profile has been made but only a limited overview is offered.	Incomplete profile with limited or no understanding of the element.
Key Information	All necessary items have been included in profile	Most items have been included in profile.	Some key items of information have been included but some are missing	Most items are missing from profile and/or profile is incomplete.
Friends	5 or more friends have been included. Explanation shows a deeper understanding of layout (and interactions) of the periodic table.	5 or more friends included but explanation shows limited understanding of the relationships between the elements on the table.	5 elements have been included but very limited or no explanation of relationships has been included.	3 or less friends have been included with no explanation.
Posts	8 or more posts have been included. Posts include information to enhance understanding of the element in an entertaining manner.	6 or more posts have been included. Most posts include relevant information.	4 or less posts have been included. Posts do not include relevant information.	2 or less posts have been included. Posts are not related to element at all.
Interesting facts	4 or more interesting facts have been included. Facts enhance audience understanding of element.	3 or more facts have been included. Facts do not really enhance audience understanding of element.	1 or more facts have been included. Facts do not enhance audience understanding of element.	Facts are missing from profile.

Figure 5.5: Fakebook task description and assessment rubric

fakebook Planning Proforma

Name: _____

Name of Element: _____

Atomic number: _____

Location on PT: _____

Year of discovery: _____

Discovered by: _____

Family/group members:

Period members:

Everyday uses of the element:

Physical Properties
 Appearance (colour): _____
 Texture: _____
 Melting Point: _____
 Boiling point: _____
 Heat conductivity: _____
 Electrical conductivity: _____
 State at room temperature: _____

Interesting facts:

1. _____

2. _____

3. _____

4. _____

5. _____

Some pictures you might include:

Useful websites to visit:
<http://www.webelements.com>
<http://www.chemicool.com>
<http://chemistry.about.com>

What to do:
Step 1: Open a file on your desktop to save photos in.
Step 2: Write a list of all the photos you will need - including a cover image and images for your elements family and friends.
Step 3: Complete this sheet to ensure you have all the relevant facts about your element.
Step 4: Go to <http://www.classtools.net/FB/home-page> to access the template for your fakebook profile.
Step 5: Use this completed worksheet to enter information onto your fakebook profile.
Step 6: Save your completed profile and use "grab" to back-up your work.
Step 7: Don't forget to comment on other fakebook profiles too.

Additional notes:

www.mississimpson.com

Figure 5.6: Fakebook planning template for students

5.4.1.2 Lesson one observation

Ruby's conducted this lesson in a very small classroom where the desks were arranged using an outer and inner layer arrangement in the shape of the letter 'U'. A classroom routine was clearly obvious: as soon as Ruby drew the class to attention the students all immediately directed their focus to the whiteboard. Ruby had already projected a *Keynote*TM presentation onto the whiteboard via a *MMIO*. This was designed to guide the whole class on the requirements of the *Fakebook* project. Ruby then began to brainstorm strategies with the class for engaging with the project task which included carefully demonstrating the functionality of the *Fakebook* tool. She also carefully explained the *Fakebook* assessment marking criteria reminding students this project would be formally assessed. During this introductory phase two students were nominated to obtain the *MacBook Air* (13 inch) laptops from the ICT resource cupboard where a sense of automaticity was noticed in the way these students then distributed the laptops amongst the class.

Key finding 5.9: Classroom architecture and norms

Ruby teaches science mostly in a small classroom inside a middle school wing of a high school. The desks are arranged so that students sit in a 'U'-shape. This arrangement allows Ruby to easily see what is on her students' laptop screens. Ruby's classroom routine involves pre-loading her digital instructional materials using her *MacBook Air* (15 inch) laptop prior to the students entering the room and projecting these via a *MMIO*. The student *MacBook Air* (13 inch) laptops are collected after the lesson commences from the middle school ICT resource cupboard and are distributed on a one-to-one basis by the nominated students. Hard copies of the learning task descriptions are provided; however, digital versions are uploaded to Ruby's website for ease of access both in and outside of the classroom.

With very little prompting the students began their work and remained on-task throughout the entire duration of this lesson, clearly excited by the idea of creating a *Facebook*-like proxy. The first 10 minutes of the lesson involved ensuring the students had commenced their element profile pages and answering lots of questions such as:

ST 1: What does normal state mean?

T: At room temperature

ST 1: So, I can put up a normal selfie of Iron then Miss!

T: laughter

ST 2: Do my interesting facts all have to be funny?

T: No, just anything informative about your element

ST 3: Why did it just change the profile picture I selected?

T: Oh, don't worry the site has a little algorithm in it and it detects where you got it from so it gets a better version

ST 4: I can't upload my images Miss

T: So, just go control, then click here. Choose your file, then go to your desk top or where you saved them? Go choose image...

ST 5: Miss, what do you mean by when was my element born?

T: When your element was first discovered? So how do you think you might find that out? (Lesson one observation: 25/09/13)

For the remainder of the lesson Ruby moved around the room engaging in discussion with individuals and small groups commenting on their *Fakebook* pages and probing their reasoning. Occasionally she would have to intervene and offered students step by step guidance in uploading images to the *Fakebook* site; in other cases, more basic digital skills support such as demonstrating how to save images, create folders or naming folders for this project. The overall instructional sequence of this lesson followed a pattern of informing the students of the task objectives, presenting the students with the digital based stimulus materials, students researching Internet resources whilst Ruby continually probed student ideas and provided formative feedback. Ruby did not conduct a plenary discussion, instead the bell rang and the students hurriedly packed away the laptops each individually returning them to the middle school ICT resource cupboard.

As a further means of triangulating and characterising the data arising from this ICT mediated lesson, Ruby's actions and operations were decomposed using Stevenson's (2008) CHAT analytical tool, as previously elaborated in Table 3.3. This involved categorising Ruby's classroom *organisation* of the students, the *use* of ICT,

(e.g. the functionality of the tool use) and the conversational *roles* that shaped the relationships between the teacher and the student (e.g. lecture, questioning, summarising). This allowed Ruby's instructional practice to be scrutinised on a minute-by-minute basis. Shown in Table 5.1 is each facet of the lesson activity shown as a percentage of the total lesson time.

Table 5.1: Pedagogical activity structure of lesson one using Stevenson’s (2008) activity matrix

Classroom organisation	Percentage of lesson observed	Conversational roles	Percentage of lesson observed	ICT usage	Percentage of lesson observed
Teacher working with whole group (D1)	26	Teachers giving information to whole class (S1)	14	Teacher using ICT (T1)	26
Teachers working with small groups (D2)	0	Teachers directing questions and answers to reproduce facts (S2)	10	Learners using ICT in a collaborative task as initiated by teacher (T2)	57
Learners working in small groups (D3)	74	Teachers directing conversation (S3)	14	Learners using ICT in a collaborative task as initiated by themselves (T3)	17
Learners working individually (D4)	0	Teacher stimulating reflections or other critical analysis (S4)	62	Learners interacting via ICT as initiated by teacher (T4)	0
Learners reporting or presenting own material to whole group (D5)	0	Learners directing conversations with peers (S5)	0	Learners interacting via ICT as initiated by themselves (T5)	0
				Learners creating using ICT (T6)	0

As a key ‘actor’ in this classroom, this data revealed that Ruby spent 26% of this lesson directly instructing the requirements of the *Fakebook* task, which she primarily did at the beginning of the lesson. By clearly establishing the priorities for the lesson, providing the students with a *Fakebook* template, along with curating a list of useful websites (made available on her own classroom website), left ample time during the lesson for Ruby to engage in more open-ended discussion with her students. For almost two-thirds of this lesson (62%) Ruby engaged in dialogic teaching whilst offering personalised instruction to small groups and individuals. Her role is best described as a mentor .

The students were tasked to learn by carrying out individual web-based research, spending 74% of the lesson time doing this. Closer analysis of the ICT activities conducted by the students revealed that 55% of the use of ICT involved exploration of Internet resources they had sourced themselves. Whilst the students were positioned individually to create their own *Fakebook* element page they were at times interacting online with one another making comments and posting ‘likes’ on each other’s *Fakebook* pages throughout this lesson time. Albeit guided by the learning task description and planning template provided, the role of the student in this lesson was that of explorer and creator. A student artefact arising from this lesson for the element Fluorine is shown in Figure 5.7 which reveals student comments and ‘likes’ posted in this class.



Figure 5.7: Student *Fakebook* artefact

5.4.1.3 Post-lesson debriefing

After this lesson, Ruby's immediate reaction was about the intensity of the students' engagement reflecting that:

Sometimes people go, 'Oh, if they are engaged they are sitting quietly and doing their own thing-but that's not always the case. It depends on what the project is. I was really happy, there was nobody who was off task, except the boys at the beginning were having a bit of giggle but only because they typed in a Google search and it had come up with, you know naked Oxygen. You know, they are life lessons to learn. Naked anything is probably going to get you an interesting picture! But then they settled down and got into it after that which was fine (Post-lesson interview: 25/09/13).

When queried about why she chose to demonstrate the use of the *Fakebook* tool in such detail at the beginning of the lesson she stated this was because, "*there's kids that have no concept of how to use technology. So, I have got to kind of make sure they understand what they are doing but also not take too much time that I am turning the other kids off*" (Post-lesson interview: 25/09/13). Ruby felt the notion of her students being digital natives was a myth stating:

A student can have an intimate knowledge of the workings of Minecraft...but yet not even know how to create a file on a desktop to save their work. So, because for them that's boring stuff, no one wants to know how to do that, that's work-related things! So there seems to be a real dichotomy in terms of their skill set...just because for them their access is ubiquitous it doesn't necessarily translate that across in terms of their skill set. So, I do have to account for that (Post-lesson interview :25/09/13)

Overall, Ruby indicated that she was pleased with the choice of the *Fakebook* tool for this activity as it hardly presented any technical challenges or require any advanced technological knowledge from her students. Instead the students were able to focus on sourcing, interpreting and synthesising information to create a *Fakebook* element page. Ruby felt that having an open access website, where all her classroom resources were

curated meant students could refer to this at any time during the lesson, as well as later at home, therefore acting as a virtual teaching support tool.

5.4.2 Lesson two: Theme Year 8 Sustainable living

5.4.2.1 Pre-lesson interview

This lesson was the fourth in a series of lessons on the concept of designing a sustainable home. The origin of this project having come from Ruby's own real-world concerns about a housing development activity that was occurring at her previous school, indicating there had been little thought in regards to designing homes for sustainability. The lesson idea was not predicated on a specific curriculum scientific understanding *per se*, rather Ruby explained she created the activity as a challenge-based project more closely aligned to meet the *Australian Curriculum ICT General capabilities*. The project was aligned to develop the ICT skills and dispositions necessary to locate and organise valid and reliable information using the Internet and to use this information as the basis to design a floor plan for a sustainable home using a specific piece of software. Students were then to accompany this floor plan with a report that justified the selection of the homes sustainable design features. Ruby elucidated the steps in her pedagogical thinking for this activity as:

What do I want the kids to hand in? What do I want it to look like at the end? How am I going to get them to that step? Now here's some virtual tools that will help you and here's some guidance and you can follow that, but it's really getting them to take that macro level idea and then going okay, now let's get into the nitty gritty, put the pieces together...then some of the kids will go, oh okay well, other kids have done it, so, yeah, I can do that. Or, oh, okay, I was thinking about a report, I didn't think of doing it that way. Okay... I've been thinking about a virtual tool but I don't know what that looks like. Now, you know I had shown them two distinct virtual tools, so one was a 3D walkthrough and, you know so I was just giving them an opportunity to almost backward plan for themselves, because for me, really, that's how I design projects (Pre-lesson interview: 21/11/13).

Ruby explained that the students had already created a basic interior and exterior house design plan using a freely available web-based drawing application for their sustainable home. In today's lesson, they would be expected to plan more nuanced elements:

They're thinking about their rooms, and thinking about what cars are going in their carport and those kind of things... it's about them going: 'How am I infusing that sustainability into that?' ...making sure that the windows are down a certain side of the building, depending on its orientations, you know, east to west... it's about getting them to think about the materials in there. For me there was a lot of questioning; so, what kind of flooring have you got? And they're going hmm? So, it's about getting them to look over their existing product that they've got, and then making it more sustainable. So, I'm really kind of challenging them to look at it, to interrogate what they've already got and, and make it better. So, that was really the purpose of today (Pre-lesson two interview: 21/11/13).

Ruby had chosen to frame this project using a real-world scenario, however she felt that her students' present ICT skills and cognitive abilities meant they would require significant scaffolding. Hence, she created some guiding design principles and stimulus thinking questions, and included this scaffolding into the Sustainable Living Homes project brief. Again, Ruby had made these scaffolding resources available on her website, including making several hard copies available during the lesson. The Sustainable Living project brief is shown in Figure 5.8.

Ruby had originally conceived this classroom project as occurring over two phases. Ruby often felt that school-based projects ended with a simple showcase whereby the other students were the recipients (Phase One); however, she was keen to involve her students in promoting these sustainable home designs to a real-world community audience (Phase Two). She believed this project was an opportunity for students to gain an understanding of the role of advocacy in contemporary society, as well as an opportunity to develop social capability around the concept of sustainability indicating that students now:

Actually they have a lot of power, and especially with social media and the way that everything's globalised now, they actually have a massive audience...kids don't want to hear us telling them about sustainability but if they can hear one of their peers it's infinitely more powerful...so it's about getting them to look beyond the scope of just getting the grade and going how can I actually make a difference, how can I impact change, how can I be involved in this, rather than just sitting back and going oh well...You know, it's about giving them that social responsibility to go "I have this knowledge, I'm going to put it out there" and hopefully that will translate when they're older, they've been used to having a voice and being up and being active, so when they actually have that political power, they're going to be the people that are mobilising and actually making change, so, that's the big goal (Pre-lesson two interview: 21/11/13).

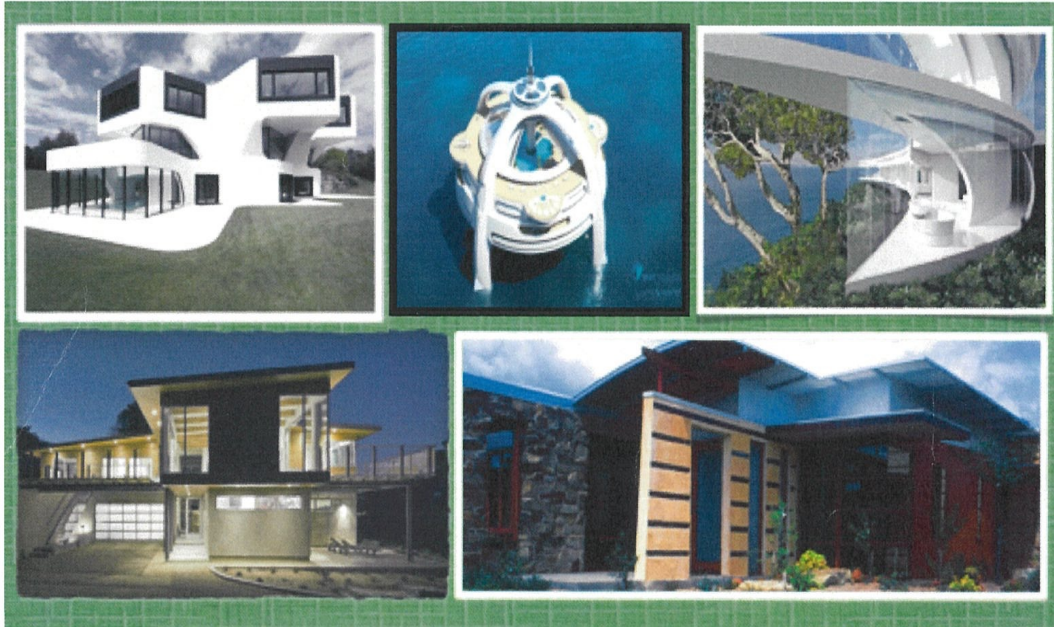
For Phase two of this project (not shown on the design brief) Ruby indicated that the students had complete agency over how they would promote their sustainable living designs to the wider community. For example, Ruby indicated that some of her students had been discussing creating a web page, some were intending to author an *iBook* and use this to talk to local primary school, whilst other students were proposing to create a *Facebook* campaign to promote sustainable home designs. Ruby envisaged that Phase two of this project would encompass a whole school term.

In selecting the digital tools for this lesson Ruby indicated that she purposefully selects open access resources from the Internet and tests them to avoid the inevitable *Mac* versus *PC* interoperability platform challenges. Ruby felt this level of planning enabled students to work on tasks at home where they may not necessarily have a *Mac* computer. For this project she had selected two specific freely available planning web-based design tools called *floorplanner.com* and *Google Sketch-up*. Preparation for this lesson also included test driving these applications: “*I had a bit of a play around and went, yep, that seems fairly intuitive to me. I'll put that on there*” (Pre-lesson two interview: 21/11/13). As projects advance Ruby also indicated that she typically continues to aggregate additional digital resources to her website often suggested by her students:

As I keep evolving this and changing it...you check to make sure the links still work and as you find stuff...it's about providing the kids with five or six options...so that they can go- 'That doesn't really suit my needs, I like that one, I don't like this'. So, really, it's become quite organic in terms of how they can contribute to it as well (Pre-lesson two interview: 21/11/13).

Ruby did not intend to use ICT herself during this lesson, instead the students would be using a computer on a one-to-one basis to continue developing their sustainable living home design. She perceived her role in this lesson to be that of monitoring the students' projects and, "*encouraging or guiding them to be looking at it a much deeper level*" (Pre-lesson two interview: 21/11/13).

Sustainable Living



Building a sustainable home...

Your design brief!

You are an architect designing a home that must comply with the principles of sustainability. You are free to **be as creative as you like** however, you must adhere to the design brief, which includes the following non-negotiable elements:

The home must have **more than one bedroom** (and a maximum of five).

Your design must **have at least 10 different energy efficient modifications** to ensure your design can be considered 'environmentally sustainable'.

Design Submission Dates

- Phase 1 Interior & exterior floor plans (Wk3)
- Phase 2 Virtual tour of home (Wk6)
- Phase 3 Project Showcase (Wk10)
- [Finished product & report]*

What do I need to produce?

1. A **floor plan** of your **interior** of your home (include furnishings).
2. A **layout of the exterior** of your home (in 3D or aerial view). Include information about the **orientation** of your house in relation to the sun and any **landscaping** you will have.
3. A **virtual tour of the interior** of your home.
4. A **scale model** of your design.
5. A **Sustainable Report** in the format of a keynote presentation, a short film or iBooks author explaining all of the environmentally friendly **features** you have included in your home and answers to the 6 questions on the following page.

It is a good idea to include diagrams/pictures of your home and annotate the sections where you have made your environmentally friendly modifications.

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How should I do it?

Research some eco-friendly **house designs** and features on the **Internet** or magazines.

Use design software such as **Google sketchup** or free online software programs such as www.floorplanner.com, www.sweethome3d.com, www.smallblueprinter.com or www.homestylr.com to develop the floor plan and layout of your house.

For a house to be really energy efficient you need to have all the right elements of design.

Make sure you have considered the major elements below:

- Orientation
- Layout
- Insulation (to walls and ceilings)
- Windows/Landscaping
- Ventilation/Draught Proofing
- Thermal mass

Start collecting materials to create the scale model of your home.



Where do I start?

These steps below are simply a guide to get you on your way:

1. **Research** some eco-friendly house designs and features on the internet.
2. **Decide which** eco-friendly **features you want** to include in the design of your home.
3. You will have to **decide on the dimensions** of your house and how many bedrooms you intend to have.
4. **Decide which software** you will use to create your design and start to become familiar with it.
5. When your design is complete, you need to **focus on your scale model**.

You can use equipment like cardboard or styrofoam to build your model. Decide what materials you will need to complete your model.

Some useful websites:

Start at http://www.dtei.sa.gov.au/energy/be_energy_smart_designing_an_energy_efficient_home or go to <http://www.originenergy.com.au/calculator> for some handy hints about how to make your home more energy efficient.

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What information do I need to include in my report?

1. Answers to the following questions:

- 1a. What is thermal mass and why is it important?
- 1b. Why is landscaping important when considering an environmentally sustainable home?
- 1c. When looking at designing a home, what is meant by the term "passive design"?

2. Write a **brief description of the climate, natural vegetation and topography** of the area where your home is to be located.

3. A **list** of all the **sustainable features** in your home.

4. Include an explanation of how your home uses the principles of **convection, conduction and radiation** for both **cooling and heating**.

5. A list of **five building materials** you've used in the construction of your home that can be considered '**environmentally friendly**'.

6. The **sources of alternative power** you've used in your design [eg. wind, solar].

Assessment Rubric

Aspects	Poor	Needs Improvement	Good	Outstanding
Overall design	Little attention was given to the design selections and most environmental modifications are missing.	Little planning went into the design elements and some environmental modifications are missing.	All 10 environmental modifications are present but not all selections are balanced.	Care was taken to balance environmental modification selections and utilise environmental design elements and principles. E.g. Orientation, layout, insulation, landscaping, ventilation and thermal mass.
Interior & exterior floor plans	Floor plans had no interior or exterior features. Layout is illogical for the design.	Floor plans had 2 or 3 features. Some information is missing and plans follow little logic from a design perspective.	Floor plans had adequate interior/ exterior features to represent the design. Layout of design is logical.	Floor plans had detailed interior/ exterior that creates a sense of realism and logic to designs.
3D Model	3D Model is a basic shape but largely incomplete.	3D Model is complete but some design features show a lack of realism (windows too big) or are missing.	3D Model is complete and effort has been made to create detail and show perspective.	3D Model is complete, recognizable from all elevations and includes other items to create a sense of realism and perspective.
Virtual Tour	Virtual tour is missing or incomplete.	Virtual tour is too brief and omits most information.	Virtual tour briefly highlights major aspects of the home, but little attention is given to environmental modifications.	Virtual tour includes a detailed showcase of the environmentally sustainable features of the home.
Physical Science Content -Heat	Descriptions are too brief or missing completely.	A brief description of convection, conduction & radiation are provided with no elaboration.	An overview of convection, conduction & radiation have been provided with some elaboration but concepts presented are not reflected in overall house design.	A detailed description of convection, conduction & radiation is given with specific examples from the house used to assist with clarification of concepts.
Report	Report is missing or largely incomplete.	Report is present but some answers to the focus questions are missing.	Report is complete but explanations are too brief or inaccurate. A minimal amount of research has been done.	A detailed explanation and diagrams have been used to answer the focus questions. Evidence of a wide variety of sources is apparent.

Annotated design samples

Here are a variety of different ways you can present your information.



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Figure 5.8: Sustainable living home project brief including an assessment rubric

5.4.2.2 Lesson Observation

The Sustainable Living Home project lesson was conducted in the school library. In this instance the students used the Library's Mac desk top computer facilities, however an additional 10 laptops were brought in from the middle school to support this lesson. This ensured each student had one-to-one access to a device. In keeping with Ruby's stated philosophy, the students were free to choose to sit with anyone during this lesson. By negotiation, Ruby also allowed students to work collaboratively (in pairs) for this task and most did. Ruby conducted a short verbal introduction to the lesson outlining her expectations of the work expected by the end of this one-hour period, and clearly emphasised the submission date for this project. During this introductory phase of the lesson the students were receivers of information, albeit exchanges of questions regarding the task ensued.

In this lesson, the students were primarily positioned to act as collators of relevant information and use this to design a floor plan for a sustainable living home. Ruby suggested two web-based drawing applications, however, did in fact offer the students agency to choose from a range of other free online drawing application tools. Ruby also encouraged students to locate relevant authoritative information about planning for a sustainable house design. The students could determine their own working pairs; although some students worked individually. After a brief introduction to the project, the students quickly retrieved their draft floor plans and continued designing their homes, engaging in lots of discussion with one another whilst doing so. Except for several boys the discussion appeared largely productive classwork related talk.

Ruby circumnavigated the room for the entire lesson visiting pairs and individual students, either checking on their progress or engaging in discussion, particularly involving students having to justify their choices of design features. Ruby also offered lots of formative feedback and seemed careful not to direct her students down a pathway, instead coaching and probing their ideas and asking points for further clarification. As an example:

ST 1: So how many sustainable features again Miss? Is it 10 or 15?

Teacher: At least 10.

ST 1: We've got 10.

Teacher: Great, OK, oh you've already labelled them in your floor plan.

That looks perfect. So, who's car is that in the driveway?

ST 2: It's mine. It's a Ferrari!

Teacher: (Laughter).

ST 1: So, we've got a fruit and vegie patch, a rainwater tank, the windows are shaded by our plants. It's got a water recycling system over there.

We've gone with fluorescent lights.

Teacher: Good

ST 1: The windows are double glazed and insulated

Teacher: But what are they insulated with? Regular material?

ST 2: umm, regular. We put solar panels on the roof and a solar hot water system over there.

Teacher: That's fantastic! Have you completed the report? Is that what you will be doing today?

ST 2: Yes, well we are trying to tie the report and the floor plan together, sort of.

Teacher: That's excellent

ST 2: But we need to look at one more building material I think

Teacher: How about you think about the type of flooring- are you using tiles or floorboards. What about you think about sustainable or recyclable materials for that. Have a little think about that. (Lesson two observation: 03/12/13)

As well as designing the floor plan the students were also required to produce a scientific report including references that justified their sustainable design features. Students had to explain how their chosen design features prevented or promoted convection, conduction and or radiation of heat energy. The students remained largely on-task throughout the duration of this lesson, clearly engaged with this real-world design-based challenge set for them. Ruby's high level of friendly and supportive engagement, clear instructional guidance along with the learning scaffolds provided via her website were the hallmarks driving the success of this ICT mediated lesson.

In decomposing the lesson using Stevenson's (2008) CHAT analytical tool, the data revealed that for 90% of this lesson the students worked in small groups (pairs) using

their laptops. In keeping with Ruby's stated intentions, the students used ICT to conduct Internet research to substantiate the new design features to their sustainable homes. Again, in this instance using free web-based authoring planning tools suggested by Ruby. The students were clearly positioned as explorers and creators in this product-oriented activity. Like the previous lesson, Ruby was seen to support several groups of students to help troubleshoot basic ICT storage strategies, including saving work and creating new documents folders. Whilst in this capacity her role is best described as tutor. Again, the significant scaffolding and curation of resources to her website enabled Ruby to offer personalised instruction for much of this lesson to small groups and individuals where her role is best described as mentor. Ruby used only a very small proportion of this lesson time to conduct a brief plenary discussion.

Table 5.2: Pedagogical activity structure of lesson two using Stevenson’s (2008) activity matrix

Classroom organisation	Percentage of lesson observed	Conversational roles	Percentage of lesson observed	ICT usage	Percentage of lesson observed
Teacher working with whole group (D1)	10	Teachers giving information to whole class (S1)	12	Teacher using ICT (T1)	12
Teachers working with small groups (D2)	0	Teachers directing questions and answers to reproduce facts (S2)	2	Learners using ICT in a collaborative task as initiated by teacher (T2)	2
Learners working in small groups (D3)	90	Teachers directing conversation (S3)	0	Learners using ICT in a collaborative task as initiated by themselves (T3)	0
Learners working individually (D4)	0	Teacher stimulating reflections or other critical analysis (S4)	86	Learners interacting via ICT as initiated by teacher (T4)	0
Learners reporting or presenting own material to whole group (D5)	0	Learners directing conversations with peers (S5)	0	Learners interacting via ICT as initiated by themselves (T5)	0
				Learners creating using ICT (T6)	86

Key finding 5.10 Classroom organisation, roles, and tool use.

Ruby positioned the students to work collaboratively on a project-based task. Almost the students consumed all the lesson time actively using ICT to add design features to their sustainable home. Ruby acted throughout the lesson in a mentoring role mainly discussing the rationale for home design features. The students were supported by a clearly articulated task brief along with obvious lesson expectations established at the beginning of the lesson.

5.4.2.3 *Post-lesson debriefing*

Overall, Ruby felt the lesson was successful except for four boys who needed prompting to remain focused on the task. She also believed that the floor planning tools and websites she had pre-selected worked well. However, Ruby indicated a sense of frustration at having to consume lesson time developing basic ICT procedural skills rather than engaging in more discourse about sustainability, reflecting:

Look, they, all of these kids have a computing class once a week, and my expectation would be that would be a skill that you would learn. But, it's not being learnt...or, it's either...a disconnect in terms of what's being taught and what kids are taking on or it's just not something that's being addressed and, that's probably one of my biggest concerns is, you've got to have the bread and butter stuff, like how to save documents and that kind of stuff because that's the frustrating part for me... the conversations become about specifics of the technology and not, "Okay, are you using recycled timber flooring, have you used/repurposed this", it's about, and for me that's the frustrating part of my job because, unless you're having a target session where you're simply going "this is how you save a document". Then that becomes a little bit troublesome because, not all of the kids need that help. So then, if I'm going to do a target session on that I've just instantly disengaged two thirds or a third of the class...so it's one of those things where I struggle (Post lesson two interview: 21/11/13).

Key finding 5.11 Trouble shooting and ICT capability of students

Ruby again spent time in this lesson supporting some students with troubleshooting basic ICT information storage strategies such as creating folders to save images for later use in this task with some students. A lack of student independence to solve routine malfunctions with relevant software hinders her ability to engage in meaningful scientific content discussions.

5.4.3 Lesson three: Year 8 Collaborative Chemistry

5.4.3.1 Pre-lesson interview

Ruby indicated that this lesson was the second lesson as part of an intended series of five. In this lesson the students were expected to continue to use the laptops to produce an engaging concept video or animation that would help explain a key middle school chemistry concept. Ruby's desire was for students to work as creators of engaging scientific content stating: *"I don't think there are a lot of good chemistry animations out there. I think it's really powerful to have kids make things for kids, it speaks to them in their language"* (Pre-lesson interview: 03/12/13). Ruby also expected that in producing conceptual videos or animations, the students themselves would consolidate their own understanding of their chosen chemistry topic.

Whilst Ruby had pre-selected several chemistry topics covered as part of the Year 8 chemistry program, she explained that she designed the activity as a project more closely aligned to meet the *Australian Curriculum General Capabilities*, of ICT capability, Critical and Creative Thinking and Personal and Social capability. The students were offered the choice of how they might work in this project including working in small groups, pairs or even as individuals, hoping that students would continue to develop social management skills in this project-oriented activity.

Drawing on her own ICT experience, Ruby had selected five different freely available web-based presentation tools for the students to work with during this project. Having tested all these tools in her own time Ruby was concerned that the free web-based *Powertoon.com* cartoon maker may be blocked by the School server. As a precaution she alerted the IT department in case of security system issues disrupting the lesson flow. Ruby explained that the primary intended audience for these concept videos or animations was the student's own peers; however, she also intended to upload these

student creations to her *YouTube* channel or as she put it, “*putting them out there to the Universe*” (Pre-lesson interview: 03/12/13).

Key finding 5.12: Pre-selecting and pre-testing student ICT tools

Ruby pre-selects and pre-tests ICT applications for their student efficacy. She selects ICT tools that are freely available from the Internet (web-based) for use in her classroom activities. As a precaution Ruby alerts the IT department when new ICT tools will be in use in case the School server blocks them.

Again, in keeping with her stated beliefs of student agency the students were free to choose from one of nine chemistry topics in this project which she stated were required topics in the *Australian: Science Curriculum* (ACARA, 2015a). However, she was willing to negotiate with students should they wish to pursue a related chemistry concept, allowing one group to pursue the topic of chemical warfare. In preparation for this project Ruby had produced a project brief which incorporated an assessment rubric to guide the quality of the students’ creations in this project. This is shown in Figure 5.9. In the previous lesson Ruby indicated she had scaffolded the activity even further by getting the students to prepare a range of key questions they wished to answer in relation to their chosen topic, to help storyboard these creations. When asked to clarify her intended role for the lesson Ruby remarked:

It feels like my role is more involved during project work. I can be helping with content or the technology...rather than just delivery of content...it really personalises the learning...It’s like guided discovery. I ask them questions, lots of questions...maybe that’s a bit frustrating for them that I ask them so many questions...but I think in that way they get to have individual conversations so that developing that relationship with the kids... really good in terms of rapport, as the kids feel like they are getting more of my time (Pre-lesson interview: 03/12/13).

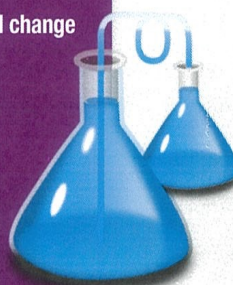
COLLABORATIVE CHEMISTRY

Presentation

YOUR TASK...

In your groups, you will need to create a computer animation, live action short film, stop-motion cartoon or a dynamic presentation explaining one of the following items:

- Particle arrangements in solids, liquids and gases
- The fourth state of matter - Plasma
- The difference between a chemical and a physical change
- Endothermic and exothermic reactions
- Everyday chemical reactions
- Atoms and atomic theory
- Density
- The many uses of carbon
- Chemical Nanoscience and Nanotechnology



Your presentations should be between **2** and **10** minutes in duration and **include** all of the elements of good filmmaking i.e. **title, credits, music, special effects** etc.

You will be given time in *class* to create your presentations but be prepared to **utilise time outside of class** to complete the project.

You will have access to **ICT** in science class (please note: you **cannot** simply cut and paste any kind of video clip or animation from the internet you must *generate your own!*).

Your **final** products will be shown in class on _____.

STEPS TO SUCCESS...

STEP 1: Decide on a **topic**

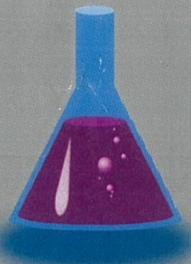
STEP 2: Decide on a **presentation format**

STEP 3: Generate some **questions** to answer

STEP 4: Determine what additional **resources** you will need (props)

STEP 5: Refer to the *marking guide* so you know what to do to gain maximum marks

STEP 6: **Assign a role** for each group member and get to work!



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STEP 2: PRESENTATION FORMATS

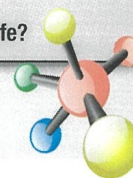
Below is a list of websites you can use to create your presentations. If you have another idea or website in mind that you would like to use, please come and negotiate with me before you start.

<http://goanimate.com>
<http://www.abcya.com/animate.htm>
<http://scratch.mit.edu>
<http://prezi.com>

STEP 3: GENERATING QUESTIONS

Establish some questions you would like to answer in your presentation. For example, if you chose to focus on "The fourth state of matter – Plasma", some questions you might need to answer are:

1. What is plasma? – Definition
2. How are plasmas formed?
3. When was it first discovered or created?
4. How are plasmas similar or different to the other states of matter?
5. Where you can find plasma?
6. How plasma is used in everyday life?



RESEARCH QUESTIONS

MARKING GUIDE

ACTIVITY	Excellent	Good	OK	Needs work
Quality	Presentation was completed & had all required elements. Video/animation was well edited & moves smoothly from scene to scene with proper use of transitions. Audio & other enhancements were well used.	Presentation was completed & contained all required items. Editing was not done as well - poor shots remain. Movie/animation is still somewhat choppy. Audio & other enhancements were utilised, but not for maximum effect.	Presentation was made, but had very little if any editing. Many poor shots remain. Video/animation was very fragmented & choppy with little to no audio reinforcement.	There was no presentation, or movie/animation was totally unedited with no transitions or audio support of any kind.
Science Content	Video/animation presents the science content in a logical & interesting way that can be watched repeatedly.	Video/animation shows the science content which an audience or viewer can follow to learn & understand.	Video/animation is scripted illogically and/or is difficult for a viewer or audience to follow.	Poor organisation makes it impossible to learn about the science concept presented.
Creativity	Presentation was engaging & entertaining. Creativity greatly enhanced audience understanding of content.	Presentation was engaging & entertaining. Creativity somewhat enhanced audience understanding of the topic.	Creativity was evident but the ideas or concepts were presented in the same way as existing presentations already in the public forum.	Little or no creativity was evident in final presentation
Teamwork	All students on the team contributed to the discussion & were part of the final project. Team members showed respect for each other.	Most of the students on the team contributed to the discussion & were part of the final project. Team members mostly showed respect for each other.	Most of the students on the team contributed at some level, but one or two people did a majority of the work.	Most of the team members did not contribute at all to the project.
Time	Presentation was within the time allotted & appropriate time was allocated for opening & closing credits.	Presentation was within time limits but an excessive amount of time was used for title & end credits – not enough time was focused on the science content.	Presentation was too long.	Presentation was too short and didn't cover enough information.

[2]

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Figure 5.9: Collaborative chemistry project brief including assessment rubric

5.4.3.2 Lesson Observation

Ruby began this lesson using a *Keynote* presentation to explain the requirements of the task with the whole class. Reviewing the assessment criteria ensuring the class understood these requirements. This was the only part of the lesson during which the students were quiet, the remainder was characterised by excited student talk. In this lesson, the students were creators of science content using reliable and contemporary science information collated from the Internet. Again, Ruby allowed her students to determine the composition of their own working teams.

Ruby's interactions with the students followed many dialogic teaching principles. Again, continually weaving her way around the room interacting with groups where she seemed careful not to direct students down a path, instead probing their ideas and providing lots of encouraging feedback them in this activity. An example of this:

ST 1: let's use Prezi

ST 2: but what topic?

ST 3: everyday chemical reactions

Teacher: It's probably best to choose your concept first and then think about what your animation needs to say

ST 1 : ok, what about something easy?

ST 2: maybe rusting

Teacher: that's a great example, do you remember what type of common chemical reaction this is?

ST 1: I think it was oxidizing or oxidation ...something like that

Teacher: Great, make sure you plan this out first. Think about what the viewer might need to also know about rusting

Just over half the class was present for this much shorter 40-minute lesson, with many students participating in other end of year preparations. However, the remaining students were highly focused, clearly engaged with this creative activity. It was a particularly noisy lesson with many students moving around the room to view each other's draft presentations. The instructional sequence followed a pattern of explaining the task requirements and discussing how to use the animation presentation tools,

students collating information from the Internet and using this to commence production of their animations followed by a very short plenary discussion.

In decomposing the lesson using Stevenson's (2008) CHAT tool the data shows that for 82% of this lesson the students were working in groups to conduct this project. This micro-analysis is shown in Table 5.3. As Ruby had intended, ICT was used by the students for most of the lesson time where it was used to conduct Internet research to source reliable information and to commence the design of the animation. The students were positioned as explorers and creators in this lesson. For three-quarters of this lesson (75%) Ruby engaged in lots of supportive mentoring, and offering formative feedback on the developing animations. Ruby again was asked to help troubleshoot basic information storage strategies, particularly how to store the project work-in-progress. As shown in Table 5.3, this accounted for 10% of lesson time.

Table 5.3: Pedagogical activity structure of lesson three using Stevenson’s (2008) activity matrix

Classroom organisation	Percentage of lesson observed	Conversational roles	Percentage of lesson observed	ICT usage	Percentage of lesson observed
Teacher working with whole group (D1)	18	Teachers giving information to whole class (S1)	15	Teacher using ICT (T1)	10
Teachers working with small groups (D2)	0	Teachers directing questions and answers to reproduce facts (S2)	10	Learners using ICT in a collaborative task as initiated by teacher (T2)	0
Learners working in small groups (D3)	82	Teachers directing conversation (S3)	0	Learners using ICT in a collaborative task as initiated by themselves (T3)	0
Learners working individually (D4)	0	Teacher stimulating reflections or other critical analysis (S4)	75	Learners interacting via ICT as initiated by teacher (T4)	0
Learners reporting or presenting own material to whole group (D5)	0	Learners directing conversations with peers (S5)	0	Learners interacting via ICT as initiated by themselves (T5)	0
				Learners creating using ICT (T6)	90

5.4.3.3 Post-lesson debriefing

Ruby indicated that in reflecting on her lessons she often approaches this by asking herself:

Where were the stress points? What could I fix next time? There are the things as teachers that we cannot control, such as what is happening at home. So, I work on all the things I can control like making sure the software works in class. I learn this stuff all at home. You know, it's quite difficult to do that at work so I do it at home (Post lesson interview: 03/12/13).

To this end Ruby was very satisfied with the ICT tools she had selected for this project and that the students had engaged with the task. She was most pleased with the quality of the work that was emerging stating: *"I think the tools I chose were quite good...I'm excited by the quality I was starting to see. I even saw one group making an animated Bohr model and they are only in Year 8!"* (Post lesson interview: 03/12/13). She was also pleased that as a capstone project for the year she was seeing evidence of the students' organisational skills at play:

There were lots of multiple tabs that were open...I wasn't surprised at how quickly they got into working productively with class time...I've been teaching them to multi-task all year...its more representative of the real world...so it was nice to see that now happening in my class (Post lesson interview: 03/12/13).

Ruby felt that the learning task descriptions and assessment rubrics created for this project were critical in supporting students in the meaningful use of ICT for learning science, which she referred to as a process of *"guided discovery"* (Post lesson interview: 03/12/13). Furthermore, having these scaffolds meant that students could get on with the task at hand so that she could engage more meaningfully in discussion with her students: *"I don't just want engagement and compliance at all costs...it's got to be a partnership...we are working together to do this...it's makes it more egalitarian"* (Post

lesson interview: 03/12/13). Furthermore, she explained by making these projects and the accompanying learning scaffolds publicly available on her classroom website they were transparent to parents. According to Ruby this, “*gives the parents an idea of what we are doing at school...one of the biggest barriers to the use of technology... can actually be the parents themselves, so this way they can see it does have grades attached to it by the rubric and that they need to know some science ...I can’t do this without their support*” (Post lesson interview: 03/12/13).

As evidenced by the plethora of digital resources curated on Ruby’s website, along with the lesson observations and artefacts detailed here, the *Australian Curriculum ICT General Capability* including the mandated science curriculum played central roles in determining the rationale for this ICT-enabled activity. As Ruby herself states, she designs these types of activities involving ICT to help produce: “*Independent, sophisticated consumers. A learner who is also a producer*” (Final interview:12/12/13). Ruby extends audience participation with her students’ science creations, and therefore engagement, by placing these onto her social media platforms such as her *YouTube* channel to give students, “a worldwide audience” (Post lesson interview: 03/12/13). Enabling her students to be “worldwide publishers” (Post lesson interview: 03/12/13). Thus, Ruby uses ICT in her support of them to become successful, confident, creative, and active citizens.

Key finding 5.13: Pedagogical repertoire

Meticulous explanation of the instructional and assessment objectives, scaffolded using task outlines detailing explicit assessment criteria guided student thinking and success in the lessons observed. Ruby curated a wide plethora of digital resources to support these lessons to her classroom website. Ruby’s role was primarily a coach, where almost three quarters of each lesson she engaged in dialogic teaching guiding and providing feedback on the design of student work. Her patient, attentive and friendly pupil–teacher interaction, were the hallmarks driving the success of these lessons. In each lesson, the students were the key users of ICT using their laptops for almost three quarters of each lesson.

Key finding 5.14: Alignment of lesson intentions to outcomes

The overall design of Ruby's lessons was in keeping with her stated beliefs of student-centered construction of science knowledge, where ICT was positioned as a tool to investigate, create, and communicate findings. Collaboration of students was strongly promoted where students were offered agency in forming these groups. Ruby designed her tasks to cater inclusively to the needs of her cohort, affording each student the opportunity to demonstrate a level of success in each of the learning tasks observed. Students were positioned to use ICT to investigate science concepts, plan their own search strategies and then create multimodal representations, albeit guided by clearly articulated learning task descriptions and a plethora of digital resources offered as a starting point. Ruby promoted the sharing of her student creations to a global audience by uploading these to various social media channels, in keeping with her stated beliefs.

A final member checking interview, lasting around 60 minutes was conducted on site to confirm the emerging themes in Ruby's ICT pedagogical reasoning and practices. Approximately one week before the final-member checking interview Ruby received a set of semistructured interview questions as well as full access to the complete video recordings. During this final interview, as well as articulating her thinking processes Ruby also drew a concept map as an attempt to visualise this reasoning. Shown in Figure 5.10 is a re-representation of Ruby's pedagogical reasoning process re-drawn with the aid of software. This graphical representation has been ratified by Ruby as a true reflection of her iterative thinking processes for ICT enabled lesson activities. Ruby was keen to emphasise that her thinking was not a linear process instead: *"There's lots of circling...coming back to each process...going from this broad scope to then funneling your thinking through...discarding things as you're thinking...for example, I think this time it will be better to do this"* (Final interview: 01/12/15).

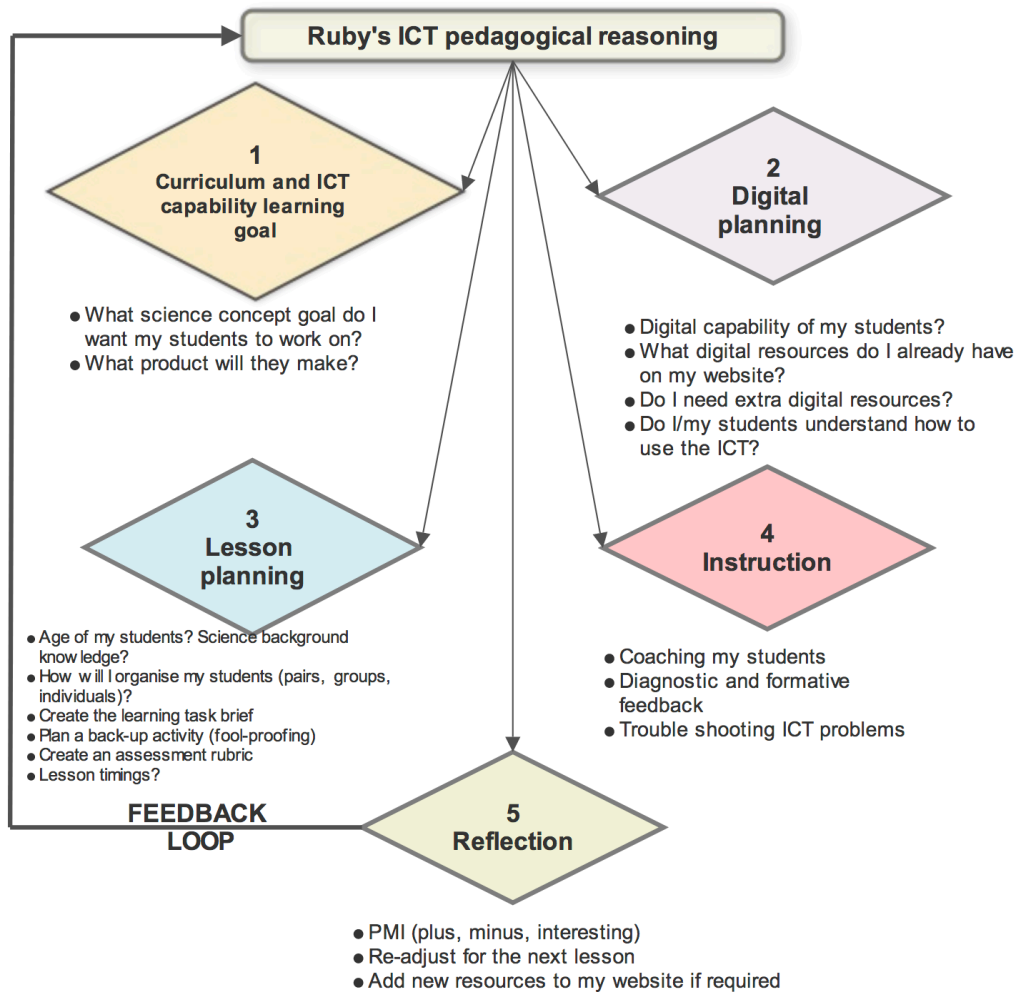


Figure 5.10: Ruby's ICT pedagogical reasoning process and actions

5.5 Chapter summary

A whole-to-part recursive analysis of the data sources revealed several key emerging facets of Ruby's pedagogical reasoning about the purposes for which ICT was used to engage students' interest, demonstrate their learning, and the teaching strategies observed. Ruby advocates a social constructivist approach to science teaching and learning (see Key Findings (KF) 5.4 & 5.5), where the learning goals centre primarily around the development of active citizenship, collaboration, creative and critical thinking skills. Ruby frames these skills and dispositions principally using the mandated science curriculum, along with the skills associated with the ICT general capability that frames

this curriculum as the context to drive these lifelong skills. In other words, the mandated curriculum forms a significant part of the context that drives the use for ICT in Ruby's classroom (see KF 5.5 & 5.13).

Active student use of ICT is fundamental to her classroom learning environment where she provides social media platforms for students to communicate their science creations to a wider audience (see KF 5.6). Knowledge production as mediated by ICT rather than knowledge consumption is Ruby's primary mode of use for ICT in the classroom (see KF 5.5).

Ruby supports students in the guided exploration of scientific concepts and as a creative tool for the communication of their scientific understandings by the meticulous preparation of task briefs and assessment rubrics (learning scaffolds) to support the quality of student work in the projects and challenges she sets (see KF 5.6 & 5.8). She also prepares 'how to use ICT guides' to support students' developing ICT capability in these endeavours. Ruby selects those ICT tools that are freely available via the web and sources ICT tools that do not have extensive registration requirements or passwords and checks that these ICT tools are not blocked by school firewalls (see KF 5.11). If ICT is used, it is chosen because fundamentally because it allows the students a learning affordance or relative advantage over traditional non-ICT resources (see KF 5.5).

Ruby's TPACK is extensive having created her own classroom website from scratch several years ago where it continues to evolve (see KF 5.7). Ruby curates all her digital resources on to this school sanctioned classroom website. These digital resources include an array of multimodal learning opportunities such as videos, games, and simulations and hyperlinks to authoritative scientific websites (see KF 5.6). Ruby spends lots of her personal time to filter and curate these ICT resources, primarily so that her students can access her curriculum flexibly at any time (see KF 5.8 & 5.10).

Ruby reasons that the aggregation of these resources into a single online open source serves primarily as a cognitive guide to direct students to quality online resources, and to support work flow in and outside of the classroom (see KF 5.6). In addition, Ruby also utilises various open source video and file sharing platforms predominantly for the dissemination of students' creations, aligned to her belief in the importance of knowledge contribution (see KF 5.4 & 5.13).

The overall instructional design of Ruby's lessons aligned to her beliefs of student-centered construction of science knowledge, where ICT is used as a tool to investigate, create, and communicate findings (see KF 5.10 & 5.13). Her practice involves engaging in meticulously explaining the task requirements at the commencement of a new project (see KF 5.10 & 5.12) leaving her then ample time to engage in dialogic teaching, coaching, and supporting her students. At times, the inability of her students to troubleshoot basic digital information storage strategies hampers her ability to engage in meaningful scientific content discussions (see KF 5.11).

CHAPTER SIX: The case of Patricia

This Chapter presents the final case study. The case study teacher presented in this Chapter is referred to by the pseudonym Patricia to protect and respect her identity. Overall this Chapter provides a descriptive and interpretive account of Patricia's beliefs in relation to ICT and how she pedagogically reasons and creates the learning environment to provide meaningful technology enabled learning experiences in a one-to-one student laptop environment. The Chapter begins by presenting the contextual factors pertinent to Patricia, as well as an account of her professional profile, beliefs, and pedagogical outlook, and is then followed by an analysis of three lessons. This data included face-to-face interviews, video-recorded lesson observations, school planning documents, teacher-planning artefacts, lesson observation notes, email exchanges, as well as a record of the array of software and digital learning resources that Patricia and her students accessed during the lesson observations. The contextual information presented at the beginning of this case study was mostly solicited from the participant during the initial teacher interview conducted at the commencement of this study. Background data pertinent to Patricia's school context presented in this case study was obtained from the School's public website and from the MySchool.edu.au website.

6.1 Data sources and analysis

Before the lesson observations began, an initial interview lasting around 80 minutes took place on site and was used to discuss the key purpose of the study as well as elicit information regarding Patricia's teaching background, pedagogical orientations, beliefs, and practices surrounding ICT for teaching and learning science. A tour of Patricia's classrooms then followed to determine the best possible video viewing position during the study.

To illuminate the pedagogical reasoning process employed by this teacher in planning for and reflecting upon the lessons observed, pre and post-lesson interviews were conducted on site. Patricia was emailed all interview questions approximately one week before an interview took place (see Appendix C); and, as with all interviews conducted in this study, the interviews were audio recorded and transcribed verbatim.

Artefacts associated with the observations such as: assessment rubrics, task briefs, including the technology that the teacher and students used during these observations, was also captured to help explain how Patricia designed successful ICT-mediated activity. The utilisation of multiple data sources gathered over the span of this study helped to capture the in-depth thinking and reasoning about teaching and learning with technology. A final member checking interview, lasting around 60 minutes was conducted to confirm the emerging themes in Patricia's ICT pedagogical reasoning and practices. During this final interview Patricia was asked to represent her general pedagogical reasoning process in the form of a diagram to illustrate graphically how she would typically design and teach technology enabled learning experiences.

Shulman's (1987) PRA model was used as an overarching lens to analyse these data sources to help reveal underlying themes for describing how this participant's reasoning affected the decisions she made in regards to the technologies that should be integrated, for which learning purpose, and how best to orchestrate the learning experience. Data were initially coded using the theoretical components as previously shown in Table 3.1. The first cycle of coding on the interview transcripts produced many representative phrases for describing this participant's thinking and representing her actions. These phrases were again coded into several code categories, for example; what key learning outcomes were being addressed; what key skills were being addressed; how was the physical learning environment organised; student organisation; student prior knowledge; what ICT tools were used and by whom; and, how did the teacher monitor the students learning. The analysis was further refined over several iterations where several codes were combined (e.g., various instructional strategy codes combined to become orchestration of the lesson) to reveal the key decisions most strongly influencing Patricia's pedagogical reasoning processes and practices.

To support this analysis each lesson was systematically coded on a minute-by-minute basis using a CHAT pedagogical activity matrix as discussed in Chapter 3, and summarised in Table 3.3. In particular, this micro-analytical strategy enabled the Researcher to decompose the actions and operations observed in each lesson to assist in the identification of how Patricia organised her students (e.g., whole class, group work, paired work, individual), the functionality of the ICT tool used, as well as help

characterise the role of the relationships observed between the teacher and the student (e.g., lecture, questioning, summarising) that shaped the activity of the lesson.

6.2 Professional profile and context

6.2.1 Professional experience

At the time of this study Patricia had been teaching science for 28 years. She is an Upper School ATAR Chemistry, Human Biology and Biology specialist teacher currently in a government metropolitan secondary school in Perth, Western Australia. She had taught at this site for over 20 years. Patricia holds a Bachelor of Science, a three- year Diploma of Teaching and a Graduate Certificate of Teaching. Patricia had also undergone extensive professional learning in gifted and talented education (GATE). She had completed all the Gifted Education Research and Resource Centre (GERRIC) training modules by the University of New South Wales.

Like Michael and Ruby, Patricia is also a *Level 3 Classroom Teacher*, a status that recognises her exemplary teaching practice in Western Australia. Patricia had also been previously nominated as a finalist in the Western Australian Science Awards for Science Educator of the Year. As part of the 0.1 full time allowance of time allocated to this *Level 3* status, Patricia regularly presents professional learning activities aimed at building capacity in science teachers and ATAR students. Patricia's remit is to help improve learning outcomes at both a state and national level at various science teacher's association conferences, including the local district Department of Education schools. At the time of the study Patricia was teaching Upper School ATAR Chemistry and Biology and Year 8 and 9 Academic Extension Program (AEP) students.

Patricia has been working with a cluster network of local feeder primary schools for the past 18 months to help develop their understanding of how to implement the new Australian curriculum for science, with a focus on improving science pedagogical content knowledge (PCK). Whilst working with this network Patricia identified a lack of understanding of key mathematical concepts and skills as barriers or gateways to engaging with the mandated science content. Subsequently she initiated a mapping exercise to scope and sequence key lower secondary science concepts and link these to the requisite mathematical skills. Her rationale for this exercise was firstly to demonstrate

how science provides a key context for the development of mathematical skills for these primary teachers, and secondly help support science teachers in her own department that were less experienced.

According to Patricia, this document will assist everyone in the district, “*to be on the same page with the Australian Curriculum*” (Initial teacher interview: 06/09/13). Furthermore, by making these mathematical and science concepts explicit she reasoned this would support teachers to help ensure students’ enjoyment of science and ultimately success. Shown in Table 6.1 is a sample from the draft version of this matrix which clearly reveals her extensive understanding of the mandated science curriculum content and its interrelationship and dependency on key mathematical skills.

Table 6.1: Mathematical and science concepts dependency matrix

Year	Mathematical concept	Science context	Thinking science reasoning pattern
8	Measurement accuracy	Measurement, scales, units, mass, length, time, temperature, liquid volumes	Variables Values
	Graphing	Input and output variables; data- quantitative and qualitative	Relationship between variables Prediction from graphs
	Graphing-line graphs, continuous data, set up of axes	Temperature vs. time X-axis independent variable Y-axis dependent variable	Graphing and interpretation
	Venn diagrams, classification, groupings	Mixtures, tissues, minerals, organism, ecosystem	Classifying Characteristics
	Ratio, proportionality, scale	Surface area: volume in relation to heat transfer, Size of animal inversely proportional to heat transfer, magnetic and heat fields, $R \propto 1/I$.	Proportionality, ratio, scale, scaling up, scaling down, direct proportion, inverse proportion
9	Probability	Small versus large samples, inheritance, needs of organisms	Probability and chance
	Correlation	Solar system models, Periodic Table trends, particle behaviours during changes of state, heat transfer, electromagnetic spectrum, explain chemical reactions, floating and sinking, density,	Formal modelling

Key finding 6.1 Professional teaching experience

Patricia is a highly experienced senior school ATAR Biology, Chemistry and Human Biology science specialist and is identified as a *Level 3 Classroom Teacher*; a status that recognises her exemplary teaching practices across all three domains of the AITSL Professional Standards for Teachers. She is highly regarded for her teaching prowess and most especially her PCK expertise, which is utilised by the local education district to mentor less experienced science teachers. Patricia is a presenter at many science-teaching associations and DoE district events.

6.2.2 School Context

Patricia teaches at a metropolitan government school, which supports Gifted and Talented (GAT) students in the Arts. The selective GAT process is coordinated centrally by the Department of Education. The GAT students are differentiated by this school upon entry into Academic Extension Programs (AEPs) for mathematics, English, humanities, and science. At the time of the study the School catered to students in Year 8 through to 12 and had an ICSEA score of one standard deviation above the median of 1000. The school has a high attendance rate, and the NAPLAN results are well above state and national averages, high completion rates of the Western Australian Certificate of Education (WACE), as well as academic success in the Year 12 final ATAR examinations. As with Michael and Ruby's school, Patricia's school had also become an Independent Public School (IPS) at the time of this study.

6.2.3 Curriculum context

Patricia uses the science curriculum mandated by the state curriculum authority (SCASA) as the basis for planning her teaching, learning and assessment materials for lower school which largely draws upon the Australian Curriculum: Science containing only minor local state variations (ACARA, 2015a). For her upper school ATAR Biology and Chemistry classes Patricia uses the state prescribed Upper School ATAR Science syllabi.

Science in lower secondary is timetabled as a standalone subject and is offered for four periods of one-hour duration per week, much like it is in most secondary schools in WA. The classes are further differentiated into either AEP or mainstream pathways for science. At the time of the study Patricia was the only teacher of the Year 8 and 9 AEP students, as such she planned the curriculum and the assessments for these classes by herself. The lessons featured in this case study were all observed in Patricia's Year 9 AEP class which she had previously taught in Year 8.

Key finding 6.2 Science curriculum planning context

Patricia uses the mandated science curriculum as the basis to plan and design her teaching, learning and assessment resources for all science classes.

6.2.4 School ICT environment

Students at Patricia's school in Year 9 to 12 had each been allocated a take home *MacBook Air* (13 inch) laptop. Patricia herself uses a *MacBook Air* (15 inch) laptop, which she leases from the DoE. Patricia also shared that most of her students owned smart devices. Patricia taught in rooms that were each equipped with short throw data projectors. The science department also had two teaching rooms with *SMART IWBs* installed, although she revealed there were often technical issues with the interactive side of these *SMART IWB* boards causing frustration amongst the staff. However, Patricia no longer taught in these venues, much preferring instead the students use their own laptops in the classroom anyway.

For some time, the School had been encouraging teachers to upload lesson artefacts, programs, and assessments to the local intranet in efforts to support collegiality, planning consistency and moderation. Students at the time of this study only had limited access to parts of the School's intranet however, efforts were being made to enable student access to view all teaching and learning resources. At the time of the study the School's intranet was not a Learning Management System (LMS) system as such, instead more like a content management system (CMS).

Patricia stated the school intranet had been converted to run both *Window* and *Macintosh (Mac)* machines, however, she found the interoperability less than reliable. As

a *Mac* user, she found uploading documents to the school intranet was still highly problematic. Despite her persistence in engaging with the school's intranet she reported that, "*I am happy to say I have given up using the [School's] intranet*" (Initial teacher interview: 06/09/13). Instead was given approval by the School's executive team (several years prior to this study) to create a classroom wiki for her senior school ATAR students, along with a classroom website for her lower school students. It is worth noting that both these digital platforms were not hosted on the School's server, instead Patricia completely manages them. As taken directly from Patricia's classroom website she offers a succinct rationale for all users; "*This class website allows all students to access their learning, even though they may be absent from class. Parents are able to keep track of the type and quantity of work that their children are to complete*". A fuller description of the pedagogical purpose and structure of: *Mrs.Patricia-Science.weebly.com*. — is offered later in this Chapter.

Alongside her classroom website and wiki, Patricia had explored other digital platforms including *Instagram*, hoping she could extend teaching and learning opportunities and support a connected community of science learners, inside and outside the classroom. By adding questions to anonymous photographs taken of her classroom activities, Patricia's "*idea was to revolutionise the use of Instagram... and expecting students to comment with the answer*" (Initial teacher interview: 06/09/13). Instead she found only superficial uses by the students stating, "*they might like a photo but they didn't say anything*". (Initial teacher interview: 06/09/13). Patricia shortly abandoned the *Instagram* platform, and whilst she was careful to make this a public account and only posted scientific photos, she was concerned at the possibility of her public perception of relating to students via social media.

Because of an internal upgrade on the School's main server, data collection during this study was suspended for a period of one term. This was because the School, like many WA DoE high schools at this time was about to rollover to a new standard operating environment known as *SOE4*. The rationale being this upgrade would reduce the number of school server networks required, improving efficiencies resulting in savings overall for the DoE. During this change over period Patricia reported access to the School's Wi-Fi networks did not exist causing her to abandon student use of laptops during class time. Instead she reported returning to using her laptop for teacher-directed

lesson activities, even on occasion having to use her own mobile phone as a hot spot to gain access to the Internet. Patricia emailed a photograph of her students taking notes during this period of down time captioning the photograph ‘21st century note taking’!

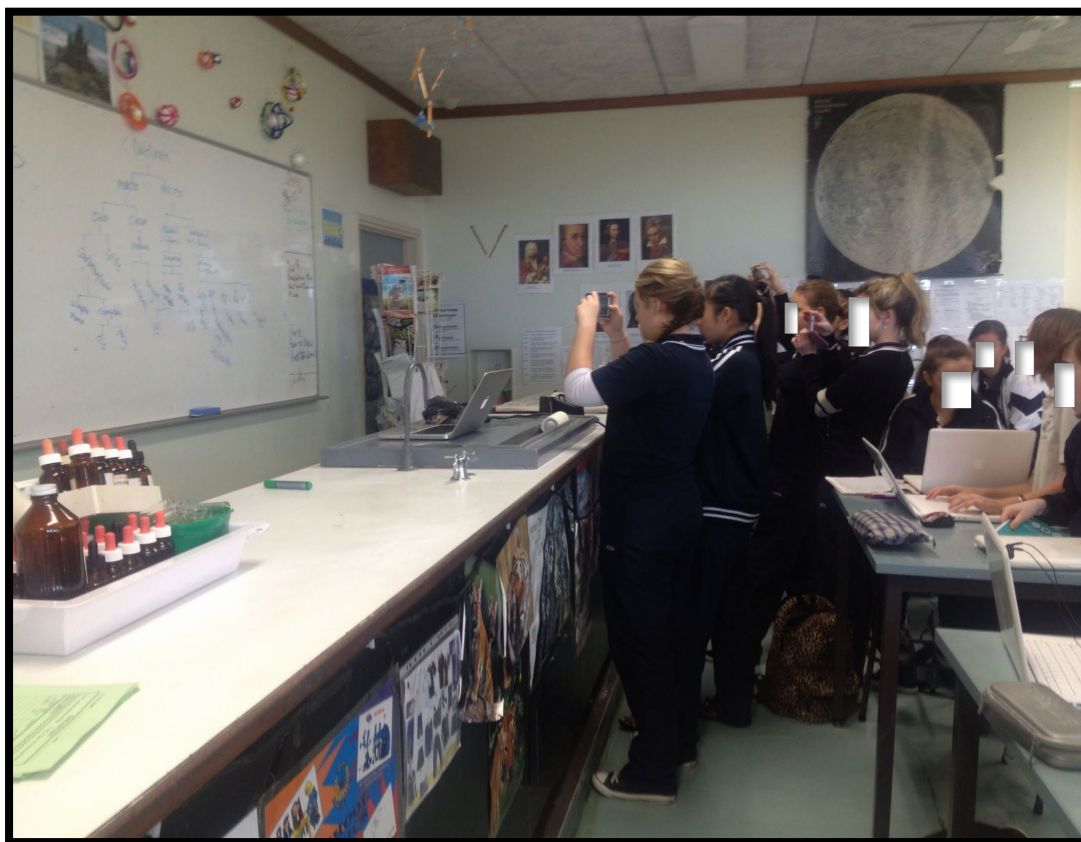


Figure 6.1: 21st century notetaking. Photo taken by Patricia (11/09/13)

With the Australian Government’s announcement to cease the National Secondary Computer Fund in 2013 this school was moving to a bring your own device (BYOD) policy. The School’s BYOD policy did not mandate a device *per se*, however, did highly recommend the continuation of Apple devices e.g., *iPad* (Wi-Fi only), *Apple MacBook Air* or *MacBook Pro*. However, other brands were permitted. For those students, unable to bring their own device the School offered *MacBook*’s, *iPads* and *Window* supported loan laptops at the discretion of the teacher.

Patricia was keen to point out that the classroom architecture and furniture had not kept pace with the change to the ubiquitous presence of digital devices in the room, especially lacking charging areas. Heavy cumbersome desks, in some cases fixed benches, were still the norm in the classrooms she taught in. Her timetable arrangement meant that most of her classes were offered in different rooms, “*generally in the day to*

day you are just running from class to class, running from room to room. I just tend to keep it the same [room layout] because the next teacher wants it the same" (Initial teacher interview: 06/09/13).

Key finding 6.3 School ICT context

The School operated on a one-to-one ratio of laptops on a take home basis for each student in Year 9 to 12. The School had chosen to adopt *MacBook Air* (13 inch) laptops for this purpose. Patricia leases a *MacBook Air* 15" laptop via the DoE for use in her classroom. Patricia was given approval by her executive to operate her own classroom website which did not sit on the School's server. Most of Patricia's students owned a smart device.

6.3 Patricia's beliefs, values, and pedagogical outlook

Patricia was keen to point assert that fundamental to her approach to teaching science is the belief that students should enjoy science whilst learning key scientific ideas:

It has to be enjoyable and in that I try to use that enjoyment and youthful exuberance into building concepts and then try to temper it down by using the resources I have, like texts and the Internet... it's about building concepts, linking, and seeing relationships (Initial teacher interview: 06/09/13).

As well as a desire to promote scientific ideas, attitudes and capabilities Patricia also revealed her aims included developing student's independence, "*the 21st learner independent learner who's comfortable with all the learning resources that they have on offer and one that has a love for learning*" (Final teacher interview: 08/12/15). Having taught across two centuries Patricia explained ubiquitous access to the Internet meant that students "*have more opportunity to take control of their learning...the tools are instantaneous...both information and the ability to produce things like documents and movies*" (Final teaching interview: 08/12/15).

Patricia explained as part of her pedagogy with Gifted and Talented (GAT) students, was an important focus on both diagnostic and formative feedback. To assist in differentiating the curriculum for GAT students she regularly employed diagnostic evaluation as a tool before the commencement of a new topic of study. This strategy allowed Patricia to better provide academic acceleration to meet the needs of these academically able students. For Patricia a significant affordance of one-to-one ICT access meant her students could access her classroom website which included her entire portfolio of curated digital learning activities and ICT resources across every science topic she teaches. This also included the extension activities she had designed over the years for her GAT students.

To assist in providing rich and frequent face-face feedback to Patricia established most of her classroom activities so students worked collaboratively, justifying when students are working in collaborative groups:

I can go and visit each group and listen and understand how students are thinking. It also reduces class size in effect because if you're doing a directed lesson you're really talking to one unit of people. So that's one end of the spectrum where you've got one unit; you're talking to them but you have no idea what they're thinking. The other end of the balance would be one-on-one tutoring...So, we have to work somewhere in the middle. So, I try and get them into say 10, 12 groups so that's only 10 or 12 entities that you have to react with, and within that of course you listen to everybody within that, but it's like a balance. Okay, life and work are about social interaction as well so that's helping people work together and share their ideas in a small safe group. Yes, collaboration allows students to demonstrate their thinking and discuss concepts. (Final interview: 08/12/15)

Critical to Patricia's approach and success in teaching science was understanding and appreciating the nature of her students as learners. The artistic nature of many of the students selected for the Arts programs at her school meant that the, "*students were predominantly visual or kinaesthetic thinkers*" (Final teacher interview: 08/12/15).

Patricia explained that her willingness to pioneer the uses of ICT at her school was driven by several factors:

So, this multiplatform nature of ICT, how you can use it to connect to the web for research or to use it to build things like movies or documents of spreadsheets, that really can be useful and satisfying the requirements of our learners. Also, our learners use their mobile devices as an extension of themselves...They're attached to them so why not try and harness that energy and that interest that they already have and try and channel it into an educational interest, because I know the theory says that they use those devices for social interaction but not education interaction (Final teacher interview: 11/12/15).

Patricia stated that whilst student use of ICT “*is mandatory, that reason is bottom of my list*” (Initial teacher interview: 06/09/13). She indicated that student use of ICT during lesson time was far more relevant than her own pointing out that, “*it's important for students because that is their world. That's their extension, that's their future, that's how they'll be working so we all have to feel comfortable using it*” (Final Teacher interview: 08/12/15).

Patricia’s interest in using ICT in the classroom had been piqued since participating in an Apple conference in 2010, a professional learning activity she had initiated herself. Patricia remembers a keynote speaker at this conference who inspired her to make the use of ICT in her classroom ambitious stating, “*to me this meant, use ICT to build a wiki...rather than just word processing*” (Final teacher interview:11/12/15). Patricia remarked on how the conference was conducted:

Inviting for group interaction...inviting reflection...the audience were free to explore while listening to the speaker, so his ideas were being backed up in the minds of the individuals as they used their devices. Audience members had a choice about how to engage with the speaker. I found this concept very powerful, and very different to how a classroom traditionally operates. It fitted with my pedagogy of guiding individual students to

reinforce their own learning in their own way. I aim to enhance student learning by providing different opportunities for students to engage, explore, explain, elaborate, and evaluate their work (Final teacher interview: 08/12/15)

This Apple conference fostered a deeper interest in the educational affordances of ICT and specifically led Patricia to exploring the development of her own classroom wiki; a type of collaborative website that invites users to create content and share resources around a specific purpose. Patricia developed her first classroom wiki using a free wiki builder and hosting service called *Wikispaces* (now defunct) for use with her senior school ATAR Biology students. In launching her wiki, she soon realised that her students required educating in ‘netiquette’ and established a set of wikis posting rules which included; not being able to use the site as a chat room; acknowledging scientific sources; staying on topic; including an identifiable username and using appropriate language.

Patricia views wikis as a valuable classroom community resource particularly for students with disabilities. Patricia explained that one of her Year 11 ATAR Biology students is profoundly deaf so she would “*write or script my lessons or at least have the main points on the wiki*” to guide this student and the education assistant throughout her lessons (Initial teacher interview: 06/09/13). Patricia noticed that in more recent times, the use of her wikis had diminished, a fact she put down to, “*perhaps being old hat now*” (Initial teacher interview: 06/09/13). However, she explained she was still willing to persist due to the significant learning benefits she had observed such as students posting, “*comments and questions and discourse, discussion pages for things like anthropogenic climate change*” (Initial teacher interview:06/09/13).

Throughout this study Patricia was keen to elaborate on the rationale for the use of her classroom website as a means of extending teaching and learning opportunities. She explained the original intent of establishing this website was in keeping with the pedagogy of the flipped classroom model; however, early feedback from her students indicated that they were not engaging with it this way. As many of her students participated in extracurricular arts activities, having anytime and anyplace access to her virtual classroom was a significant organisational benefit. Parents appreciated the

transparency as well. For Patricia fundamentally, *“it is a place for me to build lessons and to store my pedagogy...it’s a multidimensional platform so I can load up many tabs rather than a linear experience which allows me flexibility of response to student ideas, questions and constructs in my lessons”* (Final interview: 08/12/15).

Key finding 6.4 Views on teaching and the role of ICT for learning science

Patricia’s views on learning science align with a social constructivist perspective. Patricia fosters engagement with the ‘big ideas of science’ preferring to build scientific concepts through collaborative group structures enabling her to interact with all her students and for students to share their thinking. She positions ICT as a ubiquitous and natural part of her student’s world and this underpins much of the rationale for using ICT in her classroom. Patricia situates one-to-one ICT access as fundamental to her science classroom learning environment where students use ICT to learn how to collaborate in an academic space; explore information; use technology for problem-solving and critical thinking; and use a wide variety of media tools to explain their understandings to position students for success in life and in their future careers.

After experimenting with the use of wikis with senior school ATAR students Patricia sought permission to create a website for her lower school students using a popular free website builder known as *Weebly™*. *Weebly™* offers the website creator page templates with a simple drag and drop interface and the incorporation of elements such as photo galleries, slide shows, *YouTube* videos, *Google Maps*, PDF’s, and word documents. Patricia justification for this website builder was its simplicity and the ability to allow online editing from anywhere, *“I like to be able to have an idea and just get rid of it instantly and build a new page or build new resources into the lessons”* (Initial teacher interview: 06/09/13). Patricia purposefully made her website publicly available with no limiting password restrictions, *“my website is a shared resource...it’s our shared learning environment”* (Final teacher interview: 08/12/15). The website had already attracted over 26 000 unique hits at the time of this study.

Like Ruby, Patricia indicated that she views her website as a virtual classroom, primarily serving as a repository of her classroom curriculum resources. She uses her website as a launching pad for most of her lessons. Patricia explained that whilst a

plethora of educational content exists on the Internet”, *if you pick up anyone else’s lessons or work it’s not quite what you want and there’s always something wrong with it and that causes more problems, it takes away the focus the concept you’re trying to teach*” (Initial teacher interview: 06/09/13). Instead Patricia builds her own digital curriculum materials using the mandated science curriculum to plan and design her own learning activities and assessment tasks.

Shown in Figure 6.2 is the design and layout of Patricia’s website landing page serving primarily as an organisational tool and as a bulletin board for key pertinent classroom information (e.g., news feed, homework, study skills guides, text book information, competition details etc., and weekly unit outlines). Patricia indicated that this landing page offered significant organisational advantages, especially for absent students and for students to keep up to date with assessment deadlines. Patricia also runs her own science blog on this website covering topics from astronauts to volcanoes, as well as featuring articles on historical scientists revealing her significant disciplinary knowledge of science. Students can email Patricia directly via this website with science queries and can subscribe to an RSS Feed (Really Simple Syndication) allowing students a quick way to keep up to date when Patricia adds new content. Patricia suggested that being able to provide relevant and applied curriculum in one central repository meant her students could access this at any time and from anyplace. For Patricia this was one of the most significant advantages of having her classroom website and worth the time it took to maintain this facility.

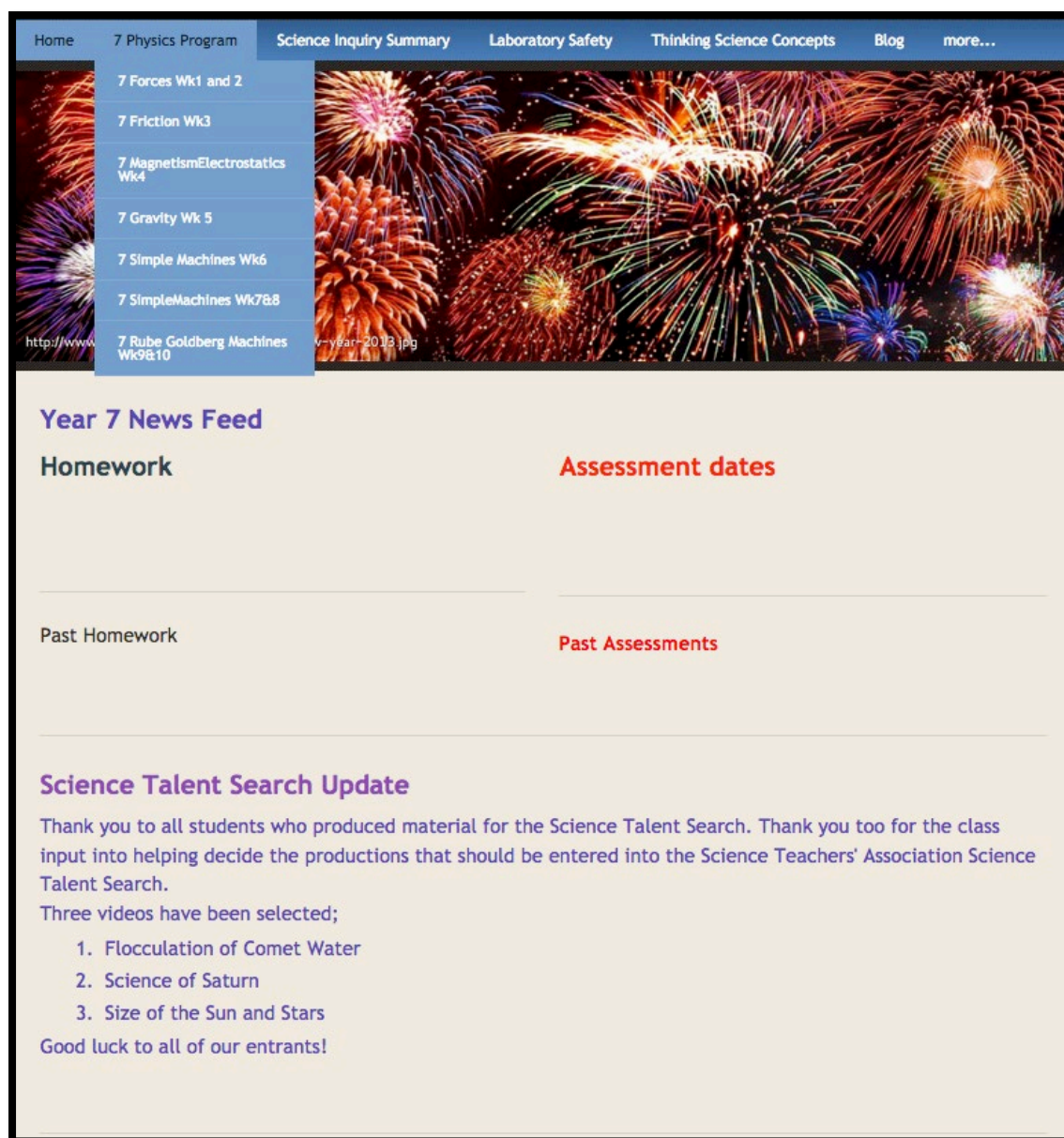


Figure 6.2: The landing page of *Mrs.Patricia-Science.weebly.com* website

Patricia's website contains a plethora of contemporary digital teaching and learning resources, organised and classified using a navigational menu across the top of the landing page. To navigate to these activities Patricia first categorises theme by year groups, delineated further into sub-parent folders using the four science content areas of the (ACARA, 2015a), that is; Biological, Chemical, Physical and Earth Sciences (see Figure 6.3). Within each of these subject areas she delineates these further into year group folders e.g., Year 9 Earth Science Program. Patricia provides further navigation by

creating weekly learning folders for each of her classes containing task briefs, assessment rubrics and a host of curated ICT resources. Shown in Figure 6.4 is an example of a Year 9 weekly learning folder.

9 Program Earth	>	9 Earth Structure Wk1
9AEP Chemistry Program	>	9 Earth Structure Wk2
9 Physics Program	>	9 Earth Structure Wk3
9AEP Biology Program	>	9 Volcanoes Wk4
8 Inquiry Program	>	9 PlateTectonics Wk5
8AEP Chemistry Program	>	9 Perth Basin Analysis Wk6 & 7
8 Biology Program	>	9 Fossils Wk8
8 Earth Science Program	>	9 Geological Time, Fossils Research Wk9 & 10
8 Physics Program	>	

Figure 6.3: Navigational menu by year group, by topic and then weekly activity folders

[Home](#)
[7 Physics Program](#)
[Science Inquiry Summary](#)
[Laboratory Safety](#)
[Thinking Science Concepts](#)
[Blog](#)
[more...](#)

http://www.pdoyes.com/images/contests/pasturelands/fullsize/Earth-layers-983f86cce087_hires.jpg

Week 2 Earth Structure

Task 1

Order the materials from least dense to most dense.
 Discuss how this order of density relates to the structure of the earth.
 Watch the video embedded below and make a diagram to summarise the information.
 Write down any questions that you could ask to clarify ideas.


Task 2 Watch the embedded video below

DYNAMIC EARTH: Earth Structure

DYNAMIC EARTH

<http://museumvictoria.com.au/melbournmuseum/discoverycentre/dynamic-earth/videos/earths-internal-structure/>

Task 3 Review of Rock-Forming Minerals and Igneous Rocks



<http://i.a.123rf.com/406wm/402/402/123rfstock/123rfstock1202/123rfstock120200014/12431307-seamless-granite-texture.jpg>

Observation of the Igneous rock Granite.

Use a binocular microscope to observe the granite sample. Note the colours, crystal size and any other features that you can.

Use the worksheet below to make detailed observations of the common rock-forming minerals. Measure the mass and volume of each mineral and then calculate the density of the minerals using the formula;

$$\text{density} = \text{mass} / \text{volume (g/cm}^3\text{)}$$

Common Rock-Forming Minerals

Figure 6.4: Exemplar of a weekly learning task for Year 9 Earth Science

In reviewing Patricia's curated resources there is a direct correlation to the content of (ACARA, 2015b). However, it was noticed that the design of Patricia's tasks aligned to a level of science inquiry skills more consistent with the achievement standards for the year above, probably expected given the academic nature of her cohort. Patricia explained an affordance of having her own website is the ability to take photos and videos of in-class work and post these immediately so students may continue working on these tasks outside of the classroom (see Figure 6.5).

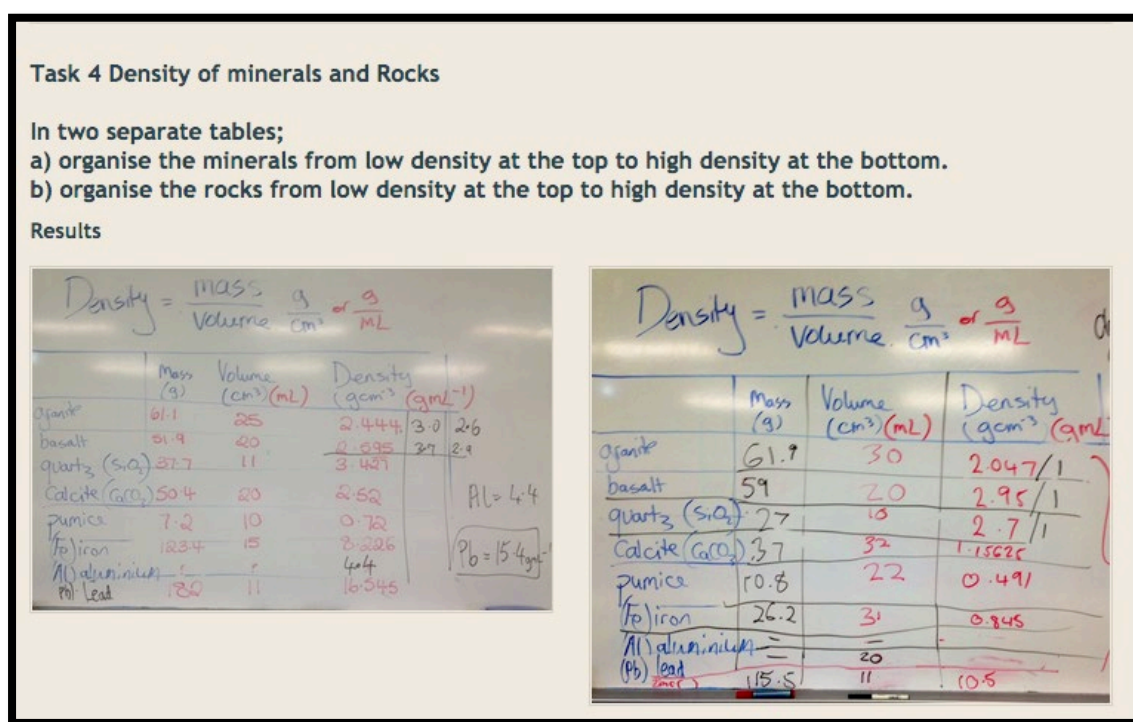


Figure 6.5: Photograph of classroom earth science data as posted on Patricia's website

Many of the digital resources that Patricia curates are interactive, including a plethora of simulations, games, and tutorials that would support self-directed learning. However, Patricia vehemently states, “it’s just not acceptable just to send students off to research a topic with no guidance about where to go or what’s valuable or what’s good” (Final interview: 08/12/13). To this end Patricia produces elaborate scaffolded tasks including assessment rubrics with defined criteria for success. She locates these learning scaffolds inside the weekly learning folders for flexibility of access both inside and outside of the classroom. As with Michael and Ruby, Patricia also felt the vast and

evolving range of freely available multimedia tools available via the Internet meant offered students more agency to express and communicate their scientific understandings in creative ways. According to Patricia, this was a critical affordance of the one-to-one laptop program as students now had, “*the ability to produce things like documents or movies. I mean that was never an option when I was at school*” (Final teacher interview: 08/12/15).

Key finding 6.5 Curation of digital curriculum resources onto open source school sanctioned classroom website

To help facilitate the meaningful use of ICT Patricia curates a plethora of free digital curriculum resources selectively drawn from the Internet and houses these on a school sanctioned website. Patricia custom-made this website using a free website maker tool. Patricia’s classroom website also enables students to flexibly access a vast range of multimodal, authoritative, and interactive digital instructional materials. The website is not password protected. Having anytime and anyplace access to her curriculum is a key part her rationale for creating and maintaining this website, along with the associated classroom organisational benefits. Importantly as well, centralising her curriculum resources into a single online platform helps to model and direct students to quality Internet based resources. Patricia also further scaffolds her students work with weekly learning folders containing task guides to support workflow both in and outside of the classroom. Navigation on her website is facilitated by arranging the folders into year groups according to topics as stipulated by the mandated science curriculum key learning areas.

Patricia explained that her technological knowledge and skills have been essentially self-taught by attending a range of professional learning workshops of which she initiated herself. She used ICT to watch *YouTube* videos to teach herself how to use specific applications such as *Garage Band* and *iMovie* and by subscribing to a variety of educational technology blogs. She enjoyed integrating ICT in the classroom and explained that this process had been, “*a logarithmic journey*” (Initial teacher interview: 06/09/13). However, creating her own wiki and classroom website to extend teaching and learning opportunities was not necessarily a view supported by everyone in her

department, making the ICT integration journey somewhat isolating at times. At the time of the study Patricia was the only teacher operating her own classroom website, *“I think I’m a special case, so I feel a bit lonely at times”* (Initial teacher interview: 06/09/13).

Patricia felt that she was still learning how to manage the classroom when all the students were working on their laptops worrying that, *“when the smiles come I don’t think they are on my website and I run around and still have to look at their screens!”* (Initial teacher interview: 06/09/13). Exacerbating her tension was that Patricia had to conduct her teaching across several different rooms, making it difficult to determine vantage points and monitor the class. Furthermore, moving from class to class meant logging in over and over again and in some rooms, she regularly found the Wi-Fi access was not as robust.

Key finding 6.6 Technological pedagogical content knowledge

Patricia’s technological capability is extensive and self-taught, having created her own wiki and classroom website from scratch several years ago. Patricia is authorised to use these virtual classrooms instead of the School’s intranet. She demonstrates considerable technological skills requiring substantial preparatory effort to build and maintain these websites for the benefit of her students. Overall, she reasons that the use of ICT is a natural part of the student’s world and therefore should be used. Patricia continues to remain interested in pursuing her own technological skills to maintain her relevance in the classroom, and for the benefit of her students. Patricia has created a vast quantity of tasks that integrate ICT into the lesson activity, and has curated a huge catalogue of multimodal and interactive digital resources to her website.

6.4 Lesson Observations

An analysis of the key decisions, as well as the teaching and learning practices for each of the lessons observed is now presented. Each lesson is presented separately using data derived from the pre-lesson interview, teaching artefacts, the lesson observation, including the post-lesson debriefing session.

6.4.1 Lesson one: Theme Year 9 AEP Getting into the fossil record

6.4.1.1 Pre-lesson interview

The lesson observed with Year 9 AEP students was part of an intended series of geology themed lessons. Patricia hoped her students would learn earth science and some biological sciences content during this sequence of activities whilst also becoming more sophisticated users of ICT. More precisely, Patricia indicated she wanted her students to learn how to:

Enumerate and differentiate the kinds of fossils. Look into the different ways to preserve fossils and elaborate on the need of various types of fossil preservation. Explain the importance of the existence and the preservation of the fossils and appreciate that extinction of species is common. Practise navigating multiple websites, downloading, sharing, editing, and filing documents (Pre-lesson interview: 27/11/13).

Specifically, in this lesson Patricia had planned an activity to introduce students to the formation of fossils; to appreciate how fossils can inform our understandings of past environments and the evolution of species. She also hoped the students would draw upon their previous understanding of the geological processes that helped to shape the Earth and geological timescales in this sophisticated learning activity. Patricia's extensive knowledge of the science in the mandated curriculum is demonstrated in the construction of this learning activity. It is clear that this lesson activity maps directly to the mandated Year 10 Biological Sciences curriculum where students are expected to understand, "The theory of evolution by natural selection explains the diversity of living things and is supported by a range of scientific evidence" (ACARA, 2015a). This activity also maps to Year 9 and 10 Science as a Human Endeavour strand where: "Scientific understanding, including models and theories, are contestable and are refined over time through a process of review by the scientific community" as well as the Year 9 Earth Science strand where: "The theory of plate tectonics explains global patterns of geological activity and continental movement (ACARA, 2015a). Patricia indicated that when designing her ICT enabled activities, she composes them of several tasks (see Figures 6.6, 6.7, 6.8, 6.9 &

6.10) that usually follow an activity pattern after the 5Es approach (Bybee et al.'s, 2006); that is engage, explore, explain, elaborate, and then evaluate.

As part of this lesson, she planned for students to take a diagnostic test to determine their prior knowledge. This diagnostic test had already been posted to her website prior to this lesson (see Figure 6.6), however, Patricia indicated she always made some hard copies available indicating some students preferred to make pen and paper notes. Overall the clear majority of Patricia's cohort made notes using their laptops. She planned to commence the lesson by engaging the students using an image of a famous opalised Australian Pliosaur (i.e. an extinct clade of marine reptiles—Pliosauroids, from the Jurassic and Cretaceous periods), known as 'Eric'. Eric had been found in Coober Pedy, South Australia. Following this introduction, the students would be directed to an external university-based website to research a range of fossils.

The students were to be guided in this research task by a set of focus questions that she had designed (see Figure 6.7). As part of her practice Patricia checks any website she plans to direct students too, to ensure the reliability of the content and to ensure that hyperlinks are not broken.

Getting into the Fossil Record
Pre Test and Post Test
Year 9

Name _____

Directions:

Pre Test

Date _____

Please answer each of the following questions. If you do not know the answer, just leave it blank.

Post Test

Date _____

You will be asked similar questions after you complete the tour. Add notes to your answers so that you can see how much you have learned!

- 1. What is a fossil?**

- 2. Preserved bones and tracks are two types of fossils. Describe three other types of fossils.**

- 3. Which is most likely to fossilise: a clam or a jellyfish? Explain your answer.**

- 4. Explain why a quick burial is helpful in the fossilisation process.**

- 5. In what type of rock would you most likely find fossils? Circle the best answer below.**
 - a. igneous
 - b. metamorphic
 - c. sedimentary
 - d. all of the above

- 6. Once a fossil has been formed, it still might not become part of the fossil record. Describe two natural processes that might destroy the fossil.**

- 7. Of all the organisms alive today, what percentage do you think will eventually become fossils? Circle the best answer below.**
 - a. Less than 10%
 - b. 10-25%
 - c. 25-50%
 - d. More than 50%

Figure 6.6: 'Getting into the fossil record' diagnostic test

Other than taking the diagnostic test individually, she would encourage the students to work in pairs on the inquiry task, indicating that in her opinion, “*the ideal situation for collaborative work is with one partner connected [to the Internet] and the other recording and sharing*” (Pre-lesson interview: 27/11/13). Like with most of her classroom activities, Patricia expected students to use her classroom website as the launching pad. She also expected students to download the ‘Getting into the fossil record’ task onto their own laptop and save any work-in-progress into a science folder as part of building their geology portfolio for this term. She felt that given the students were AEP, posting several weeks’ worth of tasks on her website gave them the option of working in a differentiated and self-directed manner.

Getting Into the Fossil Record

Focus Questions Year 9

Name: _____

Directions:

Answer the following questions as you navigate through [*Getting Into the Fossil Record*](#). You will be allowed to continue with the navigation only after you complete each task on the webpage.

You may complete this document electronically or answer as full sentences by hand in your geology portfolio.

- 1. What kinds of questions can the fossil record help us to answer?**
- 2. Describe the difference between a body fossil and a trace fossil.**
- 3. Why are organisms that are buried rapidly more likely to fossilize than those that are buried slowly or not at all?**
- 4. Describe two ways an organism can become a fossil without being buried in sediment.**
- 5. How does the environment affect the formation of fossils?**
- 6. Describe three factors that could prevent an organism from long ago from ever turning up in a fossil collection today.**
- 7. How are geologic maps useful to paleontologists?**
- 8. In your own words, explain why the fossil record is not complete.**

BONUS: You have been hired by National Geographic Magazine to journey to Inner Mongolia in search of fossils. You have the good fortune to find a site filled with many fossilized leaves, teeth, bones, eggs and even footprints from a variety of creatures. Amidst this treasure trove of ancient life you find no trace of insects. Your research partner concludes that no insects lived here at that time. What other hypothesis might you suggest to your partner?

Figure 6.7: Focus questions to guide students in the 'Getting into the fossil record' task


Following the School's server and network upgrade Patricia was still concerned about connectivity being an issue in this lesson, explaining she still had many students

struggling to connect on a consistent basis.

6.4.1.2 Lesson one observation

Patricia taught her Year 9 AEP students in a typical science classroom laboratory lined with perimeter benches with integrated sinks, glassware, and gas taps. The students sat at tall benches on lab-stools, which had been arranged into rows allowing for two students per bench. The walls were covered in student work as well as scientific posters displaying many famous scientists. A magazine stand loaded with science literature filled the corner of the room. Before the students arrived to class she had already connected her *Mac* laptop to the data projector and had navigated to the fossil's classroom webpage featuring 'Eric', a short necked Pliosaur (see Figure 6.8). Patricia indicated that setting up her ICT tools before the students arrived was part of her normal classroom routine.

As the students arrived they automatically began to log on to their laptops and navigate to this same webpage awaiting Patricia's further instructions. As this happened complaints arose from several of the students stating they could not connect to the Internet. Patricia intervened requesting that these students sit next to someone whose laptop was able to connect. Patricia explained that the School's IT Department had supplied a 'patch' meant to help resolve the student Wi-Fi connection issues and handed this around.



<http://australianmuseum.net.au/image/Skeleton-of-a-small-pliosaur/>

Getting into the Fossil Record

Information

"Eric" was a small, short-necked Pliosaur and was discovered by an opal miner in Coober Pedy, South Australia in 1987.

'Eric' is one of the most complete opalised vertebrates known and became part of the fossil collection of the Australian Museum in 1993 after money to purchase the specimen was raised by the schoolchildren of Australia (with the help of Akubra Hats).

Eric' is currently on display at the Australian Museum.
<http://australianmuseum.net.au/Omoonasaurus-democyllus>

Questions

Where is Coober Pedy?
https://maps.google.com.au/maps?q=Coober+Pedy&ie=UTF-8&ei=iSiVUuj1FYbhkgXEw4DYDA&ved=0CAoQ_AUoAg

What type of animal is a Pliosaur?

What inferences can you make regarding the habitat of the Pliosaur?

What clues do the habitat of the Pliosaur give to the type of environment that existed around present-day Coober Pedy?

How is opal formed?
<http://www.opalsdownunder.com.au/learn-about-opals/advanced/how-opal-formed-geology-opal>

Figure 6.8: Patricia's fossil webpage featuring 'Eric', a short neck Pliosaur

After taking the student roll call she began the lesson by directing the students' attention to a photograph of 'Eric' on the banner of her fossil webpage, using this image to engage her students:

ST 1: Miss, is that a platypus?

T: [laughs] Why did you say it looks like a platypus?

ST 1: Because it has beak and it looks sorta like it's got flippers.

T: Well let's put it in context. If you were to describe this to someone that could not see what would you say? What part of its body is it?

ST 2: It's a skeleton Miss. It's got ribs, a tail, and a head

ST 3: It's got a backbone.

ST 4: It's called Eric Miss, it's called a Pliosaur

T: [laughs] So, is it mammal? Is it a reptile? What else could it be if it has got a backbone? Let's look at what we have got to start with. Look at the limbs. Has he got all the bits to his limbs?

ST 5: No. Miss it's a reptile.

T: This famous little fossil was found in Coober Pedy in South Australia, how about you click on that map link to see what Coober Pedy looks like now [students navigate to the map].

T: So, you have established this fossil might be a reptile and might have flippers.

ST 6: Back in the day, in Pangaea there may have been a lake Miss.

ST 7: But how did Eric get in the middle of the land?

T: Mmmm, how did he get there?

ST 6: Maybe there was changing sea levels back then?

T: There's a few good ideas floating around here.

T: Yes, so really this little fossil can in fact tell us about the different kind of past environments that existed. If you want to see what he looks like we can take a look on this museum website link to where he is now stored [models how to locate the website.]

STs: collective ooo's.

ST 8: He was streamlined Miss

T: Yes, that's brilliant, yes, he was.

ST 9: How big was he, there is no scale on this picture?

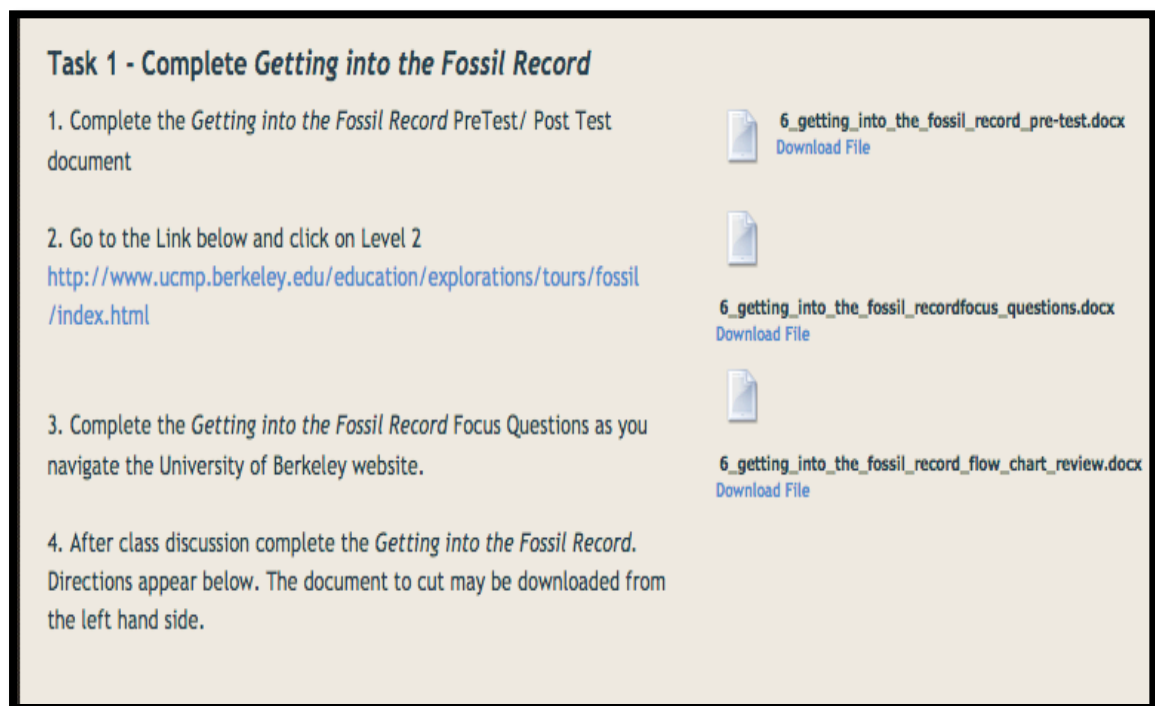
T: You are absolutely correct. Well lets' find out.

ST10: Miss, I have found a link to when South Australia had different sea levels to now.

T: Ooo, well come and write that on the board and share that with the group. (Lesson one observation: 27/11/13)

During this introductory phase the students were noticed to navigate to the various hyperlinks Patricia had pre-loaded to her website, however, at no point where they disruptive. After the class discussion about ‘Eric’ Patricia instructs the students to look at the requirements of Task one (see Figure 6.9) and continues to explain the requirements of the lesson which included taking the diagnostic quiz. Patricia then directed students to download the focus questions and use these to make comprehensive research notes about the concept of fossilisation from a website called *Getting into the fossil record* found at: <http://www.ucmp.berkeley.edu/education/explorations/tours/fossil/index.html>.

Patricia also explained that she would collect up the diagnostic quiz throughout the lesson to determine the existing level of knowledge.



Task 1 - Complete *Getting into the Fossil Record*

1. Complete the *Getting into the Fossil Record* PreTest/ Post Test document
2. Go to the Link below and click on Level 2
<http://www.ucmp.berkeley.edu/education/explorations/tours/fossil/index.html>
3. Complete the *Getting into the Fossil Record* Focus Questions as you navigate the University of Berkeley website.
4. After class discussion complete the *Getting into the Fossil Record*. Directions appear below. The document to cut may be downloaded from the left hand side.

6_getting_into_the_fossil_record_pre-test.docx
Download File

6_getting_into_the_fossil_recordfocus_questions.docx
Download File

6_getting_into_the_fossil_record_flow_chart_review.docx
Download File

Figure 6.9: A view of Patricia’s website showing *Getting into the fossil record* project

After taking the quiz individually the students automatically begin to work in pairs to view the animations, videos, images and listen to the tutorials available at this comprehensive website. For the remainder of the lesson Patricia moved constantly, interacting with small groups of students to prompt discussion about the quiz and to discover what they were learning about fossilisation. She noticed that at least one-third of

the students did not have a laptop for this lesson and that several issues ensued with connecting to the Wi-Fi. This prompted Patricia to allow one pair of students to use her laptop and to send two more pairs to the library to use the library's desk top computers.

Key finding 6.7 Extensive lesson preparation and curation of resources

Patricia had carried out extensive transformational preparation for this ICT mediated lesson, which involved a challenging learning purpose. The context and achievement standards expected in this activity were derived from the mandated science curriculum, except in this instance Patricia had challenged the students by aligning this task to Year 10 level Biological science, Year 10 level Science as Human Endeavour including some Year 9 Earth and Space science curriculum requirements. The structure of the tasks meant that students could demonstrate a high level of scientific understanding, as suited to the academic nature of this cohort. Students were expected to interpret, analyse, and synthesise information sourced from the Internet, however, had agency to do this in digital or written form. The task resources were all accessible via Patricia's classroom website ensuring flexibility of access inside and out of the classroom. She had also populated her website with additional extension opportunities.

The overall instructional sequence of this lesson followed a pattern of; engaging the students with the concept of fossilisation using an image of 'Eric', a famous opalised Australian Pliosaur; presenting the students with the digital based stimulus materials situated on her classroom website; and finally, allowing the students to explore the Internet resources she had curated. During this phase of the lesson Patricia continually probed student ideas and provided formative feedback to each group. Patricia did not conduct a plenary, instead the bell rang and the students hurriedly packed away.

As a further means of triangulating and characterising the data arising from this ICT mediated lesson, Patricia's actions and operations were deconstructed using Stevenson's CHAT analytical tool (2008), as previously elaborated in Table 3.3. This involved categorising Patricia's *classroom organisation* of the students, the *ICT usage*, (e.g. the functionality of the tool use) and the *conversational roles* that shaped the relationships between the teacher and the student (e.g., lecture, questioning, summarising). This allowed Patricia's instructional practice to be scrutinised on a minute-

by-minute basis. Each facet has been expressed as a percentage of the total lesson and presented in tabular form as shown in Table 6.2.

This data revealed that Patricia spent 26% of this lesson directly engaging and instructing in the requirements of the task, predominantly at the beginning of the lesson, with the remainder of the lesson engaging in dialogic teaching whilst working with small groups and individuals. The students spent 74% of the lesson time using their own laptops to carry out the task. Albeit, some groups lost lesson time trying to get a Wi-Fi connection, closer analysis of the ICT activities being conducted by the students revealed that the use of ICT involved exploration of Internet resources as initiated by Patricia.

Table 6.2: Pedagogical activity of lesson one using Stevenson's (2008) activity matrix

Classroom organisation mode	Percentage of lesson observed	Conversational roles	Percentage of lesson observed	ICT usage	Percentage of lesson observed
Teacher working with whole group (D1)	26	Teachers giving information (S1)	7	Teacher using ICT (T1)	26
Teachers teamwork (working with small groups) (D2)	0	Teachers directing questions and answers to reproduce facts (S2)	7	Learners using ICT as initiated by teacher (T2)	74
Learners teamwork (working in small groups) (D3)	74	Teachers directing conversation (S3)	12	Learners using ICT as initiated by themselves (T3)	0
Learners working individually (D4)	0	Teacher stimulating reflections or other critical analysis (S4)	74	Learners interacting via ICT as initiated by teacher (T4)	0
Learners working with whole group (D5)	0	Learners directing conversations with peers (S5)	0	Learners interacting via ICT as initiated by themselves (T5)	0
				Learners creating using ICT (T6)	0

6.4.1.3 Post-lesson debriefing

Since the school network upgrade Patricia found there had been challenges in connecting student laptops to the Wi-Fi: *“The children haven’t had it for 10 weeks...kids have given up bringing them [laptops] to school and are just using them at home...they have lost ICT fitness”* (Post lesson interview: 27/11/13). Despite the apparent Wi-Fi issues Patricia’s immediate reflection on this lesson was students were engaged with this activity. She also commented she had noticed some students were diverting to the web links she had provided during her introduction, however, she felt this added to the level of sophistication in the class discussion stating, *“that is what I am aiming for, maturity with ICT, some people have suggested I should ‘clam’ the laptops during the directed part of the lesson, but this is what I want”* (Post lesson interview: 27/11/13)

When queried about how Patricia selects resources from the Internet, like the one used in this lesson she explained, *“it has to be correct in the scientific way, it has to relate to the scientific concepts I am trying to develop. It’s also great if there is something already there that I can adapt, like a worksheet as I need some evidence of their work...this website was from National Science Foundation in America”* (Post lesson interview: 27/11/13). Patricia prefers to pre-select website destinations for the students, keen to point out that when you, *“make it really free and just send students off to do non-scaffolded research using the Internet they will just go to Wikipedia, sometimes that’s ok but they can’t yet distil what they are supposed to be getting out of the exercise”* (Post lesson interview: 27/11/13).

Key finding 6.8 Pre-selecting digital resources

Patricia curates digital resources from the Internet for student to use in research-based tasks primarily based on their scientific authority and relevance to the learning outcomes. She also tests the hyperlinks to ensure they are not broken. Patricia prefers to constrain Internet searching to focus student activity on the science concepts she is trying to build, akin to guided inquiry.

Patricia she sees her role in these ICT-enabled lessons as, *“an ICT encourager, helping them to learning how to hit a website and ask questions”* (Post lesson interview:27/11/13). She suggested that by designing focus questions to guide the

students' in this research work served *"to remind me as well to ask particular questions of the kids"* (Post lesson interview: 27/11/13). She pointed out that designing these ICT enabled tasks was an onerous task, however, she stated that as an affordance of ICT *"I'm still happy to do all this work because to me it is more efficient. If I get another idea I can modify these [web] pages, and continually refine, adapt and differentiate...keep re-working them"* (Post lesson interview: 27/11/13).

Finally, in reflecting upon this lesson Patricia stated she realised the need to offer students one more lesson period to complete this task. Patricia also believed that research-based lessons needed to be accompanied by tangible evidence of engagement. To this end she explained her students were expected to complete a set of fossil research event cards (see Figure 6.10), which they would subsequently add to their geology portfolios.

Getting Into the Fossil Record: Event Cards to complete and build a flow chart	
Frog Dies	Fossil frog is discovered by: (who?) (how?)
Frog is decomposed by: 1. abiotic factors such as: 2. biotic factors such as:	Frog fossilizes by: (explain how)
Fossil frog is destroyed by the Earth: (explain each) 1. melted: 2. moved: 3. crushed: 4. eroded:	Fossil frog becomes exposed by: 1. 2. 3.
Frog gets decomposed underground by: 1. 2.	Fossil frog remains buried because: 1. 2.
Frog gets covered/protected by: 1. 2. 3.	

Figure 6.10: Flow chart event card assessment task for ‘Getting into the fossil record’

Prior to the final member-checking interview where Patricia would be asked to confirm the emerging themes she was sent the videos to review she subsequently sent through a more considered reflection on this third lesson, stating:

This lesson using ICT in the classroom for: student authentic research; gathering and using evidence...navigate to class website, view images, and verbally respond. Click on links to maps etc. as stimulus for discussion...Both incidental confirmation during the directed part of the lesson and for the collaborative researched learning. Student production, in this case was a flow chart, using Excel, or Word... [My role] to build the website with images, links, other stimuli, and instructions. Direct the discussion and data projector and screen (Post lesson reflection: 01/11/15).

Patricia also explained her reasoning and pedagogy for this entire series of geology lessons:

About developing the concept of geological change through different time scales. This is one of the overarching ideas of science in the Australian Curriculum. One rationale behind using these ideas is that students who connect these ideas may use this as a tool for learning...Inquiry-based learning where the students own their mental and physical activity...connecting STEM principles to everyday life (Post lesson reflection: 01/11/15).

6.4.2 Lesson two: Theme Year 9 AEP iMovie project of Big Ideas in Geology

6.4.2.1 Pre-lesson interview

This lesson was the fourth in a series of lessons where the key focus was to create a three-minute *iMovie* (an in-built application on the *Mac* laptop) or use some other digital movie format to explain a key concept from Patricia's Earth Science program. A program she referred to as the 'Big Ideas in Geology'. Patricia expected students to choose from one of the two big ideas in geology which she stated as follows:

1. Geological Timeline

- Research and present the characteristics using a (graphical) timeline and identify how these periods of time are named of either; the eons, eras, or periods.
- Discuss the significant episodes (i.e., extinction of many species) for the periods and determine plausible reasons for the incidents.

2. Australia's Geological Past

- Present the significant episodes that happened in Australia for the geological periods. Significant events include; temperature, atmosphere, sea levels, paleogeography, flora.
- Investigate the fossils found in Australia and determine from which geological time the animals or plants (from which the fossils were derived) existed.

Patricia explained this lesson would require students to draw upon knowledge and artefacts from their geology portfolios, built up over the term, as well as conducting further Internet research to find evidence to inform the production of a short digital movie. Whilst Patricia was happy for the, *“students to work collaboratively to research and retrieve information and images...Individually, students will build an iMovie project (or other form of electronic product.)”* (Pre-lesson interview: 04/12/13). Patricia did not want to receive multiple movies on the same topic so she provided an elaborated list of over 30 geology themed topics via her website, where each student was to select one of these elaborations. Patricia explained she preferred to use a ‘jigsaw’ approach to project work, so that whilst the students could work together and support each other in terms of feedback and share images and useful websites etc., each student had an individual component of the whole task.

Patricia explained that this task was useful in that it could provide evidence of the students learning outcomes across the entire Earth Sciences program. She felt the activity itself would help to further develop student’s ICT skills. In particular: *“Develop organisational skills...practice in navigating multiple websites...choose suitable images to download...manipulate images, voice-overs, music to build both a document and an iMovie presentation of a geological concept”* (Pre-lesson interview: 04/12/13).

Patricia had prepared a project brief and uploaded this instructional document to her classroom website, making paper copies available in class as well (see Figure 6.11). In addition, she had made a storyboard planning template to help students to sequence the movie including a script. A completed student storyboard artefact is shown in Figure 6.12. Patricia indicated that her own use of ICT, as with most of her ICT enabled lessons would be minimal, instead;

Students each have a valuable tool that can be used to enhance their learning in science...It is beneficial to learn to use the MacBook and the Internet for research, deciding on appropriate material to include in the project, asking further questions and building an audio-visual project. By building an electronic project, students are demonstrating both their science understandings and their ICT skills. They are building resilience when they present their iMovies to others...as an audience student learn to behave appropriately and to show they have gained understanding by asking further questions (Pre-lesson interview: 04/12/13).

Essentially Patricia expected that this lesson would see students accomplish the following tasks:

Construct a storyboard for the iMovie Project...includes downloading and acknowledging resources and writing a script explaining the images chosen and one question that results from their research...download images...write a script—either electronically or by hand...and start to build an iMovie project (Pre-lesson interview: 04/12/13).

**Year 9 AEP Earth Sciences
Topics for Short Research Projects**

**Due Date for Presentations
Wednesday 11 December**

Introduction to the task

The following topics for research come from the objectives found within the last three weeks of your program. This project will allow you to pursue further an area of study, present what you have learned and teach others about the topic. You will achieve all this during science class time. Some homework may be needed

Audio-Visual Presentation of the task

Your **Product** will be in two parts;

1. A **storyboard of your Presentation**. This shows the images you use and your script beside the image. Include references at the end. You may download a template of the storyboard from our website, or work on the paper copy at the end of this Research Brief. Hand in this paper copy as part of your Geology Portfolio.
2. Ideally your presentation should be an **iMovie**. Each iMovie is to be of 3 minutes duration. (You may present your research as a very short *PowerPoint* or *Prezi* – negotiate with your Teacher)

Your **Audio-Visual Presentation** should consist of;

- ☐ a few images that summarise the main points of your research and
- ☐ a short voice-over
- ☐ one question that results from your research
- ☐ acknowledgements and references
- ☐ music (optional)

Arrangement of the task

There are different topics. Each topic represents one group of students.

The parts represent the work of one student. You will need to collaborate within the group to exchange research information. Individual students will submit one presentation each.

Researching the Topic

There is one hyperlink to a website to start your research. Start your research there. You may need to navigate elsewhere to find suitable images.

Acknowledge this in your credits. Reference other material that you present.

Time for Researching and Building your Project

Two class periods allocated for research and storyboarding.

Two class period allocated for building the project.

You may need time after school hours to complete the project.

Evaluation

There are two types of **Formative evaluation** associated with your research.

Your storyboard will be evaluated as part of your Geology Portfolio.

Peer and teacher evaluation of the iMovie presentation.

Presentation of iMovie's

Presentation may be through student MacBook's connected to the data projector.

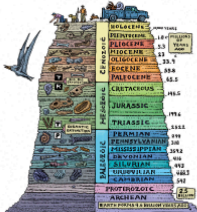


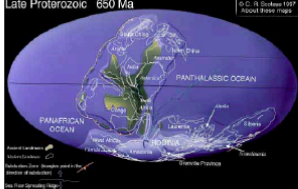
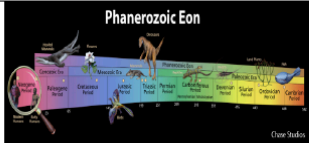
When the iMovie's are being presented the audience, students will make notes so that they too may experience the joy of learning.

Figure 6.11: Student task brief for the *iMovie* project

Storyboard Template for short iMovie Project

Title of iMovie: EONS, Eras and Periods.

Student Name: xxxx Date: 8.12.13

Image used in iMovie (sketch if you are writing this by hand)	Script for this image
	Scientists have discovered, through radiometric dating that the earth is over 4.5 billion years old. Even in Western Australia scientists have discovered rock that is around 4.4 billion years old. With such a broad time range there are certain ways that time is classified. It is commonly known as a geological time scale. They are commonly classified into several groups. Eons- Half a BY or more. Eras- Several Hundred million years. Periods- Tens of Millions of years and Epoch- millions of years. The word eon originated with the Latin word 'aeon' or the Greek 'aion' meaning age or a period of existence. There are four different eons the Hadean, the Archaean, the Proterozoic and Phanerozoic eon.
	The Hadean eon dates back to the formation of the earth over 4.6 billion years ago. As you can see the name Hadean resembles the Name Hades, the Greek god of the underworld. The period was named after this god because back during the Hadean eon the earth the conditions that people believe are typically found in hell. Many meteorites crashed into earth at this time and the earth was very volatile The atmosphere was composed mainly of hydrogen, carbon dioxide, ammonia and methane. There was no oxygen. There was no sign of life at this point in time and there was nothing that could sustain life. Very little evidence remains of this eon.
	The Archaean eon began about 3.8 billion years ago straight after the Hadean eon. The name Archaean originated from the ancient Greek word Arkhe meaning beginning, origin or ancient. The main events that occurred during the Archaean period were the establishment of plate tectonics, the first sign of life and very poor oxygen conditions. The atmosphere was composed of mainly volcanic gasses, as there were still lots of volcanic activity in the Archaean eon. The gasses were carbon, hydrogen, nitrogen, an array of toxic gasses and very low levels of oxygen around the end of the eon. Not many rocks remain from this period as they were eroded over time, covered by sediments or were simply sub ducted back into the earth due to the abundance of volcanic activity. The vapors and the steam from the high temperatures of the earth allowed for the formation of the first oceans leading to plant like bacteria or unicellular life forming in the oceans.
	A lot of change occurred during the Proterozoic eon such as the development of multicellular organisms and the accumulation of oxygen. The word is formed out of two different words Protero meaning before or former and Zoic from the Greek word Zoikos meaning animal. During this eon earth saw an amazing expansion of crust. As you can see in the image the land mass is known as Rodinia that formed around 1.1 billion years ago. North America apparently formed the bulk of this landmass. Most of the organisms on earth at the time lived in the water and it was in the Proterozoic that the first oxygen dependent life arose.
	The Earth is currently in the Phanerozoic eon. It is the only one of the eons that lie outside of the Precambrian super eon. The word Phanerozoic originated from a Greek root word Phaneros meaning visible or manifest and the Greek word Zoikos meaning animal. This eon saw to the development of animal life and the diversity of multi cellular organisms as well as hard-shelled organisms. The first vertebrates formed 500 million years ago around the beginning of the Phanerozoic eon. Homo-sapiens have only made a very small dent in this time in fact the homo sapiens only appeared 0.2 million years ago. Even though the earth is no longer as volatile as it was 4.6 billion years ago the earth is definitely still changing.

One question that results from your research.

References and acknowledgements: http://en.wikipedia.org/wiki/Age_of_the_Earth http://www.bbc.co.uk/nature/history_of_the_earth <http://www.rockinmyheadtop.com/TimeLine.htm>

<http://en.wikipedia.org/wiki/Hadean> http://mnh.lsu.edu/exhibits/online/geo_time/geo_time_eons.htm

http://www.corzakinteractive.com/earth-life-history/1_hadean.htm <http://www.nature.nps.gov/geology/ueqanps/pitac/isc650ma.html>

http://www.dinofan.com/dinofan/ByTimePeriod/LF_Period_DOverview.aspx?GEPID=14

Photo 1

http://www.google.com.au/search?q=geologic+time+scale+overview&client=firefox-a&hs=62h&rlz=org_mozilla_en-GB&official&source=images&imgref=0&sa=X&ei=DkU/XHIXmiAe01YCwDA&ved=0CAQOAUoAQ&biw=1280&bih=589&facr=&imgdl=&imgre=JXH-4Naq0mjcM%3A%3B_40729DGFEM%3Bhttp%253A%252F%252Fgreenforecast.com%252Fwp-content%252Fuploads%252F2013%252F04%252Fgeologic-time-drawing.jpg%3Bhttp%253A%252F%252Fgreenforecast.com%252Fwhat-is-the-geologic-time-scale%252F%3B1851%3B1915

Photo 2

http://www.corzakinteractive.com/earth-life-history/1_hadean.htm

Photo 3

<http://www.dailymail.co.uk/sciencetech/article-1213287/Its-oceans-200m-years-moved-land.html>

photo 4

photo 5

<http://commonfossilsofoklahoma.snrmnh.edu/geological-time-scale>

Figure 6.12: Completed student storyboard for iMovie project

6.4.2.2 Lesson Observation

As part of her normal classroom routine Patricia had set up her laptop and had navigated to her *iMovie* research classroom webpage before the students arrived in class (see Figure 6.11). After settling the students and taking class attendance she introduced the project, clarifying the outcomes and deadlines. During this part of the lesson she asked that laptops were to be closed at this stage. She explained the *iMovie* project by stating: “*As you know, I like to use everybody in the class to do something a little different and then bring this all together to make the whole...that way you start to see how elements at any level can make a whole system work...the big ideas of geology*” (Lesson Two observation: 04/12/13). She explained that some geology topics on the list would naturally follow one another so she would get those students to work closely together during this project and would get these students to present consecutively. Patricia was keen to ensure each student understood they were each required to submit a storyboard and importantly where, “*at the end of your iMovie you are to pose at least one question that continues on from your research...to get people thinking...to open up the area for more research*” (Lesson two observation: 04/12/13).

She then called upon a student [ST1] to share her *iMovie* draft, already knowing that ST1 had been engaging with this project for several days beforehand. Patricia explained this was a common occurrence amongst her AEP students and an affordance of having her classroom website meant she could upload tasks ahead of the lesson for students to engage with if they chose to. This student explained she had not yet narrated the *iMovie*, however, was happy to talk them through her draft. At this point Patricia explained to the class about an inbuilt dictation application located in system preferences on their *Mac* laptops to help them script their *iMovies*.

ST1: [using her own laptop the iMovie played in the background as the student narrated]. I had spoken to Miss Patricia about making an iMovie of my investigation of the Perth sands...I had to figure out how much calcite was in them and how to take it out. I tested Rottnest sand, sand from Nedlands beach, pure sand, and yellow construction sand...I added hydrochloric acid (HCL) to observe the reactions and I saw lots of fizzing in the Rottnest sand, and fizzing in the Nedlands sand but not much in the

construction sand and none in the pure sand. Rottnest sand fizzed heaps due to lots of crushed shells. I had to decant the solution by getting rid of the HCL by adding water and repeat it until the bubbles had all gone...I added 1.2 L of HCL to the Rottnest sand to get all the calcite out...then I let it dry out for a few days. Basically, the Rottnest sand disintegrated to nothing. It lost 99 grams so that means it was almost pure calcite, 99%...the yellow sand was 17% calcite and the Nedlands sand was 45% and the pure sand had 1%.

Teacher: so, everyone what could you do with ST1 research? You people have looked at the weathered material you took from the outcrop on the road here at the school the other day. Is there any way you could use the percent carbonate in that material to inform you of where or how the sands in our dunes around here were formed? Let me leave you with that question for this lesson

Teacher: thank you ST1, that is a brilliant piece of investigation (Lesson Two observation: 04/12/13)

Patricia then offered her own *iMovie* on the topic of *The Geology of the Perth Basin* as further inspiration to the class. As *Weebly* websites only play *YouTube* videos Patricia explained her work around was to preload her *iMovie* to her *YouTube* channel. Patricia directed the students to re-position the rows of the large science desks into groups of four for this lesson. The students eagerly went about storyboarding their *iMovie* projects and conducting research using Patricia's pre-selected websites as a launching pad. Again, there Wi-Fi connectivity issues so Patricia sent two groups to the Library to use the desktop computers.

Key finding 6.9 Classroom architecture and norms

Patricia teaches science in a variety of laboratory style classrooms. The physical desk layout is only moveable in some rooms. When available, as was observed during this study, Patricia re-arranges the classroom for group work. Patricia's classroom routine involves pre-loading her digital instructional materials using her *Mac Air 15"* laptop prior to the students entering the room and tabbing various webpages in readiness to

show the students. Each room has a data projector. Each student brings their own laptop to class, opening this as they arrive where they navigate to Patricia's website. Her routine also involves preparing hard copies of the task; however, digital versions of the tasks are preloaded to the website prior to lesson commencement. If classroom furniture is re-arranged, Patricia ensures it is put back to its original configuration at the end of the lesson.

Patricia does not sit down at any point, instead weaving in and around the tables conversing with each of the student groups. In this lesson she spent 59% of this lesson engaging directly with these small groups. The overall instructional sequence followed a pattern of; articulating the required outcomes of the *iMovie* project that was to construct an *iMovie* by synthesising information from authoritative websites and write a script. She then presented the students with the range of curated digital stimulus materials; followed by engaging the students with the student draft *iMovie* and her own *iMovie* as exemplars; and finally, the students conducted research and commenced storyboarding. During the latter part of the lesson Patricia ensured the students had selected a topic and began to probe the student ideas encouraging them to think creatively discussing how this topic related to the big ideas of geology. Again, Patricia did not conduct a plenary, instead the last few minutes were used to re-configure the classroom furniture back to its original layout.

Decomposing Patricia's actions and operations using Stevenson's CHAT analytical tool (2008) revealed she spent 34% of this lesson directly engaging and instructing in the requirements of the task at the beginning of the lesson, with the remainder of the lesson engaging in dialogic teaching whilst working with small groups and individuals. As with the previous lesson Patricia constantly moved around the room engaging in discussion with students. In keeping with her constructivist beliefs, the students spent 59% of the lesson time using their laptops to explore the curated resources, albeit a few groups lost lesson time trying to get a Wi-Fi connection. The data pertaining to Patricia's *organisation* of the students, the *use* of ICT, (e.g., the functionality of the tool use) and the *roles* that shaped the relationships between the teacher and the student is shown in Table 6.3.

Table 6.3: Pedagogical activity of lesson two using Stevenson’s (2008) activity matrix

Classroom organisation mode	Percentage of lesson observed	Conversational roles	Percentage of lesson observed	ICT usage	Percentage of lesson observed
Teacher working with whole group (D1)	34	Teachers giving information (S1)	29	Teacher using ICT (T1)	34
Teachers teamwork (working with small groups) (D2)	59	Teachers directing questions and answers to reproduce facts (S2)	5	Learners using ICT as initiated by teacher (T2)	59
Learners teamwork (working in small groups) (D3)	0	Teachers directing conversation (S3)	5	Learners using ICT as initiated by themselves (T3)	7
Learners working individually (D4)	0	Teacher stimulating reflections or other critical analysis (S4)	57	Learners interacting via ICT as initiated by teacher (T4)	0
Learners working with whole group (D5)	7	Learners directing conversations with peers (S5)	4	Learners interacting via ICT as initiated by themselves (T5)	0
				Learners creating using ICT (T6)	0

6.4.2.3 Post-lesson debriefing

Overall Patricia was delighted to see the whole class motivated by this learning activity, claiming, *“the biggest thrill for me was to see ST2 and ST3, who rarely are ever motivated, I have never seen these two physically work in class. They were engrossed...I had to modify the task and allow them to make a movie together but that’s ok”* (Post lesson interview: 04/12/13). When asked to consider a metaphor for her role in ICT mediated projects like this one Patricia indicated: *“Problem solver. Mmmm...actually, helping them to see how they can solve the problems. Saying ‘how can you get around that problem’? What are the alternatives...sometimes it’s just IT trouble shooting though”* (Post lesson interview: 04/12/13)?

Patricia did state that ICT enabled tasks such as this, required lots of preparation time, especially thinking about how she would meaningfully engage all 32 students in her class. She explained her reasoning and action process as:

I sort of work backwards when I design projects or lesson activities...in this instance I thought about the software...iMovie is something they like using...I first think what can they do with it...my aim was to keep them working on something they are interested in and mesh that with something that they have to know from my program...I go to the science program and then break the topics down...then I research the websites. I wanted an Australian context so I went to Australian government websites and found the museum website and came across some really useful others ones too. That took me three hours. Then I made an iMovie but this time using my iPad to see if that would work... but I wanted to try it myself as I’m learning...I used the Earth viewer app [an interactive application that enables the user to traverse through geological time] to take screen shots and I used Photobooth, Keynote and the iMovie app and added music...I enjoyed doing it but that—took me about four to five hours...I then equate that to how long I will need to allocate to the student lesson time (Post lesson interview: 04/12/13)

Patricia commented on the complexity of her classroom routines and management when using the one-to-one laptop program, indicating that ICT enabled activity added a

layer of variables to room organisation such as laptop charging and Wi-Fi connectivity. She also felt it was necessary when using ICT that students produce evidence of their work (see Figure 6.11). The tactic of the storyboard she explained, *“is so I have physical evidence of their science thinking...plus I have some kids who do not bring their laptops to class or those whose laptops are often not charged. Did you notice that I had to loan out my charger?”* (Post lesson interview: 04/12/13).

Patricia was asked directly to elaborate on why she spent most of the lesson interacting with students:

I’m really asking them about their progress on the task, how are they contributing, have they got any problems. I’m learning about how they think...I’m giving them an opportunity to interact with their teacher and this helps build trust between people. If you are going to ask people to put up their hand in front of everyone you have to build trust...it helps me to better understand student conceptions and meta-conceptions...we don’t need to remember knowledge so much anymore in the 21st century with our access to knowledge...how we think about things and how we came to our way our thinking is just as important...small group discussions is one step to building trust and their [students] responses are valued (Post-lesson debrief: 04/12/13)

6.4.3 Lesson three: Year 9 AEP presentation of Big ideas in Geology

6.4.3.1 Pre-lesson interview

Patricia explained that, *“This lesson is the culmination of the research and building of students’ iMovies on the big ideas in geology”* (Pre-lesson interview: 16/12/13). Today students were to present their iMovies. Patricia reasoned that when students have to publically present their work: *“They are building resilience...and as an audience the students learn to behave appropriately and to show they have gained understanding by taking notes, understanding how the topics are related and asking further questions”* (Pre-lesson interview: 16/12/13). Patricia explained that she wanted the iMovie presentations a learning opportunity and to promote group positive interdependence and to this end had constructed a note-making table. In keeping with her ‘big idea’ and

interdisciplinary philosophy of teaching science she claimed that, “*by working within the structure of the note-making table the students will build an overview...this document models how a system is made of many individual parts working together*” (Pre-lesson interview: 16/12/13). Again, Patricia makes her lesson instructions available in digital and hard copy formats (see Figure 6.12) stating, “*I hope that they occasionally check the news feed as when I post new things they come up, but I’m not sure that they do*” (Pre-lesson interview: 16/12/13).

Task 2 Note-taking from iMovie Presentations

As the iMovie is being presented make notes on the document. Each student has a paper copy but one is included to the right for you to download if you need one.

When walking through the East Street road cutting we now know we are walking back through Ancient sand dunes that stretched to Rottnest Island. We are becoming familiar with time scales and cycles. As humans we appreciate the diurnal cycle, the yearly change of seasons, the span of a human life and the spans of our past family generations.


Today, as you present your research we are entering a much longer time scale, that of millions of years.

We will begin with an understanding of the time periods of eons, eras and periods, and an appreciation of the development of earth before life appeared.

Then we will journey back in time to the Cambrian Period, through to the Quaternary Period and summarise the significant geological and biological events. We will review the geology of Gondwana with particular emphasis on the continent of Australia.

We will see how these events may have interacted to contribute to mass extinctions.

We will then meet some significant Australian fossils that have contributed to our understanding of the evolution of species.



australias_geological_past__studentssummary_of_imovies.
[Download File](#)




Figure 6.13: Note-taking instructions for use during the *iMovie* presentations

Patricia originally intended for students to upload their *iMovies* to the school’s shared drive, however, this was not available so instead students would have to connect their own laptops to the data projector. She reasoned that learning how to manipulate the audio-visual equipment was a useful skill anyway. Patricia indicated that as part of her normal routine she always considers a backup activity in case of ICT failure. Patricia stated”, *the back-up for not being able to present the iMovie is the storyboard, which was due before this lesson...Student can read their script with a background image for their*

selected websites” Pre-lesson interview: 16/12/13).

6.4.3.2 Lesson Observation

Patricia had made plenty of A3 size copies of the *iMovie* note taking sheet, asking students to collect one of these as they entered the room. As the class settled she explained the need to transition quickly between each student’s *iMovie* presentation and that she expected everyone to take notes about each presentation. Patricia had already written the names of the students presenting in this lesson on the whiteboard, expecting around 10 presentations to be shown.

The lesson basically followed an activity structure where individual students presented their *iMovies* to the whole class where Patricia assisted to help connect the students’ laptops to the data projector. For most students, this was unproblematic. The students were highly engaged whilst watching each other’s presentation, made primarily using the *iMovie* application, although two students voiced over *PowerPoints*. Patricia attempted to engage the students in higher-order discussion after each presentation, and asked the presenter what the follow-on research question was, however, most students had not remembered to even think of one. At the end of this lesson Patricia offered a reminder to the students performing next. The bell rang and the students hurriedly packed away.

The data pertaining to Patricia’s *classroom organisation mode* of the students, the *ICT usage* (e.g., the functionality of the tool use) and the *conversational roles* that shape the relationships between the teacher and the student is shown in Table 6.4. Decomposing Patricia’s actions and operations using Stevenson’s CHAT analytical tool (2008) revealed she spent only 14% of this lesson directly instructing the requirements of the task. Between each *iMovie* presentation Patricia spent 22% of the lesson attempting to engage the students in discussion and reflection about each of these presentations. Most of the lesson (64%), saw individual students presenting their *iMovie* creations and engaging in conversation about this presentation with their peers.

Table 6.4: Pedagogical activity structure of lesson three using Stevenson’s (2008) activity matrix

Classroom Organisation mode	Percentage of lesson observed	Conversational Roles	Percentage of lesson observed	ICT usage	Percentage of lesson observed
Teacher working with whole group (D1)	36	Teachers giving information (S1)	14	Teacher using ICT (T1)	0
Teachers teamwork (working with small groups) (D2)	0	Teachers directing questions and answers to reproduce facts (S2)	0	Learners using ICT as initiated by teacher (T2)	0
Learners teamwork (working in small groups) (D3)	0	Teachers directing conversation (S3)	0	Learners using ICT as initiated by themselves (T3)	100
Learners working individually (D4)	0	Teacher stimulating reflections or other critical analysis (S4)	22	Learners interacting via ICT as initiated by teacher (T4)	0
Learners working with whole group (D5)	64	Learners directing conversations with peers (S5)	64	Learners interacting via ICT as initiated by themselves (T5)	0
				Learners creating using ICT (T6)	0

6.4.3.3 Post lesson debriefing

Overall Patricia felt the lesson was successful, albeit stressful in terms of helping each presenter establishing a connection to the data projector. She realised that she had underestimated the amount of time required for the changeover between presentations and she would now have to dedicate more lessons to this activity than she originally intended. In this debriefing session Patricia was keen to elaborate on her pedagogy since the introduction of one-to-one laptops explaining that her approach still centred on collaborative structures:

But to me you can't just present it [iMovie] to the class; the class has to then do something with that information. So, I think that's why I build task briefs and worksheets - because that's part of the jig-sawing I suppose where students go and study one aspect of a broad topic, present their pieces of the jigsaw and then the class is taking notes. So that's individual accountability isn't it?...So ICT can be used to enhance all those aspects of collaborative learning (Post lesson interview: 16/12/13).

Patricia thought that this ICT-based project task was a success and reflected that in the future would likely consider using this *iMovie* project as a summative assessment task

Key finding 6.10 Pedagogical repertoire observed over the three lessons

Patricia meticulously explains her instructional material and assessment objectives using task descriptions to guide student thinking and success in the lessons that were observed. These task guides are made available via her classroom website to students before the task commences in class. These tasks are projected on the whiteboard in readiness for the student's arrival. She creates ICT enabled tasks that promote collaboration and group positive interdependence and supports these activities with a range of carefully curated digital resources. Patricia sources these digital resources from authoritative websites. Her role was primarily facilitative, acting as an IT problem-solver and as a mentor. Patricia engaged in dialogic teaching with small groups for most of each lesson, prompting and guiding the *iMovie* designs of the students. In each lesson, the students were the key users of ICT. Her pedagogical approach of engaging students with inquiry-based

collaborative projects and her patient and attentive manner were the hallmarks driving the success of the lessons that were observed.

Key finding 6.11 Alignment of stated lesson intentions to observed outcomes

The overall design of Patricia's lessons was in keeping with her stated beliefs of student-centred collaborative and active construction of science knowledge. ICT was positioned as a tool to research, create and communicate findings. Exploration of digital resources and collaboration amongst students across all three lessons was strongly promoted. There was an emphasis on helping students to use ICT to make connections between the big ideas in science, albeit this was scaffolded by clearly articulated task descriptions and guided by a plethora of authoritative digital resources offered as a starting point.

A final member checking interview, lasting around 70 minutes was conducted on site to confirm the emerging themes in Patricia's ICT pedagogical reasoning and practices. In preparation for this final-member checking interview Patricia was sent a set of semistructured interview questions approximately three weeks beforehand, along with full access to the complete video recordings. During this final interview, Patricia also offered a set of typed notes articulating her thinking processes. In this final interview Patricia was asserted that:

I see myself as a weaver of the principles of collaborative learning with ICT as the tool that I use to do that but I do believe in knowledge and of how to teach so I don't think we should give that up. It's not just a free for all for kids to go and research and make their own understandings. They need guidance; that's why we teach". (Final interview: 08/12/15).

A re-representation of Patricia's reasoning process is shown in Figure 6.14. This concept map has been re-drawn with the aid of software and has been ratified by Patricia as a true reflection of the iterative thinking processes common to the use of ICT as seen in her lessons.

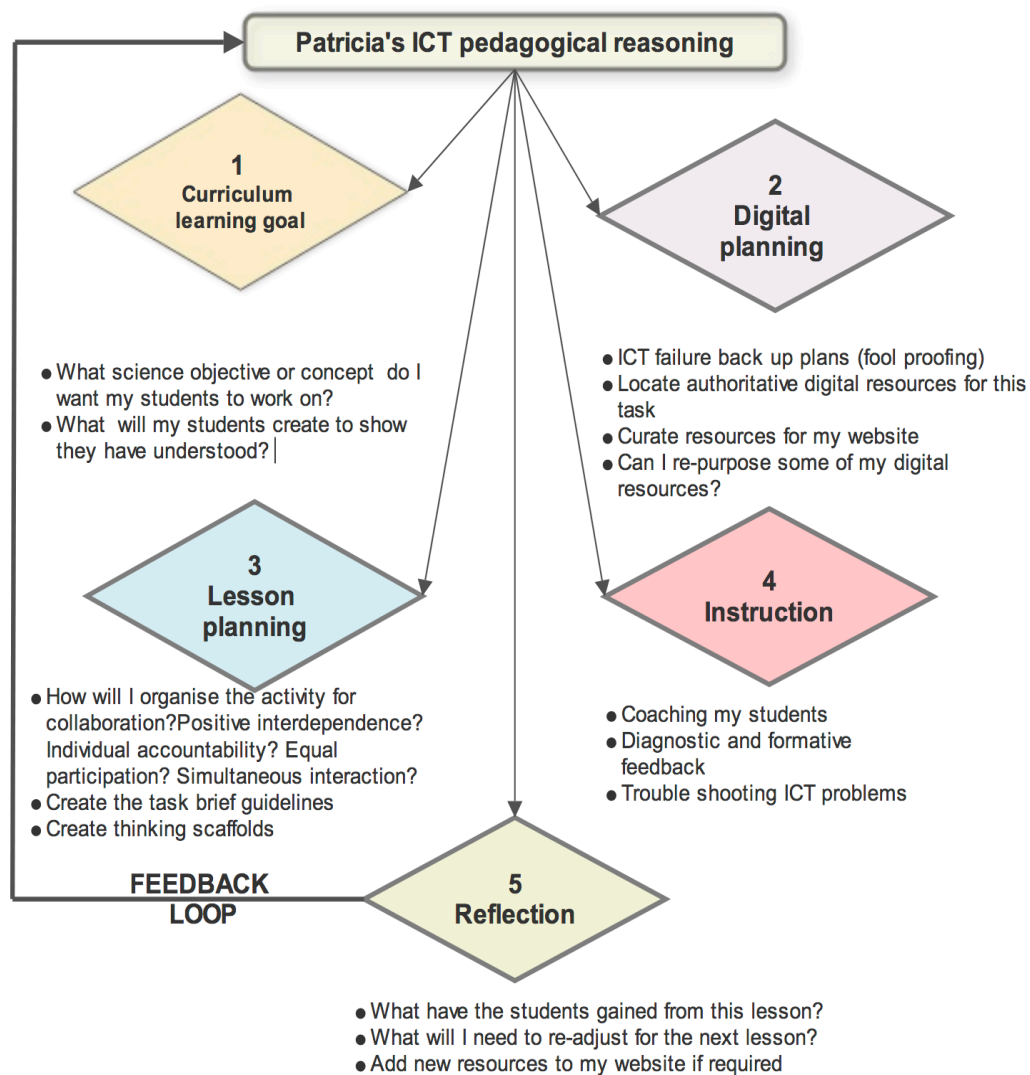


Figure 6.14: Patricia's ICT pedagogical reasoning and actions

6.5 Chapter summary

A whole-to-part recursive analysis of the data sources revealed several key emerging facets of Patricia's ICT pedagogical decision-making process used to engage students' interest as she orchestrated these learning experiences. Overall Patricia advocates a social constructivist approach to science teaching and learning using ICT (see Key Findings (KF) 6.4 & 6.10). Her learning goals centred primarily around the development of science knowledge, collaboration, individual accountability, problem

solving and critical thinking skills. Patricia frames this science knowledge and these lifelong skills principally using the mandated science curriculum as the context. In other words, the mandated curriculum forms a significant part of the context that drives the use for ICT in Patricia's classroom (see KF 6.2; 6.4, 6.5, 6.7 & 6.11).

Students own use of ICT in the classroom is fundamental to her classroom-learning environment. The students are positioned to work in collaborative group structures where knowledge production using a variety of media tools, rather than knowledge consumption is Patricia's primary mode of ICT use (see KF 6.10). Patricia guides her students understanding of science by the meticulous preparation of learning task briefs to support the quality of student work in the learning projects she sets (see KF 6.5 & 6.6). Patricia pre-selects Internet learning destinations to support the students' use of the Internet for research tasks where she chooses these websites based on scientific authority (see KF 6.8).

Patricia's TPACK is extensive having created her own classroom wiki and website from scratch several years ago where it continues to evolve (see KF 6.6 & 6.7). Patricia spends lots of her personal time to filter and curate a vast range of additional multimodal and interactive digital resources to support and extend students' understanding of science (see KF 6.7). The fundamental rationale for operating her own classroom website is so that her students can access her curriculum at any time and to direct students to quality online resources (see KF 6.6 & 6.7).

The overall design of Patricia's lessons was in keeping with her stated beliefs of student-centred construction of science knowledge, where ICT was positioned as a tool to investigate, create, and communicate findings (see KF 6.11). As was observed during the lesson observations she engages in explaining the task requirements meticulously at the commencing of a new project (see KF 6.10) leaving ample lesson time to engage in dialogic teaching, coaching, and supporting her students.

CHAPTER SEVEN: Cross-Case Analysis and Discussion

This study set out primarily to investigate the beliefs, pedagogical reasoning, learning environments and practices of exemplary science teachers in classroom environments where students had one-to-one access to laptops and Wi-fi connectivity, in other words, ubiquitous access to ICT. The Chapter presents and discusses the key findings and themes that emerged from the data. The three cases are compared using the evidence base as drawn from interview data, lesson observations and teaching and learning artefacts with a focus on the study's four research questions:

- a. What are the pedagogical beliefs of teachers who are effective users of ICT in teaching and learning? (i.e., why teachers act as they do)
- b. What pedagogical reasoning do these teachers employ in creating meaningful ICT-based learning experiences? (i.e., how do teachers decide what strategies, representations, and tasks to employ?)
- c. How do these teachers create a learning environment conducive to student learning with ICT? (i.e., what do teachers do to create this environment?)
- d. What pedagogical repertoire do these teachers use to engage students in learning science using ICT? (i.e., how do teachers implement their instructional plan?)

Along with the range of data mentioned, a final member checking interview corroborated the emergent themes in relation to the study's main research questions where video clips of lesson activity were served as prompts and points of clarification. During this final member checking interview the participants also sketched out, in the form of a diagram or flow chart, the pedagogical reasoning process they generally followed to plan, execute, and evaluate lessons that incorporate ICT (see Figures 4.7; 5.9; 6.13). This Chapter interprets these findings in relation to previous research reported in the literature and the original conceptual framework as shown in Figure 7.1, identifies themes to generate assertions in relation to these themes. In doing so it will be possible to demonstrate the unique contribution to knowledge offered by the present research.

Prior to discussing these themes, it is important to reiterate that this research was designed using a naturalistic case study approach (Yin, 2014) using purposive sampling (Patton, 2002) to collect rich qualitative data from the participants. This Chapter does not

purport to present generalised abstractions, instead, the findings have been interpreted in terms of the original conceptual framework and literature situated within the contexts of the schools (see Figure 7.1). A significant aim of this study was to present rich field case studies of exemplary teachers renowned for their expertise in the meaningful use of ICT for learning science. These portrayals of expertise are intended to serve as useful educational design tools (Shulman, 1987), instead of prescriptive teaching methods for pre-service teacher education courses where the Researcher presently works. Before presenting these themes and assertions, given the theoretical framing of this research, it is important to highlight the significance of the contextual similarities between the participants informing this research.

7.1 Teacher contexts and backgrounds

The school demographics, teacher backgrounds, curriculum and ICT context are now compared. Each of the participants informing this research were working in metropolitan Western Australian Department of Education (DoE) secondary schools classified as Independent Public Schools. Michael and Ruby were co-located on the same campus, with Michael in the senior school (Year 10-12) and Ruby working in the Middle School (Year 8-9). Patricia's school ICSEA context was very similar to that of Michael and Ruby's school, in that it was also one standard deviation above the median. Meaning that both schools had a similar level of socio-educational advantage. Both schools were renowned for their high attendance, Year 12 completion rates and success in Australian Tertiary Admission Rank (ATAR) rankings. Both schools offered an academic extension program for students in science.

Both Michael and Patricia had been teaching for over 25 years at the time of the study, with Ruby having taught for over 10 years. Each participant having qualified as a *Level 3 classroom* teacher, a status within the DoE that recognises their exemplary teaching practices across all three Australian Institute for Teaching and School Leadership (AITSL) teacher domains. This status afforded each of them a 0.1 full-time equivalent allowance of time to participate in teaching and learning projects as envisaged in their schools' business plans as directed by their Principal and/or Head of Learning Area. At the time of this study Michael was engaged as an e-Learning Coordinator to

assist other teachers across the school to integrate ICT into their learning areas (see Key findings [KF] 4.1). Michael shares his vast ICT integration expertise with the school community via an online community of practice website hosted via *Scoop.it* (see KF 4.6). Patricia was utilised by the district office to work on developing science pedagogical content knowledge with local primary school teachers (see KF 6.1). Ruby was engaged to develop a new project-based subject called Integrated Studies for the entire Year 8 middle school, from which the lesson featuring the sustainable home was observed (see KF 5.1).

The present research was conducted in lower secondary classrooms where each participant had up to 32 students in each class, each lesson lasting between 50 to 60 minutes. Science was taught four times a week in all three cases. Michael's lesson observations featured Year 10 academic extension students; Ruby's lessons were conducted with Year 8 students, and Patricia's featured Year 9 academic extension students. All three participants indicated they used the mandated science curriculum as the basis to plan their teaching, learning and assessment items for the lower secondary school context where these lesson observations took place (see KF 4.3; 5.2 & 6.2). Michael and Patricia were able to plan on an individual basis for their classes; however, Ruby worked in a middle school environment where a team approach demanded that common assessment tasks were necessary. Ruby indicated this restricted her use of ICT to some extent (see KF 5.2).

Michael and Patricia were highly experienced senior secondary ATAR science teaching specialists (see KF 4.1 & 5.1). Ruby was a middle school science teaching specialist never having taught senior secondary level science (see KF 5.1). Both Michael and Patricia's classes featured students who were considered academic extension students (see KF 4.1 & 6.1). Whilst all three participants indicated they were habitual users of ICT in the classroom, Michael had been using technology the longest at over 20 years at the time of this study (see KF 4.1). Patricia and Ruby's use of technology for teaching and learning had commenced in earnest six years before this present study. The Learning Outcomes and Pedagogy Attributes (LOPA) instrument (Newhouse & Clarkson, 2008), used as a means of confirming the suitability of the participants to inform this study revealed that they were rated at a routine to comprehensive rating by their Principals for the extent to which ICT was integrated into their classroom learning environment for constructivist purposes.

All three participants had similar ICT contexts in that laptops were available for student use on a one-to-one basis. In all three cases, this was a school provisioned *Apple Mac13-inch Air* laptop that was connected to the school's Wi-Fi system. However, for Ruby this necessitated she booked the laptops daily. Michael and Patricia's students could take their laptops home. However, the ubiquitous provision did not necessarily equate to one-to-one access in the classroom as battery issues, broken laptops and occasionally forgotten laptops would occur. As will be shown subsequently, given the collaborative nature of the instructional design of the lesson activities, these issues rarely impeded the flow of classroom work.

All three teachers personally utilised a *MacBook 15-inch Air* laptop in the classroom, leasing these computers from the DoE (see KF 4.2; 5.3 & 6.3). They each worked in classrooms fitted with a short throw data projector. Michael and Ruby had a robust campus-wide Wi-Fi network available to them at the time of the study; however, at Patricia's school, due to a server upgrade, there were times when Wi-Fi connectivity was problematic. This necessitated Patricia having to occasionally release students to go to the library to use the desktop computers to keep up with the flow of class work to be done. Notably, in addition to the school offering an intranet to house digital curriculum resources, each participant had initiated the adoption of various file sharing and video digital publishing platforms such as *iTunesU*, *YouTube*, and *Weebly* to aggregate their digital teaching and learning resources. Via these online platforms, all three participants continually curated digital media and artefacts, as well as designed curriculum and assessments items to utilise these resources (see KF 4.6; 5.6 & 6.5) thereby providing a digitally enhanced learning environment for their students. Patricia and Ruby had created their own publicly available classroom websites, preferring instead to use these platforms to the school's intranet, whereas Michael persisted with the schools LMS built using *Moodle*. In Ruby's case, she had built her own classroom website using HTML language. A summary of teacher backgrounds and their school contexts is shown in Table 3.1.

The cross-case analysis involved gathering evidence about the degree to which the themes and sub-themes applied to the three individual cases. Five key themes were found to be common amongst all three participants including; *reasoning and actions about educational goals*; *reasoning and actions about science knowledge*; *reasoning and actions about lesson planning*; *reasoning and actions about teaching and assessment*; *reasoning and actions about reflection*. The remainder of the Chapter will discuss these themes and their sub-elements, addressing where relevant the study's main research questions.

7.2 Reasoning and actions about educational goals

The participants' central educational beliefs about their view of the meaningful role of ICT in teaching and learning science were interrogated. From this analysis, several distinct educational beliefs and key features of the learning environment were found in common.

7.2.1 Lifelong learning skills for students

The most commonly occurring belief expressed among the participants was the belief in student-centred uses of ICT for the promotion of active student ownership of learning (see KF 4.3; 4.4; 5.4; 5.5 & 6.4) reminiscent of Dewey's (1897) ideas of active participation. In almost identical terms these participants expressed the same constructivist belief, as typified by Michael, "*I want my students to be engaged, lifelong independent learners*" (07/12/15). According to each of these teachers critical to this belief was the view that since each student now had access to a laptop in the classroom ICT use was to be the domain of students and not simply a tool to support lecture-based instruction. For example, Ruby used the biological metaphor of students as "*producers rather than consumers*" to explain her preferred mode of student use of ICT. In almost identical terms, the participants also expressed the view that technology and instant access to the Internet, was a natural part of a student's daily world, underpinning much of the rationale for its use in their classrooms, that is, for engagement and for knowledge acquisition (see KF 4.2; 4.4; 5.3; 5.5; 6.3 & 6.4). The participants each voiced the belief that student use of technology in the classroom was more important than their own, a

finding which correlated to students being the significant users of ICT throughout each of the lessons observed in this study. This latter point will be analysed in further detail later in this Chapter. Furthermore, these teachers expressed the view that teaching with one-to-one access in the classroom was now a key structural and functional part of their pedagogy (see KF 4.4; 5.5 & 6.4). Michael even insisted that should there be a need to return to the computer laboratory booking system, as potentially touted under the new BYOD model being introduced at his school, that he would simply not adopt this approach due to its burdensome administration processes. This finding of constructivist pedagogical orientations is consistent with the extant literature which is replete with studies that reveal that those teachers who regularly infuse technology into their classroom, as these participants all do, share similar beliefs (Baker, 2010; Becta, 2004; Drent & Meelissen, 2008; M. Hammond, 2011; Hennessy et al., 2007; Herrington, 2007; Hew & Brush, 2007; Howland et al., 2012; Keengwe & Onchwari, 2011; Linn & Hsi, 2000; Starkey, 2011).

More specifically these participants each expressed the value of using ICT to develop research skills, critical and creative thinking, problem-solving, collaborative skills, and communication skills (see KF 4.3; 4.4; 5.4; 5.5 & 6.4) or lifelong learning skills. A commonality of the ICT enabled learning tasks designed by each of these teachers involved the students working collaboratively to engage with scientific problems via Internet-based research, organising their information and then using multimedia to display these findings from a menu of choices (e.g., producing an animation, *iMovie*, or a *PowerPoint* etc.). According to these teachers the use of ICT afforded greater opportunities to represent their understandings of science knowledge and develop a range of lifelong skills including problem-solving, social skills and critical thinking, known here in Australian schools as *General Capabilities*. These *General Capabilities* have application to the future world of work and further education, resonating with the contemporary philosophy and conceptual framework of 21st century learning as outlined in the digital competence frameworks elaborated in Chapter 1 (e.g., P21 framework, ITSE Standards for Students).

Whilst Ruby was the only participant to speak directly to the notion of developing the *Australian Curriculum ICT General Capabilities* (see Figure 1.2), the participants each spoke broadly about the importance of students developing the necessary digital

literacy skills to position them for success in the 21st century (see KF 4.4; 5.4 & 6.4). Ruby having the youngest cohort, spoke explicitly about the importance of students mastering various technical operations and learning to troubleshoot ICT issues independently to become digitally competent students. In this regard, she supported her students by preparing 'How to use ICT guides' when she was introducing a new ICT tool, for example, vlogging or videocasting, and made these guides available on her classroom website (see KF 5.10). Although, during the lesson observations all three participants were observed to intercede when students had difficulties using an ICT tool and coach them through these difficulties. This also included the observation that each of the teachers drew upon other students in the class at times to act as ICT trouble-shooters.

This research is consistent with Voogt's (2010) international study of ICT use in science and mathematics classrooms, which revealed the primacy of teachers' belief in providing a learning environment that promotes lifelong learning. Expressing the value of ICT as a tool for the active construction of knowledge by students, as espoused by these teachers, is also reminiscent of the earlier work by Jonassen (1996) who did much to champion the use of computers as mind tools. Since then, numerous studies of ICT rich classroom learning environments report an association between the underlying importance of possessing constructivist-oriented beliefs as the critical determinant in operationalising ICT for higher order thinking outcomes (Bai & Ertmer, 2008; Ertmer, 2005; Hammond, 2011; Levin, & Wadmany, 2006), a belief strongly held by these teachers (KF 4.3; 4.4; 5.4; 5.5 & 6.4). The particular constructivist beliefs held by these teachers also appear to be consistent with the wider pedagogical reforms as prioritised by The Digital Education Revolution 2008-2011 agenda, and currently being promoted as deeper learning approaches. This advocacy is found in *A Rich Seam: How New Pedagogies Find Deep learning* (Fullan & Langworthy, 2014) discussed in Chapter 2.

In the most recent review by Gonski (2018) on Australia's schooling system, a stronger emphasis on the development of problem-solving, social skills and critical thinking, as expressed by these participants, is now seen as essential in preparing students for a world rapidly undergoing a digital transformation. It is important to emphasise that the participants were careful to explain that they utilised the science concepts, as drawn from the mandated curriculum as the vehicle to promote the development of these lifelong transferable skills and capabilities, in other words, a content-specific orientation

to technology integration (see KF 4.3; 5.2 & 6.2). This will be discussed in the next theme, *Reasoning, and actions about science knowledge*.

7.2.2 Collaborative learning

Each participant expressed the view that the ability to collaborate was a social capability they viewed as fundamental to success in life. It was therefore, central to achieve the way work was conducted in each of their classrooms (see KF 4.3; 5.4 & 6.4). However, as observed throughout this study the notion of collaborative activity was not in this sense mediated by ICT, instead, collaboration was achieved by the design of the learning task itself. This involved the deployment of intentional grouping of students, along with the allocation of group roles within these small groups. Patricia most explicitly spoke to the notion of positive group interdependence as essential to her classroom learning environment (see KF 6.4), a belief where the success of one person is dependent on the success of the group. In each instance the learning tasks observed throughout this study could broadly be described as inquiry-based and will be analysed in further detail later in this Chapter. This latter finding demonstrates consistencies to Prestige's (2012) study which similarly established that innovative ICT using teachers were shown to have a belief in ICT as a constructional tool best shaped through face-face collaborative classroom activities.

Each participant also expressed the belief that for small group learning to be successful, a trusting and positive teacher-student relationship was paramount (see KF 4.9; 5.12 & 6.10) and therefore an essential part of their pedagogical repertoire. Consistent with this belief was the observation of warm, empathetic teacher-student relationships as observed throughout each of the lessons analysed as part of this study (see KF 4.9; 5.12 & 6.10). The extant literature is replete with studies that reveal a correlation between teacher qualities such as empathy and warmth with above-average associations to positive student outcomes (Hattie, 2009).

Assertion 7.1

These teachers each held strong constructivist beliefs surrounding student-centred uses of ICT in the classroom to engage with scientific phenomenon and problems. A belief that the meaningful use of ICT relates to engaging students with science learning tasks that promote the development of lifelong learning capabilities; that is, research skills, critical and creative thinking, problem-solving, collaboration and communication skills. To facilitate the development of collaborative skills these teachers intentionally designed their ICT mediated learning tasks as small group activities.

7.2.3 Professional growth in digital capability and skills

The affordances of using ICT for learning not only applied to students. All three teachers referenced an eagerness and willingness to keep up to date with science knowledge, to learn new digital teaching and learning skills, including how to integrate new technology tools. The rationale for this professional learning was about remaining relevant and current in the eyes of their students, particularly in light of living in a digitally connected world (see KF 4.6; 5.7; & 6.6). They each reported they were early adopters of ICT in the classroom for teaching and learning as compared to most of their peers. In particular, Michael's journey had begun some 20 years previously where he would bring in his own *Commodore 64* computer from home to the classroom at a time when there was no network or Internet connectivity availability (see KF 4.1). Each teacher had actively pursued an interest in developing their own technological capacity over the years; however, none referenced the current compliance requirements, for example, the national *ICT standards for Teachers* or the *Australian Professional Teacher Standards* (AITSL, 2011) as the motivation for their present technological capability and skills (see KF 4.6; 5.6; & 6.5). Other than Michael, who did mention his occasional attendance at local ICT networking events, for example, Apple Distinguished Educators network, none of these teachers belonged to any professional technology associations. Interestingly, all three teachers had attended an Apple learning conference that had stimulated their initial interest in the use of project-based learning, an inquiry-based pedagogical approach common to a number of the lessons observed. Nor had these teachers engaged with any formal study on the use of ICTs during their initial teacher

education programs. Instead, their present technological capability and skills were largely self-taught, chiefly from accessing information and tutorials via the Internet.

All three science teachers indicated that their digital skills were an evolving suite; developed as Michael stated from, “*lurking the Internet*” (05/09/13) to find innovative media and technology applications in an attempt to support novel ways of learning science in their classrooms. Additionally, Michael established a *Scoop.it* site for his entire school teaching community to share innovative ICT teaching and learning resources, adding commentary about his own first-hand pedagogical insights to these resources (see KF 4.1). Informal corridor chats between Michael and Ruby also offered chances for reciprocal learning and creative collaboration. This was not the case for Patricia who referred to the sense of isolation she had felt in pursuing technology integration at her school (see KF 6.3).

Despite the literature suggesting teachers should be supported in a continuous and sustained manner to use digital information, applications, and devices (Gerard et al., 2011), these teachers had each pursued their own professional learning (see KF 4.6; 5.6; & 6.5). Notably, none of these teachers could reference any significant workplace or systemic ICT professional learning initiatives that had been provided to them either. Instead, these teachers experiences are more consistent with the extant literature, where global surveys of ICT related professional development continue to reveal that workplace-provided sustained professional development efforts are largely lacking (Ananiadou & Claro, 2009; Twining et al., 2013).

At the time of this study, only Patricia and Ruby had created a classroom website in their respective schools as part of their learning environment, the technical aspects of which have been described in the respective Case Studies. Whilst Michael utilised the school’s *Moodle* LMS rather than creating his own classroom website, he did use various public publishing digital platforms to aggregate his teaching and learning media including *iTunesU*, *Podomatic* and *YouTube*. At the time of the study he was experimenting with a new screen casting tool called *ExplainEverything*, which allowed him to create annotated multimodal science animations. In this regard, all three participants were considered innovative and entrepreneurial in their use of technology-enhanced teaching practices by their school leadership team. Furthermore, they were each fully sanctioned and given agency to pursue the development of these online platforms and consequently their

original selection as suitable candidates for this study. This was also confirmed using the LOPA instrument (see Appendix A). This finding is consistent with Drent and Meelissen's (2008) earlier work which revealed an attitude of personal entrepreneurship characterised an innovative ICT-using teacher. It is also consistent with Mishra and Koehler (2006) studies on the construct of TPACK, that is, these participants' significant efforts to meaningfully integrate technology "requires a thoughtful interweaving of all three key sources of knowledge: technology, pedagogy, and content" (p. 1029). Secondly this finding also suggests that along with a techno-entrepreneurial spirit, an attitude towards professional self-renewal, as evidenced by the many hours each participant engaged in sourcing and curating digital media, serves to promote technological capabilities and skill development, as well as amplifying a deeper interest in the uses of ICT for meaning-making in the classroom, in other words enhances TPACK.

Assertion 7.2

Driven by their own personal interest in the use of ICT for learning these teachers actively sought to further their own professional learning by exploring the Internet and engaging with the abundance of information, digital media, and innovative applications now freely available. According to these teachers, actively engaging with the Internet served to incrementally develop their digital capability and skills which served to foster a deeper interest in the use of ICT for teaching and learning science. These teachers could be characterised as having a techno-entrepreneurial mindset, taking a self-driven approach to using the affordances of the Internet for their own professional TPACK development, ultimately for the benefit of their students.

7.2.4 *Global scientific community perspective*

As pointed out by Ruby and Michael, another powerful learning affordance of one-to-one access in the classroom was the opportunity for students to explore a huge variety of real-world science perspectives. According to them, informed science citizenship is accelerated by the ability to connect their classrooms to other science content experts other than just themselves (see KF 4.4 & 5.4), allowing them to offer a more global scientific curriculum. Furthermore, as Michael succinctly put this, the

students, "*are getting out of the classroom, you are getting into the real world*" (07/12/15). Student participation in citizen science projects helps to promote the value of science knowledge for the community (see KF 4.4 & 5.4). Whilst Patricia did not specifically reference this, her classroom website was populated with a wide variety of videos featuring well-known scientists, including a plethora of hyperlinks to authoritative scientific organisations. Michael and Ruby also extend this global scientific community perspective by actively promoting student involvement in global citizen science projects such as the *Atlas of Living Australia* (<https://www.ala.org.au/>). Patricia did not reference citizen science projects in her interviews, nor was there evidence of classroom involvement in these types of community projects on her website.

Common to each teacher's practice was that they had begun to share their students' digital projects openly to a global audience using user friendly publishing platforms such as *YouTube* (see KF 4.6; 5.6; & 6.6.). Thus, promoting and affirming the value of knowledge sharing and contribution in their classrooms, a view in keeping with the open education movement. Patricia and Ruby also indicated why their classroom websites were open to the public domain.

This present finding offers further evidence that the beliefs and practices of teachers who use ICT extensively align with a more contemporary view of science education; one that involves giving students multiple opportunities to examine knowledge from a diversity of perspectives (Osbourne & Hennessey, 2003). In the literature, this is commonly known as informed science citizenship, potentially leading to a more critical perspective of the world (AAAS, 1993, National Science Education Standards, 1996, Tytler, 2007). This finding also concurs with Starkey's (2011) study of digitally able teachers who utilised the affordances of Web 2.0 to enable students to connect, collaborate and share to develop knowledge and understandings. Clearly instant access to a variety of subject matter experts, opportunities to participate in global citizen science projects and to be able to openly share digital projects on publishing platforms are affordances of ubiquitous access to ICT that these teachers used in their classrooms to help to support this goal. The P21 group (2007) has consistently advocated for a diversity and abundance perspective of expertise from professional groups and industry, to help transform and create meaningful curriculum and learning environments using ICT. However, as demonstrated in each of these cases, it was the teacher who played a pivotal

role in mediating this access through the selection and digital curation of relevant resources. In other words, transforming the learning environment by means of selecting a representational repertoire (Shulman, 1987) or as Starkey (2010) states “enabling connections: preparation for teaching (pedagogical content knowledge) “(p.342). This latter finding also reaffirms Hennessey, Deane and Ruthven’s (2005) earlier study of effective ICT practices of UK science teachers, which revealed the primacy of the teacher’s role in structuring Internet research activity by directing students to authoritative digital media and artefacts.

7.2.5 *Students as creators*

Each teacher spoke of the importance of developing the digital competence of the student to use ICT actively both to create meaning, as well as represent and communicate these understandings with a variety of audiences (see KF 4.3; 5.5 & 6.4). According to each participant, this is vastly accelerated by the affordances of the multimedia tools installed on the operating system of the *Mac* laptop itself (e.g., *iMovie*, *PowerPoint*, *GarageBand*, *Pages*, *Keynote* etc). Additionally, the array of free multimedia tools accessed via the Internet, such as *Prezi*, *Go animate* and *Glogstar*, significantly increases the range of multimedia formats or representation formats for personal expression, along with a range of online platforms as afforded by Web 2.0 technologies to share these understandings with a wider audience. As typified by Michael’s comment, “*The actual product is always open-ended. I always do that because they are all different*” (25/09/13).

These teachers had embraced the range of representation and communication affordances offered by different multimedia by integrating these digital tools into their practice to the extent that students were commonly permitted agency to choose their preferred communication and presentation mode (see KF 4.4; 5.4 & 6.4). The ability to investigate, create and communicate using a variety of ICT tools were seen by each participant as the key affordances of one-to-one computer access and lead to enhanced student motivation and engagement with the task and creativity about the task or problem the students were trying to solve (see KF 4.4; 5.5 & 6.4). This particular finding is consistent with Papert’s (1993) constructionist view of co-opting technology in the classroom as to position students as active users of technology to create a meaningful

product, a more active and learner-centred approach. Again, affirming their beliefs in a learner-centred classroom environment (Darling-Hammond & Bransford, 2005, Newhouse & Clarkson, 2008). Importantly, as was observed, these teachers guided the quality of their students work by using rubrics and/or assessment guides specifying attainment targets (see KF 4.7; 5.7 & 6.8), a finding which will be elaborated shortly. However, it should be noted that at times Ruby felt constrained in permitting full student agency with multimedia tool selection due to a common assessment regime that she was accountable to across the middle school (see KF 5.2). This particular finding would still suggest, as Somekh (2008) and others have since reported, that the failure to fully embed ICT into teaching and learning practices is not only the result of teachers' resistance to change, but is also due to a complex interplay of school cultural contexts, regulatory frameworks including curricula and assessment regimes.

These findings similarly reflect other studies of successful ICT pedagogy that have shown that allowing students to actively use a wide range of digital multimedia and other ICT tools develops a range of potentially transferable digital competencies (Thomas & Brown, 2011). In addition, the finding of teachers' belief in promoting student agency over ICT tool selection is compatible with establishing a learning environment that is more consistent with that of a learning partnership (UNESCO, 2002). Given interaction with digital technologies, particularly smart technologies are now commonplace amongst young Australian people (Smart, 2018), allowing students agency over ICT tool selection, the representation tool may also assist to foster a classroom culture of collegiality. Whilst teachers' beliefs were not explicitly referred to in Shulman's (1987) PRA model, notably Webb and Cox (2004) first showed that teachers beliefs serve as important selective filters in the ICT reasoning process. Other authors have also subsequently highlighted the relationship between teachers' constructivist beliefs and meaningful ICT integrations efforts (Ertmer, & Ottenbreit-Leftwich, 2010; Hammond, 2011; Levin & Wadmany, 2006; Prestige, 2012; Stareky, 2010). In this instance, the teachers' social constructivist philosophies are reflected in the way they allow students to select from a range of ICT multimedia tools to actively represent and communicate their scientific representations.

Assertion 7.3

According to these teachers, a significant affordance of one-to-one ICT access was the ability to connect their classroom learning environments to the global scientific community in support of informed science citizenship. Additionally, this digital connectivity afforded students opportunities to select from a wide range of communication and representation modes e.g. text, audio, photos, movies, animations *etc* as suited to their learning preferences. As reported by these teachers, a learning environment where students had agency to select their preferred digital media and ICT tools for communication enhanced motivation with the task, supported creative thinking and exposed students to a variety of digital technology related skills. These teachers also encouraged students to publish their digital works publicly using their sanctioned digital platforms e.g. classroom websites, *YouTube*, and *iTunes*TM channels. Indicating that this action also helped to promote a global scientific community perspective.

7.2.6 Digitally enhanced learning environments

All three participants expressed the level of technology infrastructure and connectivity access afforded since the Digital Education Revolution (DER) in Australia helped to promote the notion of learning anytime and from anyplace (see KF 4.4; 4.5; 5.5; 5.6; 6.4 & 6.5). This was a view in keeping with their philosophy of lifelong learning. Furthermore, working in a digitally connected classroom afforded instant access to an abundance of digital media, providing enriched opportunities to extend the classroom learning environment. Each referenced that connecting to this abundance and diversity of information could be overwhelming at first to a student, hence their preference for curating quality resources for ICT mediated lessons (see KF 4.7; 5.8 & 6.7), in other words a guided approach to using ICT. Whilst Michael had been an avid user of ICT for over 20 years in the classroom, all three teachers indicated since the provision of one-to-one laptop access they had taken the initiative to digitally curate a range of open content, data and media, often referred to as Open Educational Resources (OER), into an their own online classroom platform, both for ease of access for students and themselves and importantly to ensure the quality of these resources (see KF 4.5; 5.6 & 6.5). They each

spent a significant amount of personal time browsing the Internet for both scientifically authoritative and engaging resources. Similarly, over this period they had created their own learning and assessment tasks including units of work designed to utilise these digital resources (see 4.7; 4.8; 5.6; 5.8; 6.5 & 6.7). A further advantage of having a dedicated personalised classroom website, according to Patricia and Ruby, was the ability to instantly refresh this digital content as she came across engaging resources.

Digital curation along with the provision of a digitally enhanced learning environment were driven by their views on the affordances of ICT for learning science including several classroom management factors (see KF 4.7; 5.6 & 6.5). These views and factors included identifying and filtering relevant digital media from the abundance of information on the Internet from an authoritative and learning perspective, a desire to promote the notion of anywhere, anytime learning, promotion of a broad global community perspective, central communication repository for assessments and units of work, and as an organisational repository for accumulated digital media for future access (see KF 4.5; 5.6 & 6.5). These findings similarly reflect Conole and Dykes (2004) accessibility and abundance and diversity affordance perspective of ICT use for educational practice. The sophisticated reasoning and associated actions demonstrated by these teachers similarly reflect Shulmans' (1987) notion of *Transformation* in that significant amounts of preparation, representation and adaptation were undertaken by each of these teachers to offer a digitally enhanced learning environment.

Michael and Patricia's students were able to take home their laptops (see KF 4.2 & 6.3); however, this was not the case for Ruby's students, although she indicated that most of her students either owned a smart device or had access to a computer at home (see KF 5.3) allowing them to access her classroom website offsite. According to Patricia and Michael, the ability to flexibly access their online platforms suited the academic nature of their students, in this instance Gifted and Talented cohorts, allowing these students to take control of the learning activities at their own pace (see KF 4.5 & 6.5). This finding resonates with the notion that flexible learning environments can be deployed to support personalised and individualised learning experiences (McLoughlin & Lee, 2007), in this instance for academically oriented students within the same classroom. Ruby emphasised that offering a classroom website freed her from routine classroom organisational tasks allowing her more opportunities to engage in meaningful dialogue

and coaching her students during lesson time (see KF 5.6). It is not surprising then, as suggested by these comments, that each participant was cognisant of their students' characteristics and needs, in other words, 'who is taught', is an important construct in their pedagogical reasoning; a concept first elucidated in Shulman's (1987) PRA model.

Interestingly, none of the participants spoke about sourcing their digital media directly from nationally funded teacher curriculum repositories such as *Scootle*. In fact, Michael, and Patricia both clearly indicated a preference not to use generic curriculum storehouses, choosing instead digital resources based on their knowledge of the academic nature of their cohorts. A further selection criterion common to Ruby and Michael decision-making was consideration of the digital capability of their students. This latter finding signifies that knowledge about the students and their characteristics is an important part of their reasoning process, in other words a situated and contextually influenced approach to digital tool selection.

From an Activity Theory (Engeström's, 1987) perspective, these teachers are enabling the provision of a more expansive and innovative learning environment (community), where ICT resources (tools or mediating artefacts) are distributed in a digitally enhanced learning environment (organisation). Importantly, where these ICT resources have been filtered and curated (division of labour) by the teacher (subject) to support students in achieving learning (outcomes). However, as pointed out in other studies, the continual evaluation of the efficacy of these digital resources and tools has a significant workload implication for teachers (Allsopp et al., 2007), a factor which may impede meaningful digitally enhanced learning environments from becoming more commonplace in K-12. Again, a learner and knowledge-centred orientation (Darling-Hammond & Bransford, 2005) is evident in these teachers reasoning and actions in providing and maintaining a digitally enhanced learning environment.

Assertion 7.4

For each teacher the provision of a digitally enhanced learning environment was a key structural element of their practice based on their beliefs in the affordances of ICT for learning. The careful digital curation of resources, multimedia tools and artefacts, along with the use of an online platform as a repository allowed them to connect students to quality contemporary sources of science information, multimodal science representations and other useful interactive media to support learning science. In each case this curation, along with the maintenance of their personalised digital learning environments was not imposed on them by the school or the educational system; instead was instigated by their own beliefs in the learning affordances of ICT.

7.3 Reasoning and actions about science knowledge

Each participant shared a common form of reasoning in relation to the importance of science knowledge and related science skills indicating this was a priority in their early decision-making process (see KF 4.2; 5.2 & 6.2). The intended science curriculum learning goal itself was the practical starting point in their reasoning process for designing an ICT mediated activity (see Figures 4.7; 5.9 & 6.13). Here in Australia, the term curricular knowledge is taken to mean knowledge and understanding related to implementing mandated curriculum documentation, for example, *Australian Curriculum: Science*. This differs somewhat to Shulman's (1986) definition of curricular knowledge, a notion he related to textbooks and software, in other words, the tools and media that support the instruction of subject knowledge. The concept of curricular knowledge referred to in this following section is taken to mean the commonly accepted Australian understanding.

7.3.1 *Learning tasks aligned to mandated curriculum and achievement standards*

Direct references to science curricular knowledge were clear in the learning task guides designed by these participants to accompany the lesson activities observed. These guides both directed the students in these learning tasks and acted as cognitive scaffolds

to guide the quality of the expected work. The guides were found to relate most specifically to the knowledge structures of science, including reference to relevant skills and capabilities as defined in the *Australian Curriculum: Science* (ACARA, 2015a) (see Figures 4.5; 5.5; 5.7; 5.8; 6.6; 6.7; 6.8; 6.10 & 6.11). In comparing the learning task guides designed by each of the teachers, several key design elements were found in common. These included; an authentic context for the task; a clear description of the task; the task, objectives and assessment criteria aligned; and, processes for evaluation of quality which were well defined. Importantly these guides clearly indicated the participants' belief in building a foundation of scientific knowledge and the development of higher order thinking skills (or using their words, lifelong skills). In other words, these participants had designed their own ICT-mediated curriculum to purposefully make use of the curated digital resources to focus on building specific subject matter knowledge. In Shulman's PRA model (1987) he referred to this aspect of pedagogical decision making as *Comprehension*.

This finding also provides further evidence to support Voogt's (2010) work who found that extensive ICT using science teachers had pedagogical orientations that reflected both an emphasis on traditionally important science curriculum goals and practices, equally with an emphasis on higher order skills. Again, these aspects of the participants' beliefs and reasoning reflects both a learner and knowledge-centred orientation to the learning environments they are aiming to cultivate as advocated by Newhouse and Clarkson (2008) for the meaningful use of ICT.

There were some differences between the curricular intent framing these ICT mediated lessons. Ruby specifically referenced the achievement of specific Australian Curriculum's ICT General Capabilities such as *Define and plan searches*, and *Selecting and evaluating information* as additional considerations when framing her lessons. Indicative of Patricia's deep subject knowledge she referred to the importance of developing the notion of the 'big ideas in science', a reference she specifically related to Harlen et al. (2010) who advocated for science teaching approaches that focus on conceptual and interdisciplinary ways of thinking about science in order to develop a more holistic and analytical way of viewing the world. As elaborated in Patricia's second and third lessons, her aim was to get students to use 'big idea' thinking, so they would synthesise their geology understandings with other previously gained scientific

knowledge to explain a specific geological concept e.g., continental drift. Again, this finding with Patricia is consistent with the development of the 21st century skills frameworks highlighted in Chapter 1 and as reflected in the *General Capabilities* of the *Australian Curriculum*. However, whilst the literature is now strongly advocating for teaching and learning approaches that emphasise interdisciplinary thinking and 21st century skills, the present Australian assessment, reporting and accountability requirements do not match these curriculum reform efforts. Instead discrete subject results are still assessed and reported here (Gonski, 2018); an experience which is typical of many other curriculum and assessment frameworks around the globe (Voogt, Erstad, Dede & Mishra, 2013). A situation which if continues to persist, will likely to constrain the full integration of ICT in classrooms for learning.

As demonstrated by each participant, the ICT mediated lessons observed in this study could be broadly categorised as guided inquiry-based learning activities (Anderson, 2002) that emphasised science knowledge building. Students were expected to construct and communicate their representations having agency to choose their own digital format. As Hubber et al., (2018) point out this pedagogical approach supports an active view of knowledge construction more akin to how scientific knowledge is developed in the discipline of science. A more detailed analysis of the pedagogical activity of these lessons will be elaborated shortly to support this statement. In most instances, an assessment rubric or a set of assessment criteria was offered to scaffold the quality of student work in these science knowledge building activities (see Figures 4.5; 5.5; 5.7; 5.8; 6.6; 6.7; 6.8; 6.10; & 6.11). Analysis of these assessment guides showed alignment to the applicable achievement standards relevant for that year group to the *Australian Curriculum: Science* (ACARA, 2015a) — (see Figure 4.5; 5.5; 5.7; 5.8; 6.6; 6.7; 6.8; 6.10 & 6.11) and more broadly to several of the *General Capabilities* of the mandated curriculum (ACARA, 2015b).

Offering students criterion-based assessment guides at the commencement of a new ICT mediated learning activity, as found with these teachers (see KF 4.7; 5.6 & 6.5), aligns with quality assessment-centred instruction as supported by the seminal work in the learning sciences (Bransford et al., 2000). This type of pedagogical approach to assessment positions the students as key users of this information and aims to situate

assessment as learning, which has been shown to lead to improvements in self-regulation and metacognition (Darling-Hammond, & Bransford, 2005).

The following example illustrates the scientific knowledge and assessment centred perspective. During Michael's first lesson the students were tasked with an inquiry-based activity focused on Newton's Laws of Motion, which is a key Year 10 physics concept as stated in the (ACARA, 2015a). Having previously received some background instruction on Newton's Laws of Motion the students were expected to work collaboratively by taking on a designated role within this science research team; for example, Astronaut, to accomplish Project Moon Base. To scaffold the inquiry Michael offered a range of pre-selected authoritative Internet based resources as a launching pad to commence this task. It was expected that each team would apply their understanding of Newton's Laws of Motion to determine whether large or small forklifts would be needed to move fuel tanks on the Moon. In other words, Michael had problematised the scenario to promote higher order thinking. The students were challenged to interpret, analyse, evaluate and synthesise information and ideas, in other words actively construct this knowledge. ICT was to be used by the students to create and present an engaging representation that justified their scientific findings. This inquiry activity was also guided by a clear set of evaluative criteria where almost 75% of the available marks for this task show direct alignment to Year 10 physics and investigation skills content in the (ACARA, 2015a) and their associated achievement standards (see Figure 4.5).

In all three cases, the collection of curated digital resources, tools and artefacts revealed alignment to the structure, scope, and sequence of and achievement standards of *Australian Curriculum: Science* (ACARA, 2015a) (see KF 4.5; 5.8 & 6.7). These teaching and learning resources have already been discussed. Ruby and Patricia resources were displayed on their classroom websites using navigational menus that followed the key knowledge and skill descriptors from the *Australian Curriculum: Science* (ACARA, 2015a), that is, Biology, Chemistry, Physics and Earth and Space were used as the key parent tabs/folders (see Figures 5.2; 5.3; 6.2 & 6.3). Similarly, the arrangement of Michael's digital resources on his *Moodle* classroom site reflected the nomenclature of the *Australian Curriculum: Science* for Year 10 (ACARA, 2015a). Michael's *iTunes U* repository and *podomatic* channel which he used to house his custom-made resources, also reflected key scientific concepts from the *Australian Curriculum: Science* (ACARA,

2015a) (see Figure 4.3; 4.4). Overall the plethora of digital resources curated by each of these teachers reflects both a knowledge and assessment-centred perspective (Darling-Hammond & Bransford, 2005; Newhouse & Clarkson, 2008); a strong indication of their pedagogical decision making.

Various subsequent studies involving the meaningful integration of ICT have similarly recognised that a primary pedagogical decision for the teacher involves the careful design of the learning activity so that relevant technologies align to curriculum and learning related goals rather than a focus on the use of technology as the end goal itself (Koehler, Mishra, Kereluik, Shin, & Graham, 2014). The primary planning influences, as demonstrated by these teachers, are the learning goals of the mandated science content standards, rather than a focus on the technology itself. This ICT pedagogical decision-making process is not dissimilar then to Wienke and Robyler's (2004) TIP model and Britten and Cassidy's TIAI (2006) ICT planning instruments, outlined in Chapter 2.

In tandem with determining the science knowledge learning goals for each activity, all three participants specified that at this early stage in their thinking they also prioritised how they were going to validate students' understanding of these intended learning outcomes. Or as Ruby simply put this, "*What product will they make to demonstrate this learning*" (01/12/15). Both the science learning goals and the method of validating this learning were key pedagogical decisions that influenced the actions taken in regards to the selection of ICT resources. In other words, ICT resource selection came after consideration of the learning goals.

So far, the present research also reveals notable consistencies to Wiggins and McTighe's (2011) general instructional design model, which firstly involves teachers identifying the desired results using a backward mapping approach from the national content standards. As demonstrated by these participants, the mandated science curriculum and associated achievement standards were used as the key referent to define what the students should know, understand and be able to do, whilst at the same time considering the type of assessment method required to substantiate this learning. Clearly these participants were motivated and skilled enough to be able to navigate the challenges of operating within the required school and systemic curriculum, assessment and other regulatory frameworks to design meaningful ICT mediated activities. Yet these factors

are commonly cited as barriers to the wide scale uptake of ICT mediated learning in K-12 education (An & Reigeluth, 2012; Bingimlas, 2009; DEAG, 2012; Wachira, & Keengwe, 2011).

Assertion 7.5

A backward mapping approach identifying the desired learning outcomes from the mandated science curriculum was the starting point in the reasoning process for the design of the ICT-mediated activities planned by all the teachers. This instructional design approach also considered the relevant achievement standards from the mandated science curriculum so that the teachers took both an assessment and knowledge-centred approaches to lesson planning.

7.3.2 *Learning affordance perspective*

As previously highlighted these teachers expressed social-constructivist beliefs towards learning (see KF 4.3; 5.4 & 6.4). More specifically in terms of the role of ICT for learning science, these teachers acknowledged that accessibility, abundance and the diversity of digital media and artefacts (Conoles & Dykes, 2004) were the key learning opportunities now afforded in a one-to-one laptop environment with wireless connectivity. Importantly these teachers specified their preference for digitally curating a suite of resources as aligned to the learning outcomes of ICT-mediated activities which also included pre-testing any new technology applications they were planning to integrate (see KF 4.5; 5.6 & 6.5). They each suggested that given the abundance of information on the Internet purposeful curation serves to orientate students to scientifically authoritative ICT resources, at least in the initial stages of an activity (see KF 4.7; 5.8 & 6.8).

The plethora of teaching and learning resources populating these teachers' online platforms attests to this point and furthermore to their belief in active student learning. As well as being characterised as scientifically authoritative many of the resources were multimodal and/or dynamic in nature and included; videos, podcasts, animations, science simulations, virtual science experiments, citizen science projects, open data sources, multimedia tools, games, and quizzes (see KF 4.4; 4.5; 5.4; 5.6 & 6.5). As Michael succinctly put this, "*I never want to artificially use anything, it's got to be authentic. It's*

got to be realistic. It's got to be useful, there's no point just doing it for the sake of it" (05/09/13).

More specifically, according to each teacher, the ability to freely access multimodal digital resources particularly helps to support the learning of challenging or abstract scientific concepts as these resources allowed for repeated viewing and repeated practice (see KF 4.4; 5.5 & 6.6). Online quizzes enabled students to receive immediate feedback. According to Michael, dynamic simulations were a way to bring some costly science classroom practices such as titrations, readily into the classroom, allowing students repeated opportunities to practice this skill and engage in scientific modelling, saving expensive chemistry resources in the process (see KF 4.3). This latter research finding supports the work of Hennessy et al. (2007) which revealed that dynamic simulation tools offer students opportunities for active manipulation and are useful in promoting scientific reasoning. Angeli and Valanides' (2009) work with science teachers highlighted the importance of the teacher's role in mediating the selection of ICT media that afforded ways of transforming the content to be more comprehensible to the learner. For example, choosing digital media that offer visualisation of abstract phenomena, or dynamic processing of scientific data, and especially where those topics are challenging to reach by traditional means. This finding is also consistent with Yeh et al.'s (2014) work which similarly found that selection of ICT resources and tools by science teachers was predominantly to make science content accessible and comprehensible. Whilst these teachers curated a plethora of authoritative interactive digital media, this action alone does not necessarily lead to meaningful learning opportunities as was shown in Beauchamp and Kennewell (2008). A critical part of the teaching practice noted in this study for leveraging the potential of ICT was the high level of classroom interactivity between the teacher and the students.

The present research also reinforces the prior suggestions of Angeli and Valanides (2009; 2013) about the construct of technology mapping, that is, as teachers become more expert in understanding the connections between the affordances of software in relation to content representations, along with its pedagogical uses, technology integration efforts move towards more active learner-centred uses. This expertise resulting in a digitally transformed pedagogy. This learning affordance perspective also reinforces Osbourne and Hennessy (2003) earlier extensive international review which found that successful

pedagogy with ICT should primarily ensure that the use of ICT adds value to the learning activity. This present research finding also resonates with Wienke and Robyler (2004) technology integration planning (TIP) model, which cautions teachers to first reason about the advantage of using technology in the learning activity, that is, teachers should deliberately approach the design of a learning activity as to whether the technology-based methods offer a solution with enough relative advantage. Britten and Cassady's TIAI instrument (2005) similarly argued this fundamental rationale, as did Angeli and Valanides ICT-TPCK (2005) construct. More recently emerging in the literature is the Kolb Triple E framework (2018) which provides a more nuanced pedagogical affordance perspective to guide ICT integration decision-making including how the ICT media might enhance, enrich, and/or extend learning.

As characterised by the range of authoritative, contemporary, multimodal, and interactive digital media populating each of these teachers' online platforms the present research brings together further evidence to support the link between social-constructivist beliefs, and the selection of digital resources, artefacts, and ICT tools from this learning affordance perspective. Again, this finding highlights the influence of these teachers' beliefs' acting as selective filters (Webb & Cox, 2004) in the ICT reasoning process.

Assertion 7.6

As demonstrated by these teachers, they actively and regularly engaged with the Internet to curate a variety of digital resources and artefacts, housing these for student use in an online digital platform. Each teacher played a pivotal role in the filtering, testing and selection of these digital resources choosing those that were authoritative, contemporary, and/or were multimodal and dynamic in nature. Another key part of their rationale was to make the science content more accessible and comprehensible to the student. In other words, these teachers engaged in digitally curating ICT resources from a social -constructivist learning, knowledge-centred and learning affordance perspective.

7.3.3 *Digital curation*

Whilst different terminology was used to describe the act of digital curation for each participant this involved Internet research to locate ICT resources in support of the

learning goals (see KF 4.4; 5.5 & 6.4). Michael referred to this planning stage as *ICT resource selection* indicating this selection or ‘lurking the Internet’ activity was conducted at home; an activity which often consumed considerable amounts of his personal time. Similarly, Ruby and Patricia mainly worked from home to curate ICT resources. Ruby described this activity as *Context analysis* whilst Patricia called this stage *Digital planning*. The participants explained that a significant affordance of having created their own online platforms, whilst an onerous task at first, meant they could now easily curate ICT resources in real time. This action resulted in building up a repository of digital resources, as suited to their cohort of students which could be easily accessed and repurposed for future activities (see KF 4.5; 4.6; 5.6; 5.7; 6.5 & 6.6). In each case, the teachers had selected and curated a range of ICT resources to their online platforms prior to the commencement of each lesson (see KF 4.7; 5.8; 5.11; 6.7 & 6.8). Their rationale was to make these authoritative resources easily accessible both during and after the lesson. These preparations may have also been motivated by the desire to reduce off-task behaviour; however, throughout the entire series of lessons off-task behaviour was observed to be minimal.

So far, these findings continue to complement Shulman’s construct of pedagogical reasoning and action model (PRA). Firstly, by revealing that these teachers’ pedagogical decisions are grounded in thinking around the learning goals of the activity as it relates to specific subject knowledge aspects; a stage of reasoning referred to in the PRA (1987) model as *Comprehension*. However, to make this knowledge comprehensible to students, these teachers also carried out two further sub-reasoning processes that appear consistent with the *Transformation* stage of the PRA model (1987). As previously discussed, these teachers purposefully selected and curated a range of ICT resources to the support of the achievement of these learning goals, a process referred to in the PRA model as *Preparation*. In curating these ICT resources, a further *Transformation* sub-reasoning process was demonstrated, which Shulman referred to as *Adaptation and tailoring*. This reasoning was exemplified in the participants’ online resource collections which revealed both targeted alignment to the achievement standards of the mandated curriculum and had been purposefully organised and displayed using navigational menus labelled by science topic. As demonstrated during Michael’s exam revision lesson, there was also further evidence of *Adaptation and Tailoring* of science content involving the use of an ICT

application. For this lesson, Michael had used a free online game engine called *classtools.net* to create a range of bespoke Year 10 physics and chemistry exam practice quizzes. Ruby's classroom website was also populated with a range of games she had made using this same game engine.

7.3.4 Contingency planning

Another action referenced by each teacher in planning for ICT-mediated activities was the need to fully test drive their curated ICT resources in case of school security system issues and other technical challenges. This also included the ongoing need to maintain the currency of any curated hyperlinks (see KF 4.5; 4.11; 5.11 & 6.8). Consideration of an alternative lesson plan in case of Wi-Fi connectivity or software failure was cited by each of the participants as a necessary precautionary measure. As observed during Michael's examination revision lesson, the concept mapping tool *Twiddla* failed to work; however, seamlessly he reoriented the lesson having already previously created several physics and chemistry revision games to his online platform. This latter finding supports Feng and Hew's (2005) ICT pedagogical reasoning model which found that during the *Transformation* reasoning stage a further sub-reasoning process occurred, which these authors named *Caution*; a process that referred to the action of preparing for potential digital disruptions.

Assertion 7.7

Each teacher engaged in the digital curation of free ICT resources and tools selected via the Internet tied to supporting the achievement of the mandated science curriculum and achievement standards. The teachers also engaged in contingency planning for these ICT-mediated activities by pre-testing new ICT resources and tools to prevent school firewall issues and formulated a lesson back-up plan in case of other technical challenges. Whilst this digital curation and contingency planning consumed significant amounts of time, according to these teachers this was offset by the opportunity to focus class time directly on coaching students and promoting higher-order discussion and thinking about the content.

7.4 Reasoning and actions about lesson planning

It is important to reiterate that the participants indicated their pedagogical decision making was not a linear construct or as Ruby simply put this, “*There’s lots of circling...coming back to each process...going from this broad scope to then funnelling your thinking*” (01/12/15). This iterative notion of pedagogical reasoning was emphasised when Shulman (1987) first presented the construct of PRA. As revealed in each teacher’s diagrammatic summary of their reasoning and actions for ICT- mediated lessons this consisted broadly of five distinct forms of reasoning (see Figures 4.7; 5.9 & 6.13), two of which have already been described. Another distinct form of reasoning described in identical terms by each participant was “lesson planning”.

7.4.1 Guided collaborative inquiry-based activity

For these teachers, lesson planning meant designing a meaningful task that included a clear assessment guide to scaffold the quality of the work (see KF 4.5; 4.7; 5.6; 5.8 & 6.7). In designing these learning tasks, the teachers also considered an overall engagement strategy, including how they would organise the students. The instructional design of these tasks could be broadly classified as inquiry-based (Anderson, 2002) where the students were positioned to work collaboratively in small groups, an approach consistent with their social-constructivist views. Although Michael indicated that if students preferred to work individually, he would always accommodate this.

Following an open inquiry-based approach means students are given full agency to select the question/s to be investigated (Bell, Smetana, Binns, 2006), with evidence now indicating this instructional approach increases student curiosity and sustains engagement (Bybee et al., 2006). However, as observed in this study, the level of inquiry could be considered guided rather than open-inquiry given that the participants choose the inquiry question and/or the problem scenario, as well as directed students to utilise their curated resources. Michael was observed to actively encourage his students to explore other ICT resources using search engines once the lesson was underway. As seen in Ruby’s *Fakebook* lesson and in Patricia’s *Getting into the Fossil Record* lesson the students were observed to work on a driving inquiry question. In Michael’s *Project Moon*

Base lesson, students were seen to work on a problematised scenario, whereas Ruby's *Sustainable Home* and Patricia's *Big Ideas in Geology iMovie* lessons were both project-based activities. Whilst Michael's exam revision lesson was not framed around an inquiry question, his intention was for the students to create a collaborative conceptual map of key chemistry and physics concepts, a higher order thinking activity. Using inquiry-based approaches should also involve ascertaining the prior knowledge of students (Bybee et al., 2006). However, in this study only Patricia explicitly articulated that she took account of her students' prior knowledge as part of her normal pedagogy. Evidence of a diagnostic test for Patricia's *Getting into the Fossil Record* lesson is shown in Figure 6.6.

Engaging students via inquiry-based instructional approaches to build conceptual understanding and critical thinking skills has been strongly advocated since the science education reforms of the 1990s (Millar, Osbourne & Nott, 1998). Emphasis on problem-based and project-based learning is again being touted as central to a 21st century pedagogy (Newhouse, 2016; Scott, 2015). Furthermore, research has since maintained that when teachers actively participate in designing their own ICT-based inquiry-oriented learning activities, as each of these participants do, implement, and actively reflect on this type of curricula, this results in more successful student inquiry learning outcomes (Koehler et al., 2014; Mishra & Koehler, 2008)

Inquiry-based learning approaches particularly problem-based learning is not without its critics such as Kirschner, Sweller and Clark's (2006) scathing review of this instructional approach for science education. The research is not settled yet as to a solid pedagogical framework to guide technology-enhanced science inquiry-based practices; however, the evidence does point to the requirement of expert facilitation, particularly skillful teacher questioning to support student thinking in these types of learning environments (Hmelo-Silver, 2004; Kim, Hannafin, & Bryan, 2007). Whilst considerable preparation was made for each of these lessons in the selection and curation of digital resources, including the scaffolding offered to the students in the form of learning task guides, this did not mean a reduction in the level of classroom facilitation provided by each of these participants during the lessons. A noticeable feature of the classrooms during these observed activities was the amount of talk and interactivity both between the students, and between the teacher and small groups of students (see KF 4.9; 5.12 & 6.12).

Assertion 7.8

From an instructional design perspective, the learning activities could be characterised as guided inquiry using collaborative group structures. That is, driving questions and or problems were used as the context to lead small teams of students to develop central science concepts or principles as tied to the mandated curriculum. These activities were supported by curated ICT resources, planning templates and criterion-referenced assessment guides that had been mapped against the mandated science curriculum. This extensive lesson preparation serving to empower the students to work more independently and importantly allowed for plenty of classroom interactivity between the teacher and students.

7.5 Reasoning and actions about teaching

At various points throughout this study, each participant was asked to classify key features of their classroom learning environment around their role as a teacher, the role of the student, the role of ICT in their classroom and how these roles related to the lesson being studied. This iterative interview strategy was used in part as a means of triangulation of the emergent themes in the data. Another key theme in relation to the participants' pedagogical reasoning and actions related to their decision making surrounding how they intended to instruct and provide feedback to the students during the lesson, in other words teach the lesson.

7.5.1 *Teacher as orchestrator of learning environment*

Typifying the thinking behind the instructional design of the lessons captured in this study was the appropriation of ICT as a cognitive tool or partner (Jonassen, 1996) to inquire, solve problems, or to conduct project work ultimately to develop students as, "*Independent, sophisticated consumers; learner who is also a producer*" (Ruby: 12/12/15). The participants used various metaphors such as coach, advisor, problem-solver, mentor, facilitator of learning and questioner to characterise their role in these ICT-mediated lesson activities. Importantly, indicating this required them to establish meaningful student-centred learning challenges and for them to be available during the

lesson to support and guide students. As an example, Patricia articulated this as, “*I do believe in knowledge and of how to teach so I don’t think we should give that up. It’s not just a free-for-all for kids to go and research and make their own understandings. They need guidance; that’s why we teach*” (08/12/15).

The present findings reveal confluence to the *Instruction* reasoning process as outlined in Shulman’s (1987) PRA model. As discussed, previous attention has been directed by each of these teachers to classroom organisation (group work), management of ICT resources (online platform) and the design of an inquiry-based task including a criterion-based assessment guide to scaffold the quality of students work. The *Instruction* phase of Shulman’s (1987) PRA model represents the reflections and decisions made in the previous reasoning and action phases, more specifically according to this model, the act of teaching (instruction) is the culmination of this thinking. As evidenced by the thoughtful pedagogical reasoning already undertaken by each teacher at this point, this theoretically should leave them ample time to engage directly with students during class time. This was in fact found to be the case across the entire series of observed lessons and will now be discussed.

The pedagogical activity of each lesson was first analysed at a macro level attending to variables such as how the lesson commenced, how the students were grouped, what ICT tools were used by the teacher and by students, and how the lesson was concluded. This macro-analysis revealed that across the whole set of lessons, two distinct key lesson phases; goal setting followed by collaborative inquiry, were identified. No distinct plenary phase to any of the lessons was observed, instead, a call to action to save your work and pack-up was the norm amongst these participants, followed by words of encouragement to work from home on these inquiry-based tasks. Secondly, the pedagogical activity was further analysed using a micro-ethnographic approach (Erickson, 2006) where pedagogical activity was conceptualised as an activity system and followed Stevenson’s (2004; 2008) analytical protocol as underpinned by Engeström’s CHAT theory (see Table 3.3). This analytical tool was also useful in substantiating the teachers’ beliefs about ICT-mediated learning and the type of learning environment conducive to support this; many elements of which have already been highlighted. Several common themes in relation to the characterisation of the teachers’ pedagogical actions emerged from this detailed lesson analysis and will now be discussed. This

analysis also served to corroborate the teacher's beliefs about the role of ICT and the type of learning environments they aimed to cultivate.

Firstly, to recap using Stevenson's (2004; 2008) analytical protocol, the pedagogical category of *classroom organisation* relates to the relationship between how the *Division of Labour* was distributed throughout the entire classroom *Community* and describes the way the teaching and learning was organised: for example, whole class work, team work or individual work. A summary of the mode of *classroom organisation* across the whole of the data is shown in Table 7.2. The category of *conversational roles* conveys who is directing the talk throughout the lessons' activity; in using a CHAT lens this relates to the relationship between the *Subject* and the *Community* ranging from the teacher directing the conversation with the entire group along a spectrum to where the conversations are fully directed amongst the students. The category of *ICT usage* refers to who is controlling the use of ICT during a given activity. As can be seen in Table 7.4 the coding system also uses a spectrum of possibilities ranging from teacher-centred control through to the student initiating the use of the ICT. Using a CHAT lens then, *ICT usage* relates to the actions between the *Subject/s* and the *Tool*.

7.5.2 Phase One: Goal setting

In all three cases, the initial classroom routine involved the teacher connecting their laptop to the data projector and projecting their key instructional materials onto the main classroom whiteboard prior to the students entering the room, an indicator to the students of the lesson ahead (see KF 4.9; 5.12; 6.9 & 6.10). Michael's classroom norms revealed that his students were expected to log on to his *Moodle* page immediately upon sitting down and then to await his further instructions (see KF 4.9). Patricia and Ruby, preferring instead to gain the attention of the whole class without the use of laptops during this initial phase of the lesson (see KF 5.9 & 6.9). In Ruby's case, the initial phase of her classroom routine also involved the additional requirement of sending out two student monitors to collect the laptop trolley and distribute laptops to each individual student.

Careful explication of the learning task and assessment requirements at the commencement of each lesson was a hallmark common to each of the teacher's repertoire

(see KF 4.9; 5.12 & 6.11). Except for Michael's examination revision lesson, these inquiry-based learning tasks were each to be carried out over several lesson periods. During the initial phase of each lesson, the teacher and students engaged in task explanation and goal setting discourse which also included procedural discussions about where to locate the various curated ICT resources. In Ruby's case, having the youngest cohort, she additionally visually demonstrated the location of these resources on her classroom website.

7.5.3 Phase two: Guided collaborative inquiry

Having carefully explicated the task requirements the main phase of each lesson could be categorised as guided collaborative inquiry, where small teams worked in a self-regulated manner on the learning tasks. Using a CHAT lens, the pedagogical *organisation* of the students was predominantly group work. The student members of the classroom (*community*) had agency to select their own team composition, reflecting a social orientation to the *division of labour*. The teacher (*subject*) orchestrated the whole learning environment or *community* by carefully explaining the requirements of the learning task. As demonstrated by these practices this seemingly served to promote other beneficial social outcomes as very little off-task behaviour was noticed. Once the lesson was underway the students were then left to manage and direct their inquiry activities and projects. Albeit, an interesting feature common to all the lessons was the noticeable lack of sitting down by any of the teachers; instead, they weaved in and around the classroom desks working from behind the students' laptops allowing them to see what was on the students' laptop screens. In moving around the room, they engaged in open-ended dialogue with each team, providing warm encouragement and coaching support as the teams collaboratively engaged in their enquiries (see KF 4.9; 5.12 & 6.10).

As revealed in Table 7.1 the data show that the dominant mode of classroom organisation was found to be the students working in small groups (M=62%). Ruby favoured this mode the most (M=82%), followed by Michael (M=58%) then Patricia (M=44%). The next most dominant mode of classroom organisation was found to be the teacher working with the entire classroom community (M= 29%) with Michael engaging in this type of classroom organisation the most (M=42%). This type of classroom

organisation was found to predominantly occur at the beginning of each lesson, i.e., during the goal setting stage. As can also be seen in Table 7.1 none of the lessons featured students working individually. Using the concept of division of labour based on CHAT (Engeström, 1987), to characterise the organisation of ICT-mediated activity would be collaborative classroom action, again substantiating their constructivist views of learning.

Assertion 7.9

At the macro level this series of lessons were characterised by two distinct phases of activity. The first phase involved goal setting where the teachers carefully explained the learning task and assessment requirements to the whole class. The majority of each lesson was then taken up by a phase of activity best characterised as collaborative guided inquiry where the students worked in small groups on the task. As evidenced by the micro-ethnographic analysis of the classroom organisation across the series of lessons observed the dominant mode was found to be teachers working with small group of students (M=62%), in other words, collaborative activity.

Table 7.1: Summary of classroom organisation modes across the lessons

Classroom Organisation Mode	Total percentage of lesson observed											
	M1	M2	M	R1	R2	R3	R	P1	P2	P3	P	Overall
	Mean						Mean				Mean	Mean
Teacher working with whole group	28	56	42	26	10	18	18	26	34	36	32	29
Teachers working with small groups	0	0	0	0	0	0	0	0	0	0	0	0
Learners working in small groups	72	44	58	74	90	82	82	74	59	0	44	62
Learners working individually	0	0	0	0	0	0	0	0	0	0	0	0
Learners reporting or presenting own material to whole group	0	0	0	0	0	0	0	0	7	64	24	9

Key: M: Michael, R: Ruby, P: Patricia

As revealed in Table 7.2 two conversational role types were found to characterise the discourse across the whole of this data; the most prominent category involving the teachers stimulating critical reflections or other critical analysis amongst their students (M= 61%). That is, these teachers were observed to support learning by prompting, open-ended questioning and formative feedback amongst the teams that was respectful of the students' ideas during much of the available lesson time. The other most significant conversational role involved the teacher giving information to the whole class (M= 19%) with Michael engaging in this type of discourse the most (M=33%), followed by Patricia (M=16%) and then Ruby (M=14%). Whilst this summary does not reveal when this type of discourse occurred, this type of conversation was observed to happen mostly at the beginning of each lesson, i.e., during the goal setting stage. The only notable exception, as shown in Table 7.2, occurred during Patricia's third lesson where the students presented their geology *iMovie* projects. Here only 22% of the lesson time was consumed with dialogic teacher-student interaction, however, the students were presenting their geology *iMovie* projects, nonetheless Patricia attempted to stimulate critical reflections after each presentation.

Assertion 7.10

As evidenced by the micro-ethnographic analysis of the conversational modes occurring across the series of lessons observed, the dominant mode was found to involve the teachers stimulating critical reflections or other critical analysis amongst their students (M= 61%). In other words, these teachers engaged in dialogic practices consistent with promoting a critical thinking learning environment. The other most significant discursive role involved the teacher giving information to the whole class (M= 19%).

Table 7.2: Summary of the conversational roles across the lessons

Conversational Roles	Total percentage of lesson observed											
	M1	M2	M	R1	R2	R3	R	P1	P2	P3	P	Overall
	Mean						Mean				Mean	Mean
Teachers giving information to whole class	37	30	33	14	12	15	14	7	26	14	16	19
Teachers directing questions and answers to reproduce facts	2	3	3	10	2	10	7	7	5	0	4	5
Teachers directing conversation	14	9	12	14	0	0	5	12	5	0	6	7
Teacher stimulating reflections or other critical analysis	47	58	52	62	86	75	74	74	64	22	53	61
Learners directing conversation with peers	0	0	0	0	0	0	0	0	0	64	21	8

Key: M: Michael, R: Ruby, P: Patricia

Table 7.3 provides a summary of who was controlling the use of the ICT during the lessons. The coding categories for this aspect of ICT-mediated activity included a range of teacher-centred through to student-centred ICT resource usage possibilities. The dominant users of ICT during these lessons was found to be the students (M= 78%), with the teachers being in control of ICT on average only (M=22%) of the lesson time, again in keeping with their stated constructivist views. Whilst the data do not reflect when the teachers used ICT, this was observed primarily to occur during the goal setting phase of each lesson. More specifically, the dominant ICT usage mode was found to involve the students working on tasks as initiated by their teacher that is, using ICT to carry out an inquiry task as designed by the teacher (M=48%).

Assertion 7.11

As evidenced by the micro-ethnographic analysis of the ICT usage modes occurring across the series of lessons observed, most of the lesson time involved the students using ICT (M= 78%). More specifically when the students were using ICT this was to work on a collaborative task as initiated by their teacher (M=48%). In other words, these teachers engaged in practices consistent with promoting a collaborative thinking learning environment.

Table 7.3: Summary of ICT usage across the lessons

ICT usage	Total percentage of lesson observed											
	M1	M2	M	R1	R2	R3	R	P1	P2	P3	P	Overall
	Mean						Mean				Mean	Mean
Teacher using ICT	9	33	21	26	2	10	13	26	34	36	32	22
Learners using ICT in a collaborative task as initiated by teacher	72	49	60	57	10	0	22	74	59	64	66	48
Learners using ICT in a collaborative task as initiated by themselves	19	0	10	17	0	0	6	0	7	0	2	6
Learners interacting via ICT as initiated by teacher	0	18	9	0	0	0	0	0	0	0	0	2
Learners interacting via ICT as initiated by themselves	0	0	0	0	0	0	0	0	0	0	0	0
Learners creating using ICT	0	0	0	0	88	90	59	0	0	0	0	22

Key: M: Michael, R: Ruby, P: Patricia

Overall these findings suggest that the teacher's role is critical to the cognitive and social support required to guide student learning using ICT. Several studies of ICT rich environments have revealed that focused inquiry, as observed in this study, requires proactive teacher guidance through the zone of proximal development (Vygotsky, 1978) even when students learn to become more autonomous in these types of learning environments (M. Cox et al., 2004; Hennessy et al., 2007; Keengwe & Onchwari, 2011). Furthermore, other studies of ICT rich learning environments have shown that teachers need to strategically balance student responsibility and self-regulated learning with structured learning activities (Roblyer & Doering, 2010; Webb, 2010); again, an instructional design characteristic common to each of these participant's practice. The metaphor of 'orchestrating learning' is now commonly used to conceptualise the pedagogic role of the teacher in ICT rich learning environments (Prieto et al., 2015); a useful metaphor to portray the role Michael, Ruby, and Patricia in each of these lessons.

Assertion 7.12

Each teacher used very similar teaching repertoires involving an initial goal setting phase that involved establishing the task and assessment requirements group. For most of each lesson the students worked collaboratively in small teams in a self-directed manner. During this collaborative phase the teachers engaged in dialogic style conversations with the student teams. Warm and supportive teacher-student engagement characterised the relationships observed in these classrooms. Overall the pedagogical repertoires evoked the notion of an orchestration of learning.

7.6 Reasoning and actions about reflection

Finally, another distinct form of reasoning identified in this study related to reflecting upon the success of the lesson activity. Whilst offering very modest reviews of their own performance, as documented in the post-lesson interviews, when queried as to reflect on their role in these lessons typical descriptions were, "*Problem solver...actually, helping them to see how they can solve the problems*" (Patricia: 04/12/13). Mostly these reflections related to concerns about student progress and in relation to how well the ICT resources worked from a learning affordance perspective and as to whether any technical

challenges were presented. Almost immediately these teachers engaged in reporting how well they perceived their students to have engaged with the task and about their progress, again reinforcing their learner and assessment-centred pedagogy. In Ruby's case, she additionally reflected on concerns related to her students' lack of independence in regards to ICT capabilities that hindered lesson progression, reasoning that this represented missed opportunities to engage in discussions about the learning activity. To remedy this situation Ruby often made ICT user guides to support students in this regard (see KF 5.6).

Another critical reflection centred on the efficacy of the ICT resources these teachers had selected to support the goals of the lesson's activities. For example, Michael chose to abandon the use of the collaborative concept mapping tool *Twiddla* part-way through his revision lesson as this was hindering the lesson's learning objective which was to create conceptual maps of key physics and chemistry concepts. Again, reinforcing the key decision to use ICT only when it confers a relative advantage. Patricia's technical reflections mainly related to Wi-Fi connectivity issues that were still prevailing at the time of the study and her justification for having to send several groups of students to the library so that they could continue working on the ICT-mediated task.

7.6.1 Curate new or modify existing digital resources

According to each of the participants, having already established a digitally enhanced learning environment allowed them to easily adapt, remove and curate new ICT resources in real time, for example, as were often suggested by students during a lesson. According to Michael having curated an array of digital resources meant that contingency activities were always prepared for (see KF 4.11). Typical of these reflections and actions include Michael's comment:

The way I look at it is, that I can re-do this same lesson some other time with slight modifications, so yeah there is preparation initially, but down the track, it saves time and makes it more interesting...what is so great is you get to organise stuff...put it in somewhere in a labelled folder so I can pull it out whenever I want to do it again (Pre-lesson interview: 25/09/13).

The construct of Schon's (1983) *reflection on action* comes to mind in describing the participants' evaluation of their lessons, again consistent with Shulman's (1987) *Reflection* reasoning process. According to Shulman (1987) the act of *Reflection*, a reflexive process, leads to *New Comprehensions* or new understandings on the subject, content and curricular goals leading to a deepening of pedagogical content knowledge. In relation to the sound knowledge base required for ICT integration Mishra and Koehler's (2006) extended this construct to include technological knowledge, suggesting an interdependency between pedagogical, content, and technological knowledge, that is TPACK. The findings of this research illustrate how bringing together of these intersecting knowledge domains facilitates the meaningful use of ICT.

Whilst these participants were highly motivated to integrate ICT in their classrooms, as indicated by their educational beliefs and the considerable personal time they spent investigating and designing ICT-mediated learning opportunities, having enough professional time to design ICT-mediated lessons has been cited as a critical barrier to ICT integration efforts in schools (Lim, 2006; Tondeur, Cooper, & Newhouse, 2010). Overall the teachers' pedagogical actions were congruent with their stated beliefs about the role of ICT; primarily as a tool to connect students to rich inquiry-based learning opportunities as supported by them as orchestrators of the learning environment. In principle then, the present research is consistent with the broader literature surrounding quality ICT pedagogy (Law et al., 2008; OECD, 2013a; Rogers & Finlayson, 2004; Tamin et al., 2011; Webb, 2010)

Assertion 7.13

Each teacher engaged in a form of *reflection on action* primarily as to how well the ICT resources worked from a learning and technical perspective. According to these teachers using an online classroom repository provided them significant teaching affordances allowing them to curate additional resources in real time, particularly those as suggested by their students. Having an online collection of resources also meant they could modify the lesson if technical issues were encountered.

7.7 Reconceptualising the conceptual framework

The initial conceptual framework for this research highlighted that meaningful pedagogical approaches using ICT were set in social-constructivist learning environments requiring thoughtful decision making including a range of digital technology skills to optimise ICT use for learning. This sophisticated decision making requires the teacher to draw upon a synthesis of several teacher knowledge bases and skills known as TPACK (Mishra & Koehler, 2006), an extension of Shulmans (1986) construct of pedagogical content knowledge (PCK) to include technology. Furthermore, the literature review pointed to several studies that revealed the importance of the alignment of social constructivist beliefs surrounding the role of technology for learning is a critical determinant, if not the primary contributing factor for the meaningful integration of ICT, in other words what a teacher thinks, the teacher does.

Based on the present findings in this study an elaborated model of the ICT pedagogical reasoning and actions emerging from this study is presented in Figure 7.1. This model consists of five broad forms of pedagogical reasoning resulting in various pedagogical actions, and bears some resemblance to Shulman's (1987) PRA model. One notable difference to Shulman's model is the influence of the teachers' educational beliefs upon their actions. Importantly this model should not be perceived as a linear construct, instead, as with most teacher decision-making this is a dynamic and iterative process.

1. Reasoning and actions about educational goals. The participants each shared very similar social-constructivist views of learning where ICT was positioned as a student-centred tool primarily for science knowledge building. This also included an emphasis on using ICT to develop lifelong learning skills such as collaboration, informed science citizenship and inquiry related skills. The teachers demonstrated a techno-entrepreneurial approach by co-opting the affordances of technology for use in their own teaching practices, having each initiated the design of their own online platforms. This action enabled these teachers to offer a blended learning environment, a practice which was very uncommon in their schools at the time of this study. This action also allowed them to easily facilitate the digital curation of a huge array of science-related ICT

resources, along with a range of ICT curricula they had designed to guide students in the use of these ICT resources.

2. *Reasoning and actions about science knowledge.* As evidenced in this study, thoughtful and reasoned ICT action was primarily based on careful evaluation of the learning affordance of the selected technology/s in terms of meeting the intended learning goal. In this study these learning goals were found to be tied to achievement standards and general capabilities framework of the mandated curriculum. These teachers then digitally curated a range of resources to their online platforms to support students in meeting these learning goals.

3. *Reasoning and actions about lesson planning.* The teachers created their own ICT inquiry-based curricula designing this instructional material using a backward mapping approach as tied to the mandated curriculum. Contingency lesson planning was also a consideration if for some reason ICT access was not available.

4. *Reasoning and actions about teaching.* Students were positioned as the key users of ICT in these lessons using ICT both as a tool for scientific inquiry and as a constructional tool to create learning artefacts. At the beginning of each new ICT-mediated activity the teachers engaged in goal setting discourse with the whole class followed then by the students working in teams to conduct inquiry-based activities. During the collaborative phase of these lessons each teacher engaged in conversations to promote critical thinking.

5. *Reasoning and actions about reflection.* In this study the teachers' reflections related mostly to student progress and the efficacy of the ICT from a learning and technical perspective. Having already established an online classroom learning presence allowed these teachers to easily facilitate the curation of new ICT resources, as well as modify existing ICT-based activities. Overall the findings reveal these teachers were intelligent decision makers engaging in purposefully driven reasoned action.

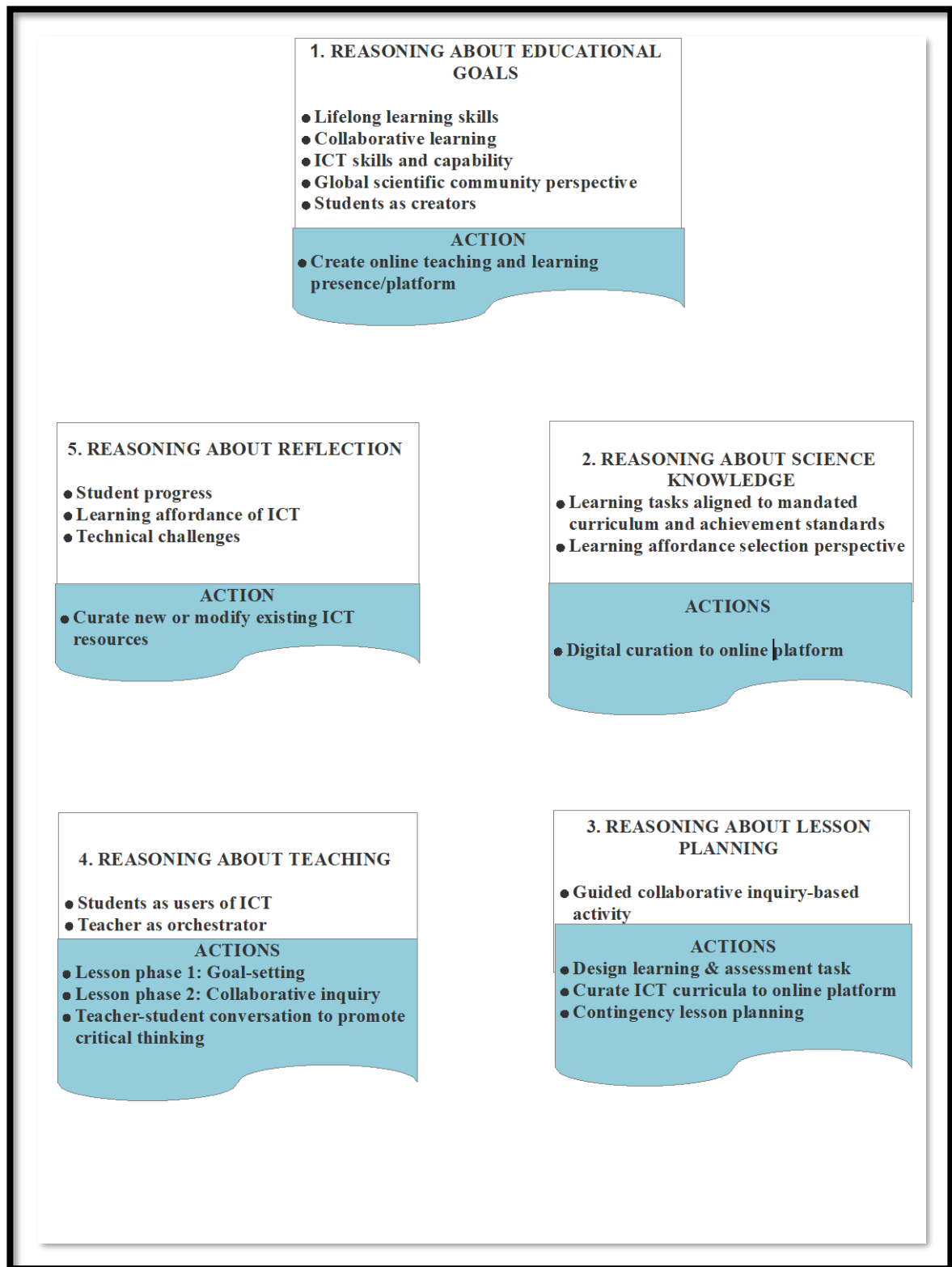


Figure 7.1: ICT pedagogical reasoning and action model

CHAPTER EIGHT: Conclusions and Recommendations

This Chapter presents an overview of the study, conclusions and implications arising from this research. The limitations of the study, along with recommendations for future research are also presented in this final Chapter. The context for this Australian research has seen a Digital Education Revolution (DER) reform agenda commencing over a decade ago that saw an investment of \$2.4 billion that notably provisioned students in Years 9-12 with one-to-one computer access (Auditor General, 2011; Digital Education Advisory Group, 2013). The DER was in part to fulfil a Federal education commitment to afford students a range of ICT-mediated opportunities to develop informational reasoning skills, creativity, problem-solving abilities, and communication skills to live and work successfully in a digital world (MCEETYA, 2009). This significant technology infrastructure provision was also set to establish transformational changes to teachers' pedagogy for the 21st century (AICTEC, 2009).

The impetus for this study was research that highlighted that despite significant technological infrastructure now embedded in schools, the effective engagement of teachers to utilise ICT for learning as envisioned in the myriad of contemporary educational policies and syllabi is still an ever-present challenge (Collins & Halverson, 2010; Lim, 2006; OECD, 2015). The extant literature also revealed that preparing students for success in the Information Age emerges only when reasoned and thoughtful pedagogical actions have taken place (Ertmer & Ottenbreit-Leftwich, 2013; Howland et al., 2012; Voogt, Knezek, et al., 2013). Yet despite this, ICT pedagogical reasoning has rarely been analysed in the literature.

This study was underpinned by Shulman's (1987) concept of Pedagogical Reasoning and Action model, later expanded by Wilson et al., (1987) and Engeström's Activity Theory (1987) linked to an interpretivist-constructivist paradigm (Denzin & Lincoln, 2008). In this thesis, the effective use of ICT has been viewed through the lens of the teacher as the critical determinant for leveraging the affordances of ICT as meaningful instructional and learning tools (Newhouse, Clarkson & Trinidad, 2005; Mishra & Koehler, 2006). Qualitative methods including semistructured interviews, video-based observational data, and an array of lesson artefacts were used to present rich field case studies of three exemplary teachers renowned for their expertise in utilising

ICT for learning science. ICT beliefs, pedagogical reasoning, and classroom practices for the meaningful use of ICT for teaching and learning were investigated through the following research questions:

1. What are the pedagogical beliefs of teachers who are effective users of ICT in teaching and learning? (in other words, why teachers act as they do)
2. What pedagogical reasoning do these teachers employ in creating meaningful ICT based learning experiences? (in other words, how do teachers decide what strategies and representations and tasks to employ)
3. How do these teachers create a learning environment conducive to student learning with ICT? (in other words, what do they do to create a conducive environment)
4. What pedagogical repertoire do these teachers use to engage students in learning science using ICT? (in other words, how do they implement their instructional plan)

The following conclusions and implications are based on the key findings presented in Chapters 4, 5, 6, along with the assertions from the cross-case analysis and discussion as presented in Chapter 7.

8.1 Research Question One: Conclusions and implications

What are the pedagogical beliefs of teachers who are effective users of ICT in teaching and learning? (i.e., why teachers act as they do).

As found in similar studies of extensive technology using teachers these participants each held strong social constructivist beliefs where the use of ICT was an essential element in their classroom learning environments (see Assertion 7.1) (Ertmer & Ottenbreit-Leftwich, 2013; Guzey & Roehrig, 2009; Hennessy et al., 2007; Howland et al., 2012). Importantly, these teachers held the belief that ICT was for the active use by students as a tool to learn with, akin to Jonassen's (1996) original conception of ICT as a cognitive partner and not as simply a didactic teaching tool. ICT was viewed by each teacher as a powerful connector enabling students to engage with a plethora of motivating, authoritative and multimodal science resources in the classroom for

knowledge building (see Assertion 7.2; 7.3). This included the ability for students to witness science phenomenon, dynamic processes and events that would otherwise not be possible in a traditional science classroom, and to carry out repeated practice science through virtual experiments, simulations, quizzes, and tutorials. Each teacher held a personal interest in leveraging ICT for learning science which was also driven by the affordance of connecting students digitally to the global scientific community, for example via citizen science projects as well as to contemporary scientific resources and real-world data. Additionally, the myriad of communication and digital presentation modes afforded by ICT offers presents students a variety of ways to personalise and represent their understandings (see Assertion 7.3). These teachers believed that ICT offered a variety of learning affordances that overall helped to promote a lifelong interest in science (see Assertion 7.1).

They each held common beliefs that meaningful use of ICT relates to engaging students with science learning tasks that promote the development of lifelong learning capabilities, akin to those referenced in the *Australian Curriculum General Capabilities* (see Assertion 7.1). Notably, these teachers held the belief that their role in ICT enabled classrooms was to design and orchestrate higher-order thinking opportunities using the affordances of ICT so that students could engage with scientific phenomenon and problem-based scenarios for knowledge building. This finding has been advocated by various authors including Angeli and Valanides (2005: 2009) and Mishra and Koehler (2008) who reinforce the centrality of the teacher in ICT enabled learning environments. It should be noted that whilst their beliefs were grounded in an overall guided inquiry-based pedagogical approach to teaching and learning science, this instructional approach was aligned to the content or knowledge as stated in the mandated science curriculum (see Assertion 7.8).

As with Pajares (1992) earlier work on the concept of teachers' beliefs, the significance of this research has again highlighted that teacher beliefs are an important filter for pedagogical decision making. Importantly, this research reinforces that teacher belief serves to create and amplify pedagogical action in regards to the meaningful integration of ICT (Bai & Ertmer, 2008; Drent & Meelissen, 2008, Ertmer, Ottenbriet-Leftwich & York, 2007; Inan & Lowther, 2010). A notable finding was that these teachers were not offered systemic external professional development opportunities,

instead took a self-directed approach in pursuing the development of their own ICT skills and capabilities (see Assertion 7.2). This involved spending lots of their personal time to prepare meaningful ICT enabled learning activities (see Assertion 7.7). However, it should be re-emphasised that these were exemplary teachers and not indicative of the general population of teachers. Given it is largely the contributions of teachers who enact the strategic plans envisioned in ICT educational policies locally and nationally, an important implication then is to provide opportunities such as bursaries, for teachers to access ongoing and sustained forms of professional development to engage with innovative and knowledge-centred learning approaches with digital technologies (Gerard, Varma, Corliss, & Linn, 2011; Twining et al, 2013). Importantly where teachers have the agency to direct this support professional learning at their point of need. In initial teacher education courses this should include modelling both the explicit use of ICT in learner and knowledge-centred ways (Bransford et al., 2005). Furthermore, technology, pedagogy and content should be fully integrated across the entire course program, including progressive opportunities for preservice teachers to integrate ICT in authentic contexts including assessments and professional practical experiences (AITSL, 2014; Darling-Hammond, 2006). A further implication of this, being that initial teacher educators must have technological capability and skills and recognise the need to maintain an understanding of the learning affordances and application of emerging ICTs in their specific areas of expertise given its pervasive use in society (Angeli & Valanides, 2009; Cox & Graham, 2009; Mishra & Koehler, 2007). This comprehensive approach to building both the ICT confidence and capability during initial teacher education is likely to reinforce a learning affordance perspective in regards to the meaningful use of ICT for the 21st century classroom, and therefore support the development of a technology-enabled pedagogy. Importantly where the use of technology ultimately becomes ubiquitous.

8.2 Research Question Two: Conclusions and implications

What pedagogical reasoning do these teachers employ in creating meaningful ICT-based learning experiences? (i.e., how do teachers decide what strategies, representations, and tasks to employ?)

Five broad forms of pedagogical reasoning and action, akin to Shulman's (1987) PRA model were evidenced in the planning and facilitation of meaningful ICT-mediated activity by these three exemplary science teachers (see Assertions 7.5; 7.6; 7.7 & 7.8). Like Shulman's original PRA model (1987) the ICT pedagogical reasoning model emerging from this study (see Figure 7.1), could also be characterised as a reflective inquiry model. More specifically where pedagogical reasoning follows a deliberate backward mapping approach from the mandated science curriculum (see Assertion 7.5), in other words ICT is selected primarily to solve learning problems. This finding of working backwards from the mandated curriculum and assessment framework is like several of the technology integration models presented in Chapter 2, including the TIP model (Wienke & Robyler, 2004), the TIA model (Britten & Cassady, 2005) and the Understanding by Design™ model (Wiggin's & McTighe, 2011).

One critical form of reasoning found in this study has been categorised as *Reasoning and actions about educational goals*. As found in this study, the educational goals driving the design and facilitation of the learning activities involving the use of ICT related to higher-order thinking skills including problem-solving and critical thinking in relation to science concepts as stated in the *Australian Curriculum: Science* (ACARA, 2015a). Students were positioned to work collaboratively in these learning activities and furthermore given agency to represent and communicate their scientific ideas using a variety of presentation modes from an array of freely available digital media (see Assertion 7.3). As such students were positioned as creators rather than consumers of information (Istance & Kools, 2013). Again, the present research demonstrates the reflexive relationship between teacher belief and the influence of this belief in their pedagogical practices (Bai & Ertmer, 2008).

Another critical form of reasoning identified was categorised as *Reasoning and actions about science knowledge*. From a practical stand-point this involved identifying the desired science concepts, processes and/or skill learning outcomes as tied to mandated science achievement standards and general capabilities framework of the (ACARA,

2015a). This established the objective/s of the learning activity. As advocated by Bransford et al (2000, 2005), these teachers approached the instructional design of these ICT-mediated activities from a knowledge and assessment-centred perspective. Similarly, as with Shulman's PRA model (1987) the teachers featured in this study carried out a significant amount of *Transformational* preparation, consuming lots of their personal time, to design and facilitate meaningful ICT-enabled activities for their classroom (see Assertion 7.7). This included selecting and digitally curating a range of free ICT resources and tools from the Internet to support the students in meeting the intended learning goal/s, primarily as to make the science content accessible and comprehensible for their students (see Assertion 7.6). Whilst these teachers each deliberately curated authoritative ICT resources into a central online repository this platform was not a didactic tool. Instead the emphasis was modelling the use of authoritative, contemporary, and accurate resources using the online platform as a launching pad for activity. This present research again underscores the critical importance of teachers having pre-requisite technological knowledge, subject matter, and curricular knowledge and the knowledge to evaluate the efficacy of ICT resources from a learning affordance perspective (Angeli & Valanides, 2009; Harris et al, 2010), in other words a knowledge base as suggested by the construct of TPACK (Mishra & Koehler, 2007).

Another form of reasoning identified was categorised as *Reasoning and actions about lesson planning* and involved thinking around the instructional design of the lesson activity itself, again akin to Shulman's (1987) *Transformation* reasoning and action stage. In keeping with their social constructivist beliefs on learning, these teachers incorporated collaborative team structures and used a driving question and or problem-based scenario as the context to lead the activity of these small teams, in other words they framed learning activities using a guided inquiry-based approach (see Assertion 7.8). As well as supporting learning with a range of curated ICT resources, these teachers offered further cognitive scaffolds to support the quality of student learning by designing planning templates and criterion-referenced assessment guides mapped against the mandated curriculum (see Assertion 7.8). An implication arising from this being that teachers should be deeply familiar with both the scope, sequence and structure of the mandated curriculum and its content. Additionally, in preparing for ICT-mediated activity these teachers pre-tested new ICT resources and tools to prevent school security system issues

and engaged in contingency planning by formulating a lesson back-up plan in case of other technical challenges (see Assertion 7.7.). The implication of this aspect being that teachers have enough lesson preparatory time

Another critical form of reasoning identified was classified as *Reasoning and actions about teaching*, a phase analogous to Shulman's (1987) *Instruction* reasoning and action phase. Having already curated a range of curriculum aligned ICT resources, including the preparation of cognitive learning scaffolds, this deliberately freed the teacher from delivering content during these ICT enabled activities. Given the intentional inquiry-based design of the activities resulted in students being the key users of ICT during these lessons (see Assertion 7.11). Importantly, these teachers rationalised that their significant preparatory actions were offset by the additional availability of in-class time to engage in coaching and purposeful dialogue to promote critical thinking and to empower their students to work independently (see Assertion 7.6 & 7.8).

The participants decision-making and actions surrounding ICT-mediated activity also involved another form of reasoning categorised in this study as *Reasoning and actions about reflection*, a phase corresponding to Shulman's (1987) *Reflection* reasoning and action phase. The reflections were concerned mostly about student progress and the efficacy of the ICT resources from both a learning and technical perspective. These reflections were carried out both during the lesson activity itself, that is, reflection-in-action as well after concluding an ICT-mediated activity, that is, reflection-on-action (Schön, 1983) (see Assertion 7.13). Whilst these teachers acknowledge that initially it was an onerous activity to establish their virtual classrooms, once established this allowed an easy mechanism for adapting learning activities in real-time, for example curating additional ICT resources or for modifying the learning activity following reflection on their efficacy (see Assertion 7.13).

It is important to reiterate that at the time of this study these teachers were working in digitally optimal conditions, where the students had one-to-one computer access and reliable network access. Nonetheless, this aspect of the research has highlighted the complexity and preparatory actions involved in planning and facilitating meaningful ICT enabled science activities for the classroom. This significant pedagogical reasoning draws upon a range of teacher professional knowledge bases as previously identified in Shulman's PRA model (1987) and then later expanded to incorporate

technology knowledge by Mishra and Koehler's (2006) into the TPACK framework. These teachers primarily acted as curators of digital content using the mandated science curriculum as the primary filter and the context to orchestrate the development of a range of the 21st century skills and competencies in their science classrooms. Furthermore, these teachers creatively acted as designers of their own relevant ICT enabled science curricula and were supported by their school leaders in this innovative approach (Angel & Valanides, 2005; Mishra & Koehler, 2008).

This finding of a technology-mediated inquiry-based pedagogy has implications for initial teacher education and teacher professional development programs to include specific emphasis on instructional designs focused on problem-based and project-based instructional approaches (Hennessy et al., 2007). Finally, this research has again reinforced that teacher belief, in this instance on the role of ICT for teaching and learning, grounds their subsequent choices and actions which in turn serves to enhance the development of their TPACK (An & Reigeluth, 2012; Cox & Graham, 2009; Bai & Ertmer, 2008).

8.3 Research Question Three: Conclusions and implications

How do these teachers create a learning environment conducive to student learning with ICT? (i.e., what do teachers do to create this environment?)

These teachers demonstrated a genuine interest in using ICT in meaningful ways and were renowned for their skills, knowledge, and capabilities with technologies. This interest in ICT for learning resulted in these teachers pursuing the provision and maintenance of their own virtual classroom repositories, along with using a range of online publishing channels; importantly they were supported by their school leadership to pursue these innovations (see Assertion 7.3 & 7.4). Each teacher offered their students a digitally enhanced learning environment; a practice which was very uncommon in their schools at the time of this study, however, this was in keeping with their beliefs about the affordances of ICT for learning science (see Assertion 7.4). Additionally, these virtual classrooms also served as online curriculum repositories allowing these teachers to easily

curate useful ICT resources in real-time and evolve their ICT-based science curricula over time (see Assertion 7.13).

Warm and supportive teacher-student engagement characterised the relationships in the classroom learning environments demonstrated in this study (see Assertion 7.12). ICT was positioned as a pivotal structural element of these classroom learning environments where its role was for active student inquiry and the creation and communication of science understandings and other learning artefacts (see Assertion 7.11). Students were offered agency by these teachers to select from a wide range of digital media tools to create representations of their science understandings and communicate this. This agency allowed students to select from a wide range of communication and presentation modes e.g. text, audio, photos, movies, animations, etc. as suited to their preferences. According to these teachers' this level of agency served to enhance student motivation and engagement, support a more personalised learning environment and exposed students to a variety of digital technology-related skills (see Assertion 7.3). Additionally, these teachers encouraged students to publicly disseminate these digital content representations via their sanctioned digital platforms e.g. classroom websites, *YouTube*, and *iTunes* channels, indicating that this action helped to promote a global scientific community perspective in their classrooms.

Maintaining a digitally enhanced learning environment was found to involve a substantial amount of the participants time (see Assertion 7.7). An important implication arising from this aspect of the research is that insufficient teacher planning time may continue to inhibit ICT integration efforts, best served if teachers are given enough time to collaborate with their peers (Ertmer & Ottenbreit-Leftwich, 2013; Wenger, 1998). Furthermore, this study emphasises the importance of initial teacher preparation and the ongoing capacity building of teachers' TPACK knowledge base for the orchestration of meaningful learning opportunities using engaging and authentic contexts (AITSL, 2014; Rogers & Twidle, 2013). This research also highlights the importance of high-quality teachers who can form positive relationships with students.

8.4 Research Question Four: Conclusions and implications

What pedagogical repertoire do these teachers use to engage students in learning science using ICT? (i.e., how do teachers implement their instructional plan?)

At a macro level, two distinct phases of classroom activity characterised the lessons observed in this study; the first phase classified as goal setting, with the second lesson phase being collaborative inquiry. During the goal-setting phase these teachers carefully orientated the whole class to the overall requirements of the learning activity and had scaffolded with a range of ICT resources and criterion-based assessment guides. Following this introductory phase, micro-ethnographic analysis revealed that much of each lesson then involved the students working in a self-directed manner in small collaborative teams on the designated inquiry task. In other words, these teachers engaged in practices consistent with promoting a collaborative thinking and learning environment.

During this collaborative inquiry phase, the teachers engaged in dialogic style conversations with student teams. The typical conversational mode involved the teachers stimulating critical reflections or other analysis amongst these small teams. In other words, these teachers engaged in dialogic practices consistent with promoting a critical thinking and learning environment (Tytler & Aranda, 2015). In keeping with the teachers' social constructivist beliefs, the micro-ethnographic analysis revealed that the dominant usage of ICT during these lessons was by the students. This present research underscores the critical role of the teacher as both a designer of engaging inquiry-based ICT-mediated activity, as well as the instructional capacity to act as an orchestrator of a learning environment that promotes collaboration and critical thinking; again, reinforcing the importance of building the ongoing capacity of teachers TPACK knowledge base.

8.5 Limitations

This research study has several limitations. Firstly, it was limited to three participating science teachers capturing three lesson observations. Secondly, all three teachers were in metropolitan schools with an above-average Index of Community Socio-Educational Advantage (ICSEA) score and furthermore where two of the teachers

featured taught academically able students. Whilst intentionally designed to capture observations where schools had deployed and maintained computers with a student ratio of one-to-one, the DER funding has since ceased. Secondary schools have now adopted a variety of computer device deployment models, mostly following a student-parent owned BYOD model. Therefore, the applicability, along with the limited scope makes the generalisability of the assertions and conclusions somewhat unwise. However, whilst the scope of the case study data is limited in its diversity, the design of this study featuring exemplary science teachers, along with the subsequent detailed analysis has provided useful insights into their ICT pedagogical reasoning and actions and is therefore considered to be significant.

Interview responses may be influenced by what the participant believes to be the correct thing to say concerning the issue or concept being interrogated by the researcher (Partington, 2001); however, to ameliorate this, lesson observation data was also captured to corroborate the emerging themes. Whilst these lesson observations were video recorded enabling micro-ethnographic analysis (Erickson, 2006) observations still represent a point-in-time moment and do not capture the lesson before or after. Therefore, this case study design is best taken as a referent to illuminate quality teaching concerning the concepts of ICT pedagogical reasoning and actions in specific circumstances.

8.6 Further research directions

It is acknowledged that the findings and assertions about ICT beliefs, pedagogical reasoning and practices have originated from three case studies of exemplary teachers working in a one-to-one environment; therefore, a broader scope of research would be useful to build on the findings of this study which has highlighted exemplary practice in optimal conditions. Studies of ICT beliefs, practices and reasoning conducted in BYOD environments and longitudinal studies of growth in these elements of TPACK would be most useful to inform initial teacher educators, as well as provide useful data to inform the development of professional learning resources to support the growth of expertise.

8.7 Concluding comments

This research has reinforced that whilst providing enough ICT equipment and the necessary technological infrastructure to students and teachers is vital, equally mobilising the affordances of ICT for the Information Age is highly dependent on a teacher's attitude and aptitude to use ICT from a learning affordance perspective. As an initial teacher educator this research also serves as an imperative to provide preservice teachers with as much exposure to the new 'work smarts' (FYA Foundation for Young Australians, 2017) in their course training, alongside developing the necessary pedagogical content knowledge to support the foundations of a digital pedagogy; one that includes the skills of working as a designer of meaningful tasks, a digital curator, mentor, co-collaborator and learning orchestrator. The interrogation of this real-world teaching practice has ultimately revealed a common willingness by these exemplary teachers to continually engage in a practice of thoughtful experimentation with the emerging array of digital resources and tools; serving to incrementally develop their technological aptitude and moreover serving to act as a model of lifelong learning for their students.

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APPENDIX A

Learning outcomes Pedagogy Attributes Instrument Source: Adapted from LOPA instrument C-SaLT (Newhouse & Clarkson, 2008)

Learning environment component	Developing	Routine	Comprehensive
Investigation of reality	Some learning activities incorporate aspects of real situations. Typically, at the end of a learning sequence students apply knowledge and skills to an example situation. Examples may be used as an introduction.	Routinely the focus of learning activities is to investigate real situations. This will tend to involve problem-based learning with the connection to reality evident throughout.	All learning activities are organised around the investigation of real situations from which knowledge and skill development emanate.
Knowledge building	Activities support learners in demonstrating their understanding involving the coverage of information, which they are to remember which may take account of their prior knowledge.	Activities regularly support learners to integrate new ideas with prior knowledge and demonstrate their own understanding. While the aim is to develop deep understanding, this may be uneven with some superficial approaches to knowledge.	Learning activities support learners to integrate new ideas with prior knowledge and to construct models to demonstrate the fullness and complexity of their understanding.

	Developing	Routine	Comprehensive
Active learning	Some opportunities are provided for students to actively manipulate objects and tools but often students passively attend to the teacher and instructional materials.	Activities routinely support learners to actively manipulate objects and tools, to pose and investigate problems and recognise when they need more information.	Activities engage learners in actively manipulating objects and tools and reflecting on what they have done. They are involved in mindful processing of information to pose and investigate problems where they are responsible for the result.
Authentic assessment	Students are assessed on some assignment work although much of the assessment structure is based on tests, which are typically independent of regular student activity.	Routinely assessment is based on what students do and what they demonstrate they understand.	A cohesive assessment program is employed that emerges from learning activities, contributes to student learning, and uses real life examples.
Engagement, motivation, and challenge	Many activities are designed around an understanding of the interests and motivations of the learners with some involving a degree of challenge.	Activities tend to be designed around an understanding of the interests and motivations of the learners but involve significant challenge and are suited to their needs.	Activities engage learners in actively and wilfully working towards achieving cognitive goals, which, they can articulate.
Student productivity	Most student activity contributes towards intended	Student activity usually contributes towards intended	All student activity contributes towards intended learning

	learning outcomes. Efforts are made to reduce the time and effort spent on unnecessary repetitive tasks.	learning outcomes. Very little time and effort is spent on unnecessary repetitive tasks.	outcomes and their time on task is maximised.
Higher level thinking	Some activities engage learners in developing higher-order thinking skills going beyond the usual receiving of information, routine practice, and simple reproduction.	Activities regularly engage learners in developing higher-order thinking skills through problem solving although many activities may still focus on lower-order thinking.	Activities engage learners in solving complex and ill-structured problems and support them in developing higher-order thinking skills such as analysis, synthesis, and evaluation.
Learner independence	Activities support learners in making some decisions about their own learning. They are sometimes expected to work on long-term activities independently of the teacher.	Activities regularly involve learners in working independently of the teacher on long-term activities. They are encouraged to take responsibility for their own learning to the extent developmentally possible.	Activities support learners to maintain their own learning, to take up opportunities as they arise, to make key decisions about their own learning and to become life-long learners.

	Developing	Routine	Comprehensive
Collaboration and cooperation	Some activities involve learners in working with peers on shared activities. They sometimes communicate with peers or mentors to support their work.	Activities typically involve learners in cooperating or collaborating with others. They regularly work with groups of students on shared activities and communicate with peers and mentors to support their work.	Activities support learners to work in learning and knowledge building communities, exploiting each other's skills while providing social support and modelling and observing the contributions of each member.
Learning Styles	A range of activities are if suite a variety of learning styles typical of the learners. Learners are sometimes supported to reflect on their own learning.	Activities often allow learners to engage with experiences that suite their own learning style. They regularly reflect on their own learning.	Activities allow learners to engage in a manner that suites their own learning style. Learners are supported to reflect on the decisions they make and strategies they use as they learn.

APPENDIX B

Analytic memo record

Lesson observation	1	
Date/time	25 September 2013 8.30-9.30am	
Participant 1	Michael	
Lesson title	Newton's 2 nd Law	
Year group	10 Academic Extension Group	
Lesson plan elements	Lesson observations	Memo Evidence link
Key content addressed	<p>PHYSICAL SCIENCE</p> <p>The motion of objects can be described and predicted using the laws of Physics (ACSSSU229)</p> <ul style="list-style-type: none"> Using Newton's Second Law to predict how a force affects the movement of an object 	See learning task given to students
Key skills addressed	<p>QUESTIONING & PREDICTING</p> <ul style="list-style-type: none"> Formulating questions that can be investigated scientifically <p>EVALUATING</p> <ul style="list-style-type: none"> Evaluating information from secondary sources as part of the research process <p>PROCESSING & ANALYSING DATA</p> <ul style="list-style-type: none"> Constructing a scientific argument showing how their evidence supports their claims to support <p>COMMUNICATING</p> <ul style="list-style-type: none"> Using the internet to facilitate collaboration in joint projects and discussions Presenting results and ideas using a range of presentations to communicate science ideas 	See assessment rubric as part of learning task given to students
General capabilities addressed	<ul style="list-style-type: none"> Numeracy Critical and creative thinking 	Graphing- higher order thinking as related to a problem-using the Internet to gather

	<ul style="list-style-type: none"> • ICT capability • Personal and social capability 	useful research information -working in teams with role-based tasks		
Prior knowledge of students	Recognise that a stationary object or a moving object with constant motion, has balanced forces acting upon it	Had worked on this concept for several lessons prior		
How did the lesson commence?	Talked about a recent PD he attended on the value of working in a group before introducing group investigative task	Students could enter the room as soon as they began to arrive		
What teaching and learning activities did the students work on during this lesson?	Summary of key activities	Students role	Teachers role	Learning environment
	<ul style="list-style-type: none"> • Initial planning, role allocation of the task • Watched the pre-selected videos • Commenced collection of research data • Students ran many ideas past Michael 	<ul style="list-style-type: none"> • Student as self-directed learner • Student as a team member 	<ul style="list-style-type: none"> • Teacher as expert guide • Teacher promoting self-directed learning • Teacher probing and promoting scientific reasoning • Teacher guiding the flow of the task by: • Teacher as advisor to groups • Teacher as trainer • Teacher as a collaborator 	<ul style="list-style-type: none"> • Constructivist approach to T&L • Student centered • Project based learning • Engaged students in learning the curriculum by engaging them in solving a complex problem set around a challenge • Teacher's role was to set up the project • Arrange access to all the required resources • Established an organizational structure for the groups • Then supported the students to succeed throughout the project
How was the lesson concluded?	Told would have to work on this at home but would be given more class time to work collaboratively, and particularly as many students absent due to carnival			

How were the students organized?	Groups of three-max of 4	Students chose to work with whom they liked, however, they all seemed to end up working with the people already on their tables
What ICT tools did the teacher use during this lesson??	<ul style="list-style-type: none"> • Mobile phone- took role on this • MAC lap top-leased from DoE • MIMIO data projector and IWB • Wireless presenter 	<ul style="list-style-type: none"> • Teacher completed class registration using his mobile phone <p>Had already pre-connected his lap top and had powered on the data projector prior to students entering the room</p>
What ICT tools did the students use during this lesson?	<ul style="list-style-type: none"> • MAC lap top • Logged on to MOODLE page to find learning task and websites suggested by Michael 	When Michael is addressing the group he always says “shut your lap tops folks” and waits for this before he addresses the group
How was the learning environment organized to assist student learning, safety, logistical or management issues?	Room is a typical secondary science laboratory set up with tables of 4- 6 students and wooden perimeter benches with sinks, gas taps.	All task brief sheets were pre-loaded on to his MOODLE page which also contained all the hyperlinks to other resources that could help them research for this task
How did the teacher monitor student learning during the lesson?	Once investigation task was set up Michael walked around the room constantly and offered feedback or provoked scientific reasoning with lots of open-ended questions	Never sits down
Teaching and learning documents Associated with this lesson		<ul style="list-style-type: none"> • Michael used a Keynote presentation to introduce task • Learning task description -only available digitally via class Moodle page • Pre-loaded suggested hyperlinks to Moodle

TIME	VIDEO POINTS TO CLARIFY
0:30	Clarify the entry protocol to class Student all seem to open MACs to log on- Is this to MOODLE?
2:00	Conducts roll via smart phone- is this iPhone-Tell me how this works?
4:30	When you began to address the whole class to introduce the lesson you say ‘shut your lap tops’-do you always use this as a sign Do you always review the previous lesson and homework that you may have set?
5:42	Introduces Newton’s Second Law investigative task, mentions it will be done in groups of 3 or 4

	How important is group work in your classroom? How important is this strategy to you? What are the main benefits that you see?
6:25	You tell them about your recent PD and use evidence about group work, you mention diversity of groups...is this important to you? If so why?
7:35	You discuss how each of the students will play a role in this investigation. At this point you have a PPT displayed on your data projector summarizing the key points in the task. Do you always do this? Why? Does everything you display on your data projector get placed on your MOODLE page? Why?
7:45	Your investigative task is what we call open guided inquiry ...here you have set the RQ and set it using an interesting scenario of a research mission to the Moon....do you always do this? Do you ever do pure open inquiry? If not, why not? Is time a limiting factor?
8:54	You explain the group roles: Astronaut Experimental role Theoretical role Do you always do this? If so why?
11:01	You inform students that the task brief is already on MOODLE and on it are three pre-selected videos Do you always preview these hyperlinks? Why did you do this?
11:34	You state you would prefer them to find their own evidence sources. Why is this?
11:56	You conduct a brainstorm on the whiteboard re: the types of products the students could design Why do you offer open-ended products/representations?
13:01	You challenge the students to come up with a catchy project name and query them about RAFT Role Audience Format Task
13:43	You ask the students to think about how to make their presentation creative e.g. wear costumes Why do you try and promote creativity?
14:24	You bring up your MOODLE page and direct students to the assessment rubric..this is an assessed piece Do you always produce a rubric to guide tasks? Why?
15:08	SWIVL drops out....Michael notices it has lost tracking From this point on had to switch to FLIP camera to record remainder of lesson
Student activity	Why do you think your students were so engaged in this task? What role does ICT play in this learning episode?

APPENDIX C

Final member checking semistructured interview questions

1. What type of learner are you trying to produce?
2. What is the main reason you use ICT in your science lessons?
3. You have mentioned on several occasions that your student's use of ICT in the classroom is more important than your own. Why is this?
4. Can you elaborate on why so much of the lesson activities I have observed in your classroom involve the students working in pairs or in small groups?
5. I have noticed that you provide task briefs and rubrics for the activities your students do in the classroom. Why is this?
6. When ICT is being used in your classroom I notice that you constantly move from group to group engaging in dialogue. Can you describe what you are doing during these interactions? Why is it valuable to use so much of your time doing this?
7. I have noticed that for the clear majority of your lesson time your students are engaged and on –task. What do you attribute this to?
8. I have observed that the use of ICT both within and between your lessons is both for 'informational' purposes as well as 'constructional' uses of ICT. How would you characterise the uses of ICT in your classroom?
9. Can you please give me a word or phrase to describe the following aspects of your learning environment?

Aspect of the learning environment	Characteristic
Your role as a teacher	
Your students' role	
The role of ICT in your lessons	
Your approach to teaching and learning	
Your approach to assessment	

10. We know that teachers have this rich body of knowledge called 'pedagogical content knowledge' that they draw on and that they use what we call 'pedagogical

reasoning' to draw upon that knowledge base to plan for lessons, to deliver lessons and to assess them. What is visible to me is what happens in your classroom. What is not visible to me is how you put this all together to deliver these sophisticated science lessons that incorporate ICT. What I want you to do is to talk me through the process you follow to plan a lesson that will incorporate ICT. So, lets' start with what things do you draw upon, and what decisions do you make as you reason about how you will put this lesson together. Just talk me through it- if you like you could sketch out this process on a flow chart if that will help you at all.

**** Can you please describe the intent of your classroom website? Why is it publicly available? Can you describe any learning benefits that you have noticed since you created this digital resource? How onerous has the maintenance and evolution of this site been?**

APPENDIX D

Ethics request approval letter for teachers

School of Education
Edith Cowan University
2 Bradford Street
Mount Lawley
WA 6050

Dear <xxxxxx>

Project: Learning science in an online world

I (Julie Boston) am conducting a research project that will investigate how teachers use ICTs effectively in their teaching to promote students' learning of science. It is anticipated that the study will contribute new knowledge about how effective teachers think through their choice of ICT's and their use of them in their teaching to capitalise on the affordances of ICT in science teaching and learning.

The research findings arising from this study will be used to inform the development of professional learning materials aimed at supporting the capacities of pre and in-service teachers to provide meaningful technology-enabled science learning experiences. Research of this kind also has design implications for ICT school planning and the development of pedagogically sound science educational ICT tools and curriculum resources that are targeted to the Australian Curriculum.

You have been invited to participate in this project as you have demonstrated a keen interest in incorporating digital technologies in authentic contexts in teaching and learning and have been recognised by your school for your ability to exploit the rich opportunities afforded by 1:1 computing environment to foster learning in science. Your school is one of three schools invited to take part in this research project. This research project will run from August to December 2013.

What does participation in the research project involve?

Research data will be gathered by audio-recording a series of pre-lesson interviews to explore your reasoning about the choices of ICT's and how you plan to use them to enhance learning in your science lesson. Planning documents will also be collected for analysis. You will then be video recorded as you teach these lessons, which make use of ICT's to promote science learning. The focus of the video will be on you as the teacher, however because this will be capturing normal teaching activities some of the student's images will be included in the video footage. The lessons will be video recorded using one camera with an FM transmitter microphone and I will record field notes of key events. Following the observed lesson, I would like to conduct a post-lesson interview to explore your reflections on the effectiveness of the use of ICT's. Research data will be gathered for three lessons and these lessons will be negotiated for times entirely suited to you. Following the final lesson; a video-stimulated interview will be conducted to explore key themes emerging from the data. Other than inadvertent capture on video, no other student data will be gathered. All video data collected from this project will be held on a secure, password accessed only computer and any reports of this research will not name any teachers, schools, or students.

To what extent is participation voluntary, and what are the implications of withdrawing that participation?

Participation in this project is entirely voluntary. If you or a student decides to withdraw from the study no further research data will be collected from that individual, however, data collected to that point would be retained. There will be no consequences relating to any decision by an individual or their School regarding participation. A decision not to participate or to withdraw from the study will not affect the relationship with the research team or ECU. Students, with their parent's consent, will be invited to participate in the research by being videoed during lessons. Should consent not be given for a student to be video recorded they will be seated in a position in the classroom not covered by the camera.

What will happen to the information collected, and is privacy and confidentiality assured?

The identity of participants and the school will not be disclosed at any time, except in circumstances that require reporting under the Department of Education Child Protection policy, or where the research team is legally required to disclose that information.

Participant privacy, and the confidentiality of information disclosed by participants, is assured at all other times. The data will be stored securely on a password-protected computer on campus at ECU Mount Lawley. The data will be stored for a minimum period of 5 years. The data will be used only for this project. Some video clips may be selected for use in professional learning for teachers and pre-service teachers or for use in educational contexts to demonstrate best practice. Before they are used in this way, separate written consent for the use of each specific clip will be obtained from the teacher and the school principal to ensure that only positive image of teaching and learning are shared. Consistent with Department of Education policy, a summary of the research findings

will be made available to the participating site(s) and the Department.

Do all members of the research team who will be having contact with children have their Working with Children Check?

Yes. No risks have been anticipated for the teacher or students involved in this project. The researcher who will record the lessons has full WACOT registration.

Is this research approved?

Edith Cowan University Ethics Committee have approved the research, and meets the policy requirements of the Department of Education.

Who do I contact if I wish to discuss the project further?

If you would like to discuss any aspect of this study with a member of the research team, please contact me on the number provided below. If you wish to speak with an independent person about the conduct of the project, please contact the Research Ethics Officer, ECU Ethics Committee on 6304 2170 or research.ethics@ecu.edu.au.

How do I indicate my willingness for our school to be involved?

If you have had all questions about the project answered to your satisfaction, and are willing for your School to participate, please complete the Consent Form on the following page.

This information letter is for you to keep.

Kind regards

Julie Boston

Lecturer in Science Education

Edith Cowan University

Ph: (08) 6304 5702

Email: julie.boston@ecu.edu.au

ACHER CONSENT FORM**Project: Learning science in an online world**

- I have read this document and understand the aims, procedures, and risks of this project, as described within it.
- For any questions I may have had, I have taken up the invitation to ask those questions, and I am satisfied with the answers I received.
- I am willing for this School to become involved in the research project, as described.
- I understand that participation in the project is entirely voluntarily.
- I understand that the School is free to withdraw its participation at any time, without affecting the relationship with the research team or Edith Cowan University
- Data can be withdrawn from the study at any stage of the project
- I give permission for the research findings to be reported at academic conferences and in journal articles and for selected highlights that I have approved from video footage to be used for teacher professional learning

programs, provided that: only students who have given consent to be filmed are included on the video; me

students are only named by their first name, and as the class teacher I am only named by my surname and that my school is not named.

- I understand that the School will be provided with a copy of the findings from this research upon its completion.

Name of Participant (printed): _____

Name of School: _____

Signature of Participant: _____ Date: / /

Please return the signed consent form to:

Julie Boston

School of Education

Edith Cowan University

2 Bradford Street

MOUNT LAWLEY WA 6050

APPENDIX E

AUTHORISATION TO USE HIGHLIGHTS PACKAGE FOR PROFESSIONAL LEARNING PURPOSES

Research project: Learning science in an online world

This consent form relates to the research study concerning teachers' effective use of ICTs in science teaching and learning. The project involves collaboration between Edith Cowan University and <XXX> School.

We request your consent to use the named video files as examples of effective teaching and learning practices for teacher professional learning purposes. The video clips will be used to show other teachers and student teachers what the effective use of ICTs in science teaching looks like. These short video excerpts will be viewed by other teachers at conferences, workshops or on password protected secure web sites that can only be accessed by teachers participating in professional learning programs. Please review the following video clips: < xxx.MP4; xxx.MP4>

Please sign below to confirm that you approve the use of these video clips for teacher professional learning purposes and affirm that:

- They provide positive images of teachers, students, and teaching and learning practices;
- Do not include images of students whose parents have not consented for them to be included; and
- Students are only named by their first names, the teacher by surname only and the school is not named.

Name of Teacher _____

Signed _____

Name of Principal _____

Signed _____

Date _____