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Improving Science Teaching Through the Use of Video Reflection and a PCK-Based Teaching Framework

This thesis is presented in partial fulfilment of the

Master of Education

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Edith Cowan University
School of Education
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Keywords

21st Century skills; Effective Teaching; Goal-setting; Pedagogical Content Knowledge (PCK); Professional Learning Community (PLC); Reflection; Science education; Science teaching; Scientific Inquiry; Scientific literacy; Self-Efficacy; Self-tracking video; Standards; STEM; Teacher's Approach to teaching and Learning; Teacher Framework; Teacher Professional Development; Teacher Reform; Teacher Skills and Knowledge; Video Club

Abstract

Effective teaching and teachers are vital for improved outcomes in Science, Technology, Engineering and Mathematics (STEM) education and scientific literacy. Supporting the goals of contemporary science education calls for constructivist learning approaches, with an emphasis on inquiry-based, student-centred learning, which demands that teachers develop a wider repertoire and more innovative pedagogical skills. Pedagogical Content Knowledge (PCK) research was used to prepare a conceptual framework of effective teaching skills and knowledge areas which was used in a teacher professional development (PD) initiative. This qualitative study employed a case study methodology with a small group of experienced, secondary Science teachers. An ethnographic, participatory action research (PAR) approach supported the use of self-tracking video in the classroom for the purpose of individual teacher reflection. The teachers then collaborated in a video club professional learning community (PLC) to collectively reflect on effective teaching skills and knowledge. The study concluded that experienced Science teachers found the use of video-supported reflection and participation in a supportive PLC positive and beneficial. It aided their self-reflection and goal-setting and was perceived as enhancing other PD programs that the teachers were engaged in. Participants also felt that the shared experience consolidated collegial relationships and discussion and led to positive feelings. The study provided further insights about elements of effective teaching building on earlier PCK research.

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Glossary

21st Century Skills	A set of recommended core competencies for students for success in today's world ("21st Century Skills," 2016)
ACARA	Australian Curriculum, Assessment and Reporting Authority
AfL	Assessment for Learning
AITSL	Australian Institute for Teaching and School Leadership
Differentiation	Tailoring instruction to meet individual needs.
Education Council	Australian national body coordinating school education policy
GPK	General Pedagogical Knowledge
IBL	Inquiry Based Learning
Incheon declaration	Declaration on education adopted at the World Education Forum in Incheon, South Korea in 2015
iPad	Apple brand tablet
Jigsaws	Teaching strategy which breaks classes into groups or breaks assignments into pieces so that students work together to complete the learning activity
Learning Walks	A group of teachers visiting multiple classrooms at their own school with the aim of fostering conversation about teaching and learning
NRC	National Research Council (US)
NSES	National Science Education Standards (US)
OECD	Organisation for Economic Co-operation and Development
OFSTED	The Office for Standards in Education, Children's Services and Skills (UK)
PAR	Participatory Action Research
PBL	Problem or Project Based Learning
PCK	Pedagogical Content Knowledge
PD	Professional Development
PGM	Peer Group Mentoring

PISA	Programme for International Student Assessment
PLC	Professional Learning Community
POE	Teaching/inquiry strategy where students Predict, Observe, Explain
SCK	Subject/Science Content Knowledge
SMK	Subject Matter Knowledge (an alternative to SCK)
The Standards	Australian Professional Standards for Teachers
STEM	Science, Technology, Engineering, Mathematics
SWIVL	Technology used to hold a video recording device (phone/iPad/tablet) which pans around to track the wearer of a small microphone and tracking device.
Think/Pair/Share	Teaching strategy where students think individually, the share with a partner (pair) then share with the class
TIMSS	Trends in International Mathematics and Science Study
TPACK	Technological Pedagogical Content Knowledge.
UNESCO	United Nations Educational, Scientific and Cultural Organization
Video Club	A small group of teachers who meet to discuss video-aided reflection on their teaching and may or may not share video excerpts of their teaching with each other.

Statement of Original Authorship

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

i. incorporate without acknowledgment 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 of this thesis; or
iii. contain any defamatory material;

Signature: ___[redacted]_

Date: ___13/2/2020_____

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Chapter 1: Introduction

School science education has long been deemed important for a country's economic and innovation productivity (Alonzo, Kobarg, Seidel, 2012; De Boer, 1991, 2000). This is particularly true in the current context of needing to prepare young people to deal with increasing technological advances and global challenges in energy, healthcare, food, waste, climate, environment and other 21st century endeavours (Alonzo et al., 2012; Murphy, MacDonald, Danaia, & Wang, 2019; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2016). There are current concerns that young people are not sufficiently engaged in school science education (Alonzo et al., 2012; Lyons, 2006; Osborne, Simon, & Collins, 2003) and this is supported by achievement trends in international testing regimes such as the Programme for International Student Assessment [PISA] and the Trends in International Mathematics and Science Study [TIMSS] (Martin, Mullis, Foy, & Stanco, 2012; Mullis, Martin, Foy, & Hooper, 2016; OECD, 2010; OECD, 2014; Riddle & Lingard, 2016; Thomson, Wernert, O'Grady, & Rodrigues, 2017). This has led to a push to improve the teaching and learning outcomes of school Science (Gonski et al., 2018; Marginson, Tytler, Freeman, & Roberts, 2013; Office of the Chief Scientist, 2014; Osborne et al., 2003). The demands upon Science teachers, leading to greater pressures to adopt innovative teaching practices was the impetus for this study which looked at an initiative to deliver meaningful professional development to experienced Science teachers in an innovative way.

This chapter outlines some of the pressures upon science education and the issues and research associated with delivering effective science teaching, which will be further discussed in Chapter 2. The context of making professional development activities effective and meaningful for practising, experienced teachers is presented, with the goal that they may be likely to adopt more innovative practices. The use of an ethnographic, participatory action research, case study to trial a video-based professional development initiative with a small group of practising, experienced Science teachers is outlined. The scope and significance of this research and an outline of the structure of the remaining thesis is presented.

1.1 BACKGROUND

In 2001, Hackling, Goodrum and Rennie raised the concern that the Australian education system was not adequately preparing all members of society to be scientifically and technologically prepared and productive members of the community nor producing sufficient Science graduates. More recent reports (Gonski et al., 2018; Marginson et al., 2013; Office of the Chief Scientist, 2014) show that this is still a concern, particularly with the current and predicted changes in technology and the workforce alongside global challenges such as environmental concerns, climate change, energy needs, food security and communications and technological advances. Reportedly, Australian students are not sufficiently engaged in school science studies and therefore not choosing to pursue further science courses (Alonzo et al., 2012; Bøe, Henriksen, Lyons, & Schreiner, 2011; Lyons, 2006; Osborne et al., 2003).

Over the past few decades, there has been much debate about what and how to teach school Science. In Australia, three key approaches, discussed in detail in Chapter 2, have emerged, involving: the importance of scientific literacy; the nature of science; and science inquiry (Anderson, 2002; Banilower, Cohen, Pasley, & Weiss, 2010; Hackling et al., 2001; Lehrer & Schauble, 2006; Marginson et al., 2013; Millar, 2006; Office of the Chief Scientist, 2014; Tytler, 2007). It is widely acknowledged that inquiry-based science teaching represents a range of instructional approaches compatible with a constructivist theory of learning (Park, Jang, Chen, & Jung, 2011). A constructivist position points to the idea that knowledge is not transmitted from one knower to another but is actively built up by the learner, thus requiring well designed inquiry activities (Driver, Asoko, Leach, Scott, & Mortimer, 1994). The US National Science Education Standards (NSES) defines inquiry learning as "the activities of students in which they develop knowledge and understanding of scientific ideas as well as an understanding of how scientists study the natural world" (National Research Council [NRC], 1996, p. 23). Park et al. (2011) suggest that an effective Science teacher "should start with questions about nature, engage students actively; concentrate on the collection and use of evidence, and not separate knowing from finding out" (p. 249). This type of teaching requires more from teachers than just knowing the content and how to teach it (Bautista & Schussler, 2010; Park et al., 2011). Studies have reported that student achievement in science is higher when teachers are effective in using inquiry-based pedagogy (Alonzo et al., 2012; Bautista & Schussler, 2010; Johnson, 2009).

It is widely recognised that effective teaching is the most important factor in student learning and achievement (Marginson et al., 2013). Tytler (2007) states that "Quality teaching is

critical to successful outcomes for students and innovative and effective programs" (p. 57). Research has led to conceptualising what effective teachers do through the construct, Pedagogical Content Knowledge (PCK) (Townsend, 2015). Shulman (1986), followed by others (Cochran, De Ruiter, & King, 1993; Kind, 2009; Lee & Luft, 2008; Magnusson, Krajcik, & Borko, 1999; Park et al., 2011; Park & Oliver, 2008; Townsend; 2015) put forward the idea of Pedagogical Content Knowledge (PCK) as a way of describing what teachers know and do which encompasses strong content knowledge; an understanding of student misconceptions; and knowledge of assessment and curriculum; amongst a range of general pedagogical skills used by effective teachers which is guided by a teachers' beliefs and orientations to teaching. The US NSES has incorporated the concept of PCK as an essential component of professional development for science teachers. They defined PCK as "special understandings and abilities that integrate teachers' knowledge of science content, curriculum, learning, teaching and students, allowing science teachers to tailor learning situations to the needs of individuals and groups" (NRC, 1996, p. 62). The concept of PCK is used as a theoretical framework throughout this study and is discussed in detail in Chapter 2.

The conception of teaching as a reflective practice is widely embraced: "the teacher is a reflective practitioner who continually evaluates the effects of his/her choices and actions on others (students, parents and other professionals in the learning community) and who actively seeks out opportunities to grow professionally" (Rich & Hannafin, 2009, p. 52). In order to do this effectively, teachers need to be provided with the time and opportunity for critical reflection on their teaching. The reflection-action process is considered a highly effective dimension of a teacher's development (Jones, 2008). They can use reflection to consider what needs to change in their teaching and how to implement that change.

Use of video technology has been recognised as a means for teacher reflection (Chavez, 2007; Harlin, 2014; Rosaen, Lundeberg, Cooper, Fritzen & Terpstra, 2008; Sherin & van Es, 2005). Research has shown its effectiveness with pre-service teachers to help them notice elements of their teaching and student thinking. Sherin and Han (2004) found that a video club model helped teachers improve their noticing, attention on student actions and development of student thinking. These researchers contend that this type of professional learning community (PLC), where teachers participating in the use of video technology meet on a regular basis for the, is more likely to lead to a change in discussion and 'colleagueship' which has the possibility of leading to reformed teaching practices. This is best done when combined with the use of a

reflection tool or framework and an element of collaboration, coaching or peer input (Bryan & Recesso, 2006; Harlin, 2014; McCullagh, 2012; Rich & Hannafin, 2009; Sherin & van Es, 2005; van Es, 2010). This research is analysed in Chapter 2.

Science teachers face the demands of delivering a broad range of learning outcomes for diverse groups of students. This is coupled with the pressure of implementing engaging student-centred, innovative, inquiry-based teaching and learning. The challenges of this prompted the researcher to explore the elements of effective science teaching and how a group of practising, experienced teachers could be supported to reflect on and develop their knowledge and skills using a video-based model.

1.2 CONTEXT

Teachers are the biggest factor influencing student engagement and achievement (Marginson et al., 2013; Tytler, 2007). A report from the Office of the Chief Scientist (2014) states the need for Science, Technology, Engineering and Mathematics (STEM) teachers to have the ability to deliver course content with "confidence and inspiration" (p. 21). While it has been shown that an inquiry-based, constructivist, student-based practice is best for student learning, many teachers lack the expertise and confidence to implement this and see it as more time-consuming and less effective (Johnson, 2006; Johnson, 2009; Johnson, Kahle, & Fargo, 2007; Johnson, Zhang, & Kahle, 2012; Rennie, Goodrum, & Hackling, 2001). One of the most difficult aspects of change for practising teachers is changing their beliefs about, and orientations to their style of teaching and what works (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991; De Boer, 2000; Johnson, 2009; Tytler, 2007).

Efforts to help teachers make significant changes and incorporate new strategies and programs must help them to acquire new knowledge and beliefs (Magnusson et al., 1999). Practising teachers are extremely busy and they face difficulties accessing meaningful professional development, often the opportunities available do not meet the specific individual needs of teachers (Kamener, 2012; Polly & Hannafin, 2010; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). Many researchers state that teachers learn best when professional development is learning area specific, is based around the classroom and involves collaboration and time for action and self-reflection (Johnson, 2009; Jones, 2008; Marginson et al., 2013; Yore & Treagust, 2006). One way to enable the professional learning activities recommended by research is the

emergence of video technology as a means for teachers to reflect on their own teaching. This combined with time for collaborative discussion and sharing through professional learning communities (PLCs) has been shown to have positive effects for teachers, particularly in allowing them to question their current beliefs about the nature and purpose of teaching and may lead to reformed teaching practices (Lee & Luft, 2008; McNicholl, Childs & Burn, 2013; Morine-Dershimer & Kent, 1999; Townsend, 2015; Van Driel & Berry, 2012).

Research about PCK and effective teaching was synthesised to produce a conceptual framework, presented in Chapter 2, to be used as a lens or guide throughout the study. Many teachers are unaware of the concept of PCK and although much research has been carried out it is unclear how PCK may be used for teacher development (Bertram & Loughran, 2012). Despite this, Townsend (2015) suggests that as teachers develop a high level, integrated version of PCK they would make improvements in constructivist teaching strategies, be more aware of their personal teaching orientations, and develop greater confidence. The researcher, as an experienced Science teacher and school leader was keen to explore the concepts of PCK and the use of video technology alongside a PLC as a means of professional development for practising, experienced Science teachers.

1.3 PURPOSE

This study is a response to the above-mentioned focus on quality Science teaching and the use of student-centred and inquiry-based learning activities. The purpose of the study was to engage secondary Science teachers within a regional, independent K-12 school in Western Australia in a structured collaborative professional learning experience. The initiative made use of self-tracking video technology for self-reflection and a professional learning community in the form of a video club, in which participants met three times over a period of three school terms and discussed their reflections, thoughts and feelings. The teaching framework based on PCK concepts was introduced, clarified and explored with the group and used to guide discussion and reflection during PLC meetings.

The study sought to evaluate the professional development value of the self-tracking video use and participation in the video club PLC. It aimed to investigate how the initiative influenced participants' self-reflection and goal setting as well as changes in their thinking, beliefs and behaviours. Concepts regarding what is required for effective teaching and how this relates to

PCK were also explored. Responses to questionnaires and the collaborative discussions from the video club meetings were analysed for these purposes.

1.3.1 Research Questions

1. How useful is a video club model and PCK-based teaching framework as a means of professional development and teacher capacity building for practising, experienced Science teachers?

2. In what ways have practising, experienced Science teachers changed their beliefs, thoughts and behaviours, and teaching practices through the process of being part of a video club and using a PCK-based teaching framework?

3. What can be learned about effective teaching skills through experienced Science teachers' participation in a collaborative video club?

1.4 SIGNIFICANCE AND SCOPE

1.4.1 Methods

This study used a qualitative ethnographic, case study approach, incorporating participatory action research. It was conducted within the school where the researcher currently works as the Head of Learning Area of a small secondary Science department. Six teachers, including the researcher, volunteered to take part in the professional development initiative. Teachers were invited to respond to an electronic questionnaire at the beginning and the end of the study. They were also encouraged to record videos of their lessons for the purpose of self-reflection and take part in researcher-facilitated collaborative discussions. These discussion sessions allowed the participants to form a professional learning community, known as a video club, where they discussed their reflections, thoughts, feelings and beliefs. This took place over three school terms.

The data collected consisted of the two sets of questionnaire responses and transcripts of three video club meetings. The video recordings remained private to the individual teachers. Each

of the data sources underwent content analysis using a constant comparative method to identify key ideas, commonalities, differences and themes regarding professional development, and effective teaching. This was used to analyse and identify changes in the discussion, thinking, and behaviours over time. The conceptual framework devised using theories of pedagogical content knowledge (PCK) was used as a basis for data analysis and comparison. A set of themes were identified and further analysed to look for relationships between them and these were synthesised into categories and diagrammatic representations.

1.4.2 Rationale and Significance

The participants in the study were likely to benefit from personal and professional development and improvements in their collegial discussion which could potentially lead to positive changes in teaching. Previous research suggests that the use of a video club model helps teachers to improve their "professional vision" (Sherin & Han, 2004, p. 179) and to move their focus from teacher actions to student learning, with some teachers adopting more student-centred approaches (Eroz & Tuga, 2013; Rosaen et al., 2008; Sherin & van Es, 2005; van Es, 2010; Tripp & Rich, 2012b). Teachers in previous studies found the experience of viewing themselves teaching a positive experience (Coffey, 2014) but that the collaborative discussion element was the most significant part of the process (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Griswold, 2004; Sherin & van Es, 2005; van Es, 2010). Studies have shown that through the use of videotape and reflection most teachers began to acquire targeted content knowledge and elements of a conceptual change orientation toward science teaching (Smith & Neale, 1989).

Current video and PCK research has focused mostly on teacher education and pre-service teachers. Within published research to date, a video-club model has not been used alongside the construct of PCK for staff development and capacity building of practising secondary Science teachers. This study could be used to extend research about the possibilities of the use of a video-club model as an effective model of PD for teachers, particularly in regional areas. Townsend (2015) found that teachers in regional and remote areas have less access to PD for many reasons and the use of video and PCK could be of use to them and may enable them to be part of remote-area professional learning communities.

This study could potentially contribute to the understanding and development of pedagogical content knowledge (PCK) and effective teaching requirements of experienced

teachers. Researchers such as Townsend (2015) and Abell (2008) state that more studies of master teachers are needed to define the target of knowledge growth and learning and development progression of PCK. From this, further refinement of PCK theory may be possible, aiding in the development of a PCK rubric or continuum as described by Townsend (2015). There is a need to articulate and document what teachers know and are able to do in order to understand effective PCK (Kind, 2009; Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001).

1.4.3 Limitations

The findings of this study are limited to the particular context described, it is up to the reader to determine transferability to other contexts (Merriam, 1998). The relationships between the participants and the particular school setting will have influenced the positive outcomes of the study. The researcher also played a large role in this study, as she was an active, contributing participant and was also the Head of Learning Area and so had a particular position in relation to the other teachers involved. While this was not a negative factor, it is likely that this will have influenced the findings in a number of ways. An awareness of possible issues of bias is discussed in Chapter 3. Other potential limitations lie in the timing and length of the study, the data collection instruments used and the nature of the data providing information about the thoughts and feelings of the participants rather than a measure of the effectiveness of the program.

1.5 THESIS OUTLINE

In this chapter I have outlined the external pressure on Science education to deliver a broad range of outcomes and the demands that this places on teachers. Issues related to quality teaching and teacher professional development were discussed, giving an overview of concepts and research relating to PCK. The use of video technology PLCs as a form of professional development was also introduced. The exploration of such an initiative with a group of practising, experienced Science teachers was presented, with the purpose of encouraging teacher reflection and moving towards more innovative, inquiry-based teaching methods. A summary of the ethnographic, case study methodology used, the setting and the associated limitations was given.

The remaining chapters are organised as follows. Chapter 2 discusses the relevant background research and literature. Chapter 3 gives a detailed account of the research methodology and methods employed. In Chapter 4 the findings are presented as a set of identified themes and an overview of each data source using thick description and participant voice. Chapter 5 synthesises the data into a set of five key findings relating to the original purpose of the study along with a discussion of the limitations. In Chapter 6 the key findings are discussed with reference to the research questions such that some conclusions and suggestions for action and further research are considered.

Chapter 2: Literature Review

Science teachers face a lot of political, societal and systemic pressure to deliver a variety of student learning outcomes and it is common for teachers to ask ‘how can I do a better job?’. To respond to this question it is necessary to look at some others such as ‘what is the purpose of school Science?’, ‘what is the best practice for effective Science teaching?’, and ‘what skills and knowledge do effective Science teachers have and how can they be developed?’. Following this line of reasoning this literature review begins by looking at approaches to what is considered important for school Science education. Concerns about Science education have led to a consideration of what best-practice Science education should include. The review of literature further examines the current trends in school Science education such as the push for STEM education initiatives and the inclusion of ‘21st Century skills’ which involves the development of communication, collaboration, creativity, critical thinking and other transferable skills. The goal of delivering a relevant science education for all and the associated importance of scientific literacy contributing to learners developing an understanding of the nature of science is also examined. Each of these ideas is discussed and described to give the reader an idea of the complex role of Science teachers today.

The aims and outcomes of Science education suggest a set of ‘ideal’ practices which can be thought of as a move away from traditional teaching toward more ‘reform’ practices. This review discusses the reforms suggested by research in four areas General reforms are changes at the more general, administrative or community level. Curriculum reform relates to planning for STEM initiatives and interpretation of The Australian Curriculum: Science (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2009). Pedagogical reform applies to incorporating more constructivist, collaborative, student-centred inquiry-based learning, as essential for making learning more engaging and meaningful. Each of these informs teacher-specific reform areas.

The central part of this literature review discusses some of the research and models presented which describe what effective teachers are required to know and do. It focuses on the ideas around PCK as a particular knowledge base of teachers separate from subject content knowledge (SCK) and general pedagogical knowledge (GPK) (Shulman, 1986). Some of the different views about the categories of teacher knowledge and how they are related is presented.

The Australian Professional Standards for Teachers (Australian Institute for Teaching and School Leadership [AITSL], 2013) are described to give an indication of how they fit with the models described and some of the differences are identified. The models discussed and 'The Standards' have been used to construct a conceptual framework about effective teaching skills and knowledge for use in this study.

The final section of the literature review presents research about effective professional development for teachers and how teachers can enhance their PCK. Research into the use of video reflection and Professional Learning Communities (PLCs) is presented showing how such methods can fit the ideals of effective professional development and behaviour change theory, allowing teachers to identify, implement and evaluate changes in their teaching. It is hoped that through the use of a PCK-based conceptual framework of effective teacher skills and knowledge alongside a professional development initiative utilising video technology and a video club PLC, Science teachers may be enabled to assess how they can develop their teaching to meet the evolving demands of school Science education.

2.1 SCHOOL SCIENCE - WHAT'S THE ISSUE?

This study came about from a desire to unravel what Science teachers should and could be doing in order to improve student engagement and outcomes and how to help teachers develop these skills. This is not an easy task as there are many influences on what teachers are required to do. In order to examine the best practice for science teaching, it is necessary to consider the purpose and goals of school Science education. It is important to recognise that over time the expected science learning outcomes have evolved as systems and schools try to cater to a wider variety of learners and their perceived needs. It could be argued that if teachers are to adequately engage science learners and improve learning outcomes, they must have an understanding of the science-related skills and knowledge required of today's school leavers. In this section, the increasing importance of school Science and STEM education for the purpose of economic and political competitiveness as well as preparing informed citizens is presented. It also touches on some of the international findings about science education and the current trends and requirements of Science education today. The dilemma of delivering a science education for all is considered and what this means for schools and teachers today.

2.1.1 Purpose and Goals of Science Education

The purpose and content of school Science education has long been debated and evolving (De Boer, 2000). The 19th century brought many exciting scientific discoveries and innovations which led to science studies being given a high level of status and importance (De Boer, 1991). After World War I and II and into the 'space race', countries such as the US and the UK put science education in the spotlight as a way to create a scientifically productive workforce to deal with emerging issues (De Boer, 2000). Tertiary institutions compelled schools to put greater emphasis and time into preparing students for further Science studies, at the same time there was a call to include applied and practical studies (De Boer, 1991). Throughout the last few decades vocational and applied studies have been given greater focus and the need for STEM skills has been highlighted (De Boer, 1991; De Boer 2000). Leading into the 21st century, school curriculum reform in Science has been based around the need for democratic, universal and general education for all students in order to produce critically aware members of society (De Boer, 2000).

The research shows that schools and teachers are faced with the requirement to produce adequately prepared Science graduates as well as preparing the general population to be contributing and thoughtful citizens with a well-rounded knowledge of science skills and concepts (Gonski et al., 2018; Hackling et al., 2001; Marginson et al., 2013; Office of the Chief Scientist, 2014). In recent decades most countries around the world have recognised the importance of Science for a variety of outcomes as described by Alonzo et al. (2012). Fostering science achievement and interest is viewed by many as critical to a nation's future. From an economic perspective, the next generation of scientists and engineers will be responsible for innovations that drive a nation's economy. To benefit from these innovations, citizens and workers need ever-higher levels of scientific and technological sophistication. In addition, advances in science and technology are critical for improving standards of living and for providing solutions to challenges of the modern world, including those related to health, energy, environment, and security (p. 1212).

The importance of science and technology for economic and political gains has led to increased pressures and expectations on teachers and students. Around the world, concerns have been raised about results in international standardised testing. Many report that there has been a decline in achievement, interest and engagement in Science studies in Australia which is having

an impact on attracting and retaining STEM graduates (Alonzo et al., 2012; Bøe et al., 2011; Lyons, 2006; Osborne et al., 2003).

2.1.2 Pressures on Science Education

Political and economic pressures have made their way into classrooms everywhere meaning that teachers are faced with ever-increasing demands. Countries such as England, Sweden, Canada, Denmark, France, Germany, India, Ireland, Japan, Korea, The Netherlands, Norway, New Zealand, and the USA as well as Australia and others have reported a decline in interest and engagement of students in Science subjects and related careers, as well as decreased achievement (Alonzo et al., 2012; Lyons, 2006; Osborne et al., 2003). These findings are also represented in the two international testing regimes, the Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS), along with independent studies that have assessed students' achievement, interest and motivations in Science education (OECD, 2010; OECD, 2014; Martin et al., 2012; Mullis et al., 2016; Riddle & Lingard, 2016; Thomson et al., 2017). Collectively these studies evaluated students' content knowledge and application of science, alongside surveys about their attitudes and opinions towards Science.

Reports often cite poor rankings in international testing as a reason for Science pedagogy and curriculum reform in Australia, however, the data show that it is not as straightforward as poor student performance alone. A report by the Australian Education Council (Education Council, 2019) stated that "Australian students' achievement in international STEM assessments such as the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS) is generally high, however, there are signs of stagnation and decline" (p. 5). Australian students show achievement which is better than more than half of the countries tested, on average achieving between the intermediate and high benchmarks. This result has been relatively stable for 20 years which is similar to New Zealand and England (Mullis et al., 2016; Riddle & Lingard, 2016; Thomson et al., 2017). It is this perceived stagnation which is worrying when compared to the consistent improvements seen in some countries such as Slovenia and Singapore and overall improvement by countries such as the United States (Mullis et al., 2016; Riddle & Lingard, 2016; Thomson et al., 2017). In fact, concerningly for Australia, results from the 2015 TIMSS (Education Council, 2015; Mullis et al., 2016; Riddle & Lingard, 2016; Thomson et al., 2017) showed that since 1995 more countries

have improved their Science score than have decreased with East Asian countries such as Singapore, Japan, China, Korea and Hong Kong consistently performing at the top of the rankings. The findings show that the most improved countries increased the proportion of students achieving at the very top benchmark whereas countries such as Australia, Norway and Sweden have seen a decrease in these numbers. Also, the proportion of students achieving at the low benchmark has not seen an overall improvement in Australia since 1995 whereas many countries have raised this aspect in overall student performance (Mullis et al., 2016). Clearly, a study of the reforms being undertaken by high achieving and improved education systems is warranted, however while countries such as Australia look to Singapore and Taiwan for answers, many of these high achieving countries are looking at moving towards more 'western-style' learner-centred pedagogy (Elliott, 2014). So, while these tests have some use, they do not necessarily give a clear picture of the state of Science education and may well be contributing to the problem as teachers feel the pressure to prepare students for such testing.

The Australian Education Council (Education Council, 2019) also reports that "Students' participation in STEM subjects has declined in recent years, particularly in advanced subjects" (p. 5). Many developed countries, including most of Europe, the UK, Canada, New Zealand, Japan as well as Israel, Korea and India, and others have reported decreased enrolment in Science courses at high school and university (Lyons & Quinn, 2010). Studies show that in Australia over the past 25 years the proportions of final year students choosing Science courses has dropped (Education Council, 2015; Lyons & Quinn, 2010; Palmer, Burke, & Aubusson, 2017). In contrast to this, the National Science Foundation in America reported that in 2008 school and university Science enrolments were actually on the increase (Lyons & Quinn, 2010). However, Lyons and Quinn also report that in Australia the proportions stated may not tell the full story as subject offerings and retention rates of students completing high school have changed which will have influenced the proportions completing individual Science subjects, in some cases the number of students taking one or more Science subjects has actually remained the same or increased (Lyons & Quinn, 2010). In the setting for the current study, decreasing numbers of students taking Science courses and continuing in science-related fields at a tertiary level has not been an issue. In fact, students at the school involved report that they enjoy and see value in studying the sciences. Nevertheless, there is pressure on schools and teachers due to reports of a lack of suitable Science graduates.

The apparent declining rates of students taking Science courses and continuing into science-related careers is often attributed to a loss of interest in and enjoyment of studying sciences (OECD, 2010; OECD, 2014; Martin et al., 2012; Mullis et al., 2016; Riddle & Lingard, 2016; Thomson et al., 2017). According to the 2006 PISA results (OECD, 2010), Australia was ranked 54th of 57 countries in terms of students' general interest in learning Science, and 45th in terms of mean enjoyment of Science. Many studies show that students enjoy science topics per se but they do not necessarily enjoy their school learning experiences (Osborne et al., 2003). The 2015 TIMSS results (Mullis et al., 2016; Riddle & Lingard, 2016; Thomson et al., 2017) show that in most countries interest in Science declines as students progress through school but that this is true of all subjects (Eccles & Wigfield, 1992; Kahle & Lakes, 1983). Lyons and Quinn (2010) found that students' interest and attitudes towards Science have not changed for 40 years. It appears that the research leads to an unclear picture of student interest and engagement in science subjects and how it contributes to their ongoing participation in science. However, it is clear that students and science outcomes can only benefit from making science education more interesting and engaging. Older studies (Boe et al., 2011; Darby, 2005; Lyons, 2006) found that there was a disparity between the curriculum on offer along with the use of traditional, transmissive pedagogical approaches and the needs and interests of students. This is an area requiring more up to date research to investigate whether recent reforms have or are making a difference to student interest and achievement.

Lyons and Quinn (2010) report that students in Australia who choose science subjects are motivated by an interest in the subjects as well as the perceived need for their future studies or career. Science engagement is not only about what happens in the classroom, but that students' choices regarding STEM and science-related studies are also often based on external motivations. Students in Australia, New Zealand, Norway and the United States have been shown to be more likely to pursue science studies in order to enable university and career pathways (Boe et al., 2011; Hipkins & Bolstad, 2006; Lyons & Quinn, 2010). Boe et al. (2011) suggest that STEM choices are motivated by the job market and high salaries but this is metered by concerns about job security, subject difficulty and workload. More than two decades ago, the decline in the perceived role of Science for career pathways was identified through the 1996 TIMMS data (Martin et al., 2012) which showed that in Australia, many students rated the value of Science as lower than in countries such as Singapore, United States, Canada, England and New Zealand, and it seems that this perception remains (Lyons & Quinn, 2010). Classroom practice and curriculum

can have a role to play in turning this around but it also indicates a need for external and societal changes such as job status and awareness, pay-rates and career opportunities.

Today education systems are still grappling with the complexity of providing a Science education for all, where science skills and knowledge are recognised as the key to boosting productivity and the economy as well as required for thoughtful, informed citizens (Gonski et al., 2018; Office of the Chief Scientist, 2014). Almost 20 years ago the results of an Australia-wide study by Rennie et al. (2001) identified that an "ideal science education will provide an appropriate school experience for all students to achieve a level of scientific literacy, and also provide a suitable background for those (perhaps 20%) who wish to become scientists or pursue other science-related careers" (p. 466). The question remains about how to achieve this and how can teachers be better prepared to provide it. This evolution of Science education needing to cater for a wide variety of learners and carrying the burden of producing professionals and citizens who can grapple with emerging and future global challenges places high demands on systems, schools and teachers as to how to go about this.

2.2 AUSTRALIAN SCIENCE EDUCATION TRENDS

The discourse around the purpose of school Science education revolves around not only what to teach but also how it should be taught. In this way, discussion about Science curriculum and pedagogy are intertwined. In this section, current trends and drivers of Science curriculum and pedagogy in Australia are presented. The current push for increased STEM graduates and the trickle-down influence this has had at the school level is presented. The widespread goal of Science education of producing citizens who are scientifically literate and having students do science as authentically as possible in order to understand the nature of science is discussed (Anderson, 2002; Banilower et al., 2010; Hackling et al., 2001; Lehrer & Schauble, 2006; Marginson et al., 2013; Millar, 2006; Office of the Chief Scientist, 2014; Tytler, 2007). These goals of science education fit with current trends of '21st century education' which aim to help students develop a range of general skills to prepare them for the perceived demands of jobs and communities of the future (Dede, 2010; Saavedra & Opfer, 2012). The current Australian Curriculum: Science is presented (ACARA, 2009), discussing how it incorporates the various current purposes and goals of Science education.

2.2.1 STEM and 21st Century Skills

Science and innovation are recognised worldwide as the key for boosting productivity and the economy, this has led to a focus on STEM education (ACARA, 2016). In this section, the importance of producing young people capable of contributing in STEM areas is discussed and how this has led to increased pressure on teachers in STEM areas, such as secondary school Science teachers, as they face the need to produce high-calibre graduates as well as implement new curriculum and pedagogical initiatives that target levels of integration across STEM subjects. The National STEM School Education strategy states that

> STEM education is a term used to refer collectively to the teaching of the disciplines within its umbrella – science, technology, engineering and mathematics – and also to a cross-disciplinary approach to teaching that increases student interest in STEM-related fields and improves students' problem solving and critical analysis skills. (Education Council, 2015, p. 5)

Australia's Chief Scientist's report *Science, Technology, Engineering and Mathematics: Australia's Future*, (Office of the Chief Scientist, 2014) emphasises the importance of a "STEM-literate population that celebrates discovery and entrepreneurship as well as a reliable pipeline of STEM graduates" (p. 9). The Australian government's *Review to Achieve Educational Excellence in Australian Schools* (Gonski et al., 2018) also links the importance of preparing students for the future and improved outcomes in STEM. STEM has become a national priority in Australia due to findings and suggestions such as those above as well as international trends, students' underperformance in STEM-related testing and fewer students choosing STEM subjects (ACARA, 2016; Murphy et al., 2019).

The goals of reducing the 'dropout' of STEM students and graduates and producing a STEM-literate population have been interpreted at the school level in different ways (van den Hurk, Meelissen, & van Langen, 2019). STEM education is seen as able to equip students for a rapidly changing world; to be able to source, interpret, and apply understanding; develop active learning skills, complex and creative problem-solving, critical thinking, design thinking, and more (Bybee, 2010; Murphy et al., 2019). From early childhood through to high school, STEM has become more than just an acronym for a set of discipline areas, it has become an entity in its own right, incorporating a cross-disciplinary approach with a set of associated skills (Education Council, 2015; Murphy et al., 2019). Schools and teachers are now compelled to adopt STEM

initiatives in a bid to try to engage students in these learning areas and be seen as innovative and forward thinking. Both elementary and secondary classrooms are integrating STEM curriculum and pedagogy into their school day (Margot & Kettler, 2019). However, there are many approaches and opinions about STEM education, a meta-analysis of STEM initiatives (van den Hurk et al., 2019) found that at this stage it is unclear as to the effectiveness of the various interventions and programs, and schools and teachers are left with questions about best STEM education practices.

According to the Australian STEM report presented by Marginson et al. (2013) countries which are performing well in STEM areas have reformed their curriculum and pedagogy to make it more engaging and practical "through problem-based and inquiry-based learning, and emphases on creativity and critical thinking" (p. 15). They have moved towards more student-centred approaches while still maintaining a rigorous depth of content. Many studies and reports suggest that curriculum and pedagogy should encourage real-world, authentic and creative problem-solving tasks (Murphy et al., 2019; Office of the Chief Scientist, 2014). In an Australia wide analysis of state STEM policy papers, Murphy et al. (2019) found that few of the papers had explicit actions for implementing STEM learning, except to encourage the adoption of inquiry or project-based learning pedagogies, nor consensus as to whether STEM education should be delivered through discrete disciplines or in an integrated way (Murphy et al., 2019). They found that "in order to meet the demands for delivering integrated, inquiry-driven STEM education that develops in all children the necessary STEM capabilities and dispositions, highly skilled educators are required at all levels of the educational journey" (p. 126). The National STEM Strategy (Education Council, 2015) only suggests that schools and education systems need to reevaluate the national curriculum and their teaching practices to develop effective curriculum, teaching approaches and assessment resources which both focus on the individual STEM building blocks but also deliver effective and interesting cross-curricular learning. This leaves a lot of the work up to individual schools and teachers.

An associated outcome of STEM education is the connection with '21st century skills' due to the potential for STEM education to explore current and future social, technological, environmental, energy, and health-related challenges (Bybee, 2010; Murphy et al., 2019). There are many models and definitions of 21st Century skills, however, they all focus on skills such as critical thinking, problem-solving, collaboration, communication, curiosity and information analysis and organisation (Dede, 2010; Saavedra & Opfer, 2012). Murphy et al.'s (2019) analysis

of Australian state STEM policies found that interdisciplinary skills such as problem-solving, critical analysis and creative thinking as well as collaboration and digital technologies were often given greater priority than disciplinary knowledge. Other capabilities such as communication, interdisciplinary thinking, independent thinking and inquiry skills were also mentioned. The National STEM Strategy (Education Council, 2015) states that "today's students need to acquire core subject knowledge as well as the skills of collaboration, critical thinking, creativity and problem solving – and STEM education has a crucial role in achieving this" (p. 5). This is supported by Bybee (2010) who states that through STEM investigations and projects "Students can develop 21st Century skills such as adaptability, complex communication, social skills, nonroutine problem solving, self-management/self-development, and systems thinking" (p. 31).

The focus on school STEM has been driven by a top-down need for increased output in professional science, technology and engineering fields. This requirement has led to multiple perspectives on how best to prepare students for such a challenge. The research shows that there is some confusion about how best to achieve this at the school level. Teachers in STEM areas, such as secondary Science, are being asked to deliver high calibre graduates in the respective science disciplines but also to implement engaging, interdisciplinary STEM initiatives. Many Science teachers wonder how they are to develop the core concepts and knowledge required to engage with integrated STEM projects at a high level as well as produce graduates with the content and background knowledge required for further study and contributions to the field (Bybee, 2010). This has led to Science teachers questioning their curriculum and pedagogical practices as will be discussed in a later section.

2.2.2 Scientific Literacy and the Nature of Science

The recent STEM push has had a large impact on thinking about science education, however, one aspect of STEM education initiatives has been around for quite some time and that is the goal of having students develop a level of understanding about the relevance of science in the world which is termed *scientific literacy* and the *nature of science*. The National Research Council of America (National Research Council [NRC], 1996) suggests four goals for science learners: know and understand the natural world; generate and evaluate scientific evidence and explanations; understand how scientific knowledge is constructed; and, participate in scientific practices and discourse (as cited in Schneider & Plasman, 2011). The 2016 Incheon declaration

(United Nations Educational, Scientific and Cultural Organization [UNESCO]) states that "Quality education includes the development of those skills, values, attitudes and knowledge that enable citizens to lead healthy and fulfilled lives, make informed decisions and respond to local and global challenges" (p. 31). It is clear that teachers are being asked to do more than transmit traditional science knowledge.

There are many definitions and schools of thought regarding scientific literacy (Banilower et al., 2010; Lehrer & Schauble, 2006; Millar, 2006; Pearson, Moje & Greenleaf, 2010). Yore and Treagust (2006) point to the definition provided by the PISA, "Scientific literacy is the capacity to use scientific knowledge, to identify questions and draw evidence-based conclusions in order to understand and help make decisions about the natural world and changes made to it through human activity" (p. 305). This definition encompasses the main ideas put forward by most researchers (Bautista & Schussler, 2010; Bybee, Carlson-Powell & Trowbridge, 2014; Rennie et al., 2001; Yore, Bisanz, & Hand, 2003). Yore and Treagust (2006) point out that

> . . . science literacy requires in a fundamental sense that people be proficient in science language, thinking, ICT, and emotional dispositions, as well as in a derived sense that they understand the nature of science, the big ideas of science and the relevance of the interactions among science, technology, society and environment. (p. 295)

A core concept related to and coming out of, the scientific literacy research is the idea of students, and society generally, having an understanding of the nature of science (NOS). NOS is regarded as the way science is done (Bautista & Schussler, 2010) and consists of the understanding of the use of empirical evidence, critical thinking, creativity, the tentative and inferential nature of knowledge in science and reliance on theories and multiple methods of investigation (Bautista & Schussler, 2010; Tytler, 2007). This view requires that teachers have students perform and reflect on practical activities that align as closely as possible with scientific practices (Bautista & Schussler, 2010). This idea of learning about NOS and scientific literacy has always been present (Hipkins, 2007) but is becoming more of a focus and could be seen as essential in an age of fake news and science sceptics. There has been a call for scientific literacy to be the main focus for school science (De Boer, 2000), and the international testing regimes of PISA and TIMSS now include scientific literacy and associated nature of science skills as the main component of their testing frameworks and rationales (Mullis & Martin, 2017; OECD, 2019).

2.2.3 The Australian Curriculum

The Australian Curriculum: Science (ACARA, 2009) which informs individual state-based curriculum recognises the current trends, purposes and goals of Science education already presented. While the curriculum is not a focus in this study the current curriculum learning goals and outcomes impact on the planning and decisions made by teachers about what and how they teach. The Australian Curriculum: Science puts forward broad descriptions of learning area outcomes as well as General Capabilities and Cross Curriculum priorities which encompass many of the 21st Century skills. Teachers, schools and systems are expected to interpret the curriculum statements and deliver appropriate learning activities and outcomes for their context.

Along with discipline understanding, the Australian Curriculum aims to develop appreciation, interest, curiosity, exploration, inquiry skills, critical thinking skills, an understanding of NOS, scientific literacy and applied understanding (ACARA, 2010). The Australian Curriculum: Science (ACARA, 2009) has been designed to support students to

> develop scientific inquiry methods, a foundation of knowledge across the disciplines of science, and develops an ability to communicate scientific understanding, use evidence to solve problems and make evidence-based decisions about local, national and global issues and to participate, if they so wish, in science-related careers. (Curriculum, Science, Foundation - Year 12 section)

The curriculum structure consists of three strands each with sub-strands which can be broadly considered as descriptions of learning outcomes at each year level. The first strand in the Australian Curriculum: Science (ACARA, 2010) is Science Understanding which encompasses the scientific knowledge of four sub-strands related to science disciplines such as chemistry, physics, biology, earth sciences, astronomy and others. It refers to the facts, principles, theories and models of Science topics established over time and provides broad descriptors of the content to be learned. The second strand is Science as a Human Endeavour which encompasses many of the NOS and scientific literacy ideas, highlighting "the development of science as a unique way of knowing and doing, and the importance of science in contemporary decision-making and problem-solving" (ACARA, 2010, Science, Structure, Science as a Human Endeavour, section 7). It has two sub-strands, being the Nature and development of science and the Use and influence of science. The third strand is Science Inquiry Skills, consisting of five sub-strands which further develop NOS and scientific literacy skills through proposing questions,

investigating, analysing data and communicating findings. It involves problem-solving, critical thinking and creativity.

The curriculum documents make the point that the three 'strands' are closely integrated and that "the work of scientists reflects the nature and development of science, is built around scientific inquiry and seeks to respond to and influence society's needs. Students' experiences of school science should mirror and connect to this multifaceted view of science" (ACARA 2010, Science, Structure, Relationship between the strands, section 9) This gives an indication of how teachers should approach the teaching of Science but it requires that teachers interpret both the content and context as well as the pedagogical approach that best suits them and their students.

2.3 SCIENCE EDUCATION REFORM

The research presented so far outlines the underlying purposes and goals for school science education. The findings presented in the previous sections suggest that school Science requires curriculum and pedagogy which:

- Prepare students for further science study
- Prepare students for science careers, trades and the workforce
- Prepare all students to be informed citizens with a good level of scientific literacy and an understanding of the nature of science plus a range of 21st century skills.
- Improve student achievement on external testing in order to improve international rankings
- Foster interest and engagement in Science and STEM, leading to higher levels of participation in Science courses and reduced 'drop out' of science students.

This list represents the dilemma faced by systems, schools and teachers to accomplish all of this. It is little wonder that there is some thought that current science education is not achieving its aims and students are not engaged with science education as required. However, this is not new, a nationwide study conducted by Hackling et al. (2001) nearly twenty years ago points to nine elements of ideal science teaching, seven of which relate to the content, the teachers, and the students, including the way science, is presented and assessed:

- science curriculum which is relevant to the needs, concerns and personal experiences of students;
- teaching and learning of science centred on inquiry;
- students investigating, constructing and testing ideas and explanations about the natural world;
- science assessment which serves the purpose of learning and is consistent with and complementary to good teaching;
- science teaching and learning environments characterised by enjoyment, fulfilment, ownership of and engagement in learning;
- mutual respect between teachers and learners; and,
- science teachers who are lifelong learners, supported, nurtured and resourced to build the understandings and competencies required of contemporary best practice.

In order to accomplish this, most studies and research suggest various changes and reforms in either implementation, curriculum or pedagogy in order to attempt to do it all. Lyons and Quinn (2010) suggest that teachers need to make lessons more exciting, enjoyable, interesting and relevant with a more flexible curriculum which caters for a wider range of students. The Education Council (2015) adds that "Schools and education systems need to facilitate STEM engagement through effective curriculum, teaching approaches and assessment resources to improve learning outcomes in the classroom" (p. 9). This section discusses the shifts required in terms of general, curriculum, pedagogy and teacher reforms.

2.3.1 General reform

To achieve the stated outcomes of school Science, some researchers suggest that changes to policy and the implementation of strategies at a higher level can influence motivation for science learning (Education Council, 2015). These changes include university entrance incentives, improved pay for STEM careers, and job and career satisfaction and stability (Boe et al., 2011; Education Council, 2015). Some findings also call for system and school-level reform such as changes to external and high stakes testing and assessment, greater flexibility in timetabling and curriculum delivery and time for teacher collaboration (Lyons, & Quinn, 2010; Margot & Kettler, 2019). The expectation of integrating the 21st-century skills, scientific literacy and cross-curricular STEM initiatives, requires school and system support in the way of time, resources,

expertise and cross-curricular communication (Margot & Kettler, 2019). The National STEM school education strategy suggests that "approaches work best when supported by a whole-of-school collaborative effort" (Education Council, 2015, p. 11).

2.3.2 Curriculum reform

Studies have shown that there is a disparity between the science curriculum on offer and the needs and interests of students (Darby, 2005). Murphy et al. (2019) advocate improvements and changes to curriculum interpretation and delivery along with pedagogical reform to improve student engagement. Curriculum reform includes reconsidering learning programs and activities to include a focus on STEM, integrated learning projects and inclusion of inquiry, scientific literacy and NOS. However, this presents some issues, teachers are faced with the dilemma of how to deliver the depth and breadth of discipline knowledge to adequately prepare students for future studies and implement integrated projects in a meaningful way.

STEM initiatives taken by many schools have seen them try to implement interdisciplinary, problem- or project-based learning activities (Margot & Kettler, 2019). ACARA (2016) reports that evidence suggests that STEM knowledge, understanding and skills are strengthened through emphasising connections between content and different learning areas and through the use of "authentic learning opportunities for students in answer to an identified problem or in the creation of a solution" (p. 6). It was found that such projects improved engagement and transferability of skills and knowledge between learning areas and awareness of future opportunities. They also strongly impacted on students' development of general capabilities and 21st century skills. While it was found that integrated STEM projects can deliver content from STEM disciplines it is variable and inconsistent, which requires a change in thinking and beliefs of teachers about what knowledge is required (Margot & Kettler, 2019). On the other hand, the skills associated with scientific literacy and NOS as outlined in the Science Inquiry Skills, Science as a Human Endeavour and the General Capabilities as well as the 21st-century skills were very evident within STEM learning tasks. However, teachers reported that less confident learners did not enjoy the open-ended nature of tasks and some found it difficult to work in groups. They also found that it required more of the staff involved in terms of planning and implementation as well as timetable flexibility.

While cross-curricular integration is not always possible "scientific knowledge and scientific thinking should be inseparable goals of education" (Lehrer & Schauble, 2006, p. 160). "To think of science as merely a body of organized knowledge is to conceive of it as being static" (Bybee et al., 2014, p. 39). If one of the goals of Science education is developing scientific literacy and the ability to tackle future challenges, the students need not only content knowledge but also an understanding of 'how science works' or the nature of science (Osborne, & Dillon, 2008, p. 8). It seems that many teachers focus first on the knowledge outcomes and give less attention to developing an "understanding of the means of answering scientific questions" (Bybee et al., 2014, p. 40). This may be a result of pressures from standardised testing, however, TIMSS and PISA testing are now including inquiry skills and scientific literacy items which may prompt a shift in focus (Mullis & Martin, 2017; OECD, 2019).

ACARA (2010) states that the Australian Science curriculum was written to be taught in an integrated way. Teachers are expected to teach the Science Understanding outcomes in a way that students can apply it to their lives, the lives of others and the role of science in society. Teachers are to use the Science as a Human Endeavour strand to help plan this and to encourage Science Inquiry Skills through investigating, analysing, evaluating and inquiry-based activities. Inquiry has many meanings in education, however, Bybee et al. (2014) suggest that as well as being a teaching and learning strategy it is also a knowledge area requiring that students understand the process and practices of scientific inquiry. "The product of the process of inquiry is scientific knowledge. Unfortunately, it is the product— knowledge— not the process, that has characterized science teaching" (Bybee et al., 2014, p. 39).

Many teachers lack the confidence and skills to implement and deliver curriculum reform (Rennie et al., 2001) and rely on resources such as textbooks and other curriculum packages. One of the programs which goes some way to achieving curriculum reform outcomes is the US-based, American Association for the Advancement of Science (AAAS) "Project 2061" which states that "schools do not need to be asked to teach more and more content, but rather to focus on what is essential to scientific literacy and to teach it more effectively" (as cited in Millar, 2006, p. 1500). Project 2061 outlines the developmental and constructivist nature of various science understandings. The "21st Century Science" project in the UK (Millar, 2006) has taken this further, developing a learning package for 15-16-year olds, with a focus on science explanations broken into units with a scientific literacy and inquiry context. This is paired with resources and ongoing teacher support and professional development (PD). A similar project in Australia is the

"Science by Doing" initiative for Y7 - 10 which combines learning resources, inquiry-based and scientific literacy activities along with teacher support and PD (Australian Academy of Science, n.d.). Perhaps these sorts of programs and other educative curricula need to be expanded and made more available or more widely known by teachers to support them to implement 'best practice' reforms associated with scientific literacy and inquiry-based instruction

2.3.3 Pedagogy reform

It is reported that most countries are moving away from traditional knowledge transmission style teaching and learning towards more active-learning educational methods (Elliott, 2014). While traditional teaching methods can be effective for acquiring basic skills and a certain amount of knowledge, it does not achieve many of the stated aims of Science education outlined previously (Lyons, 2006; Hawkins, Yamada, Yamada, & Jacob, 2019). Science education reform around the world has been rooted in constructivism. Constructivism comes out of the ideas of Vygotsky and Piaget and is based on the idea that cognitive change and learning relies on challenging previously held ideas and discovering new beliefs and ways of thinking (Bybee et al., 2014; Slavin, 2019). Constructivist learning has some key aspects: it emphasises social learning, it is student-centred, contextualised and inquiry-oriented, and it relies on scaffolding to complete complex yet achievable tasks (Osborne et al., 2003; Park et al., 2011; Slavin, 2019; Townsend, 2015).

For many, a constructivist approach is synonymous with an inquiry approach (Park et al., 2011). Inquiry has become a central word used to characterise good science teaching and learning (Anderson, 2002; Blessinger & Carfora, 2015). Bybee et al. (2014) state that "Science as a human activity is dynamic. It is what scientists do when they behave in the tradition of scientific investigation. When scientists question, explore and experiment, they demonstrate the inquiring nature of science" (p. 39). The US National Science Education Standards (NSES) define inquiry learning as "the activities of students in which they develop knowledge and understanding of scientific ideas as well as an understanding of how scientists study the natural world" (as cited in Park et al., 2011, p. 249). The Australian Education Council (Education Council, 2015) suggests the use of hands-on, inquiry-based activities which build on students' curiosity. Inquiry teaching should engage learners with real-world based, scientifically oriented questions using collaborative and individual learning experiences.

Studies suggest that school Science education can be made more engaging, relevant and meaningful by having students participate in authentic problem- or project-based learning (PBL) and inquiry-based learning (IBL). These types of activities encourage students to seek solutions to problems or questions and often involve some level of integration of learning areas or science topics. Blessinger and Carfora (2015) suggest that "IBL can be used to foster higher-order thinking, develop deeper intellectual capacities, as well as clarify personal values, identity, and meaning-making" (p. 4). While many see PBL and IBL as being predominantly student-directed, Blessinger and Carfora point out that the level of teacher input and guidance is dependent on the context and that students need to learn "how-to-learn" in such a way that "increasingly higher levels of self-directed learning is fostered" (p. 4). Many teachers are reluctant to adopt PBL and IBL as they do not feel confident in their own abilities and feel that the understanding constructed by learners is variable and "often deviates from what the teacher had intended" (Bybee et al., 2014, p. 120). However, studies have reported that student achievement in science is higher when teachers are effective in using inquiry-based pedagogy (Alonzo et al., 2012; Bautista & Schussler, 2010; Johnson, 2009).

The research presented makes it clear that teachers need a range of pedagogical approaches which promote students completing practical applications of scientific methods in order to achieve the goal of scientific literacy and gaining an understanding of the nature of science. Park et al. (2011) state that an effective teacher

> should start with questions about nature, engage students actively, concentrate on the collection and use of evidence, and not separate knowing from finding out. This type of teaching requires more from teachers than just knowing content and how to teach it (p. 249)

The curricular and pedagogical reforms suggested place many demands and pressures on today's Science teachers' time, skills, knowledge and beliefs. Hattie (2008) and Banilower et al. (2010) present the view that it is not a case of traditional teacher-centred learning being 'bad' and constructivist, child-centred approaches as 'good' but that effective teachers will use a range of appropriate strategies to suit the context and learning objectives. Townsend (2015) puts forward the view that an effective teacher should select from a range of teaching approaches to facilitate students' personal and social learning, which may include effective constructivist teaching as well as substantial teacher input.

2.3.4 Teacher reform

Studies report that teacher quality is critical to student outcomes and implementation of innovative and effective pedagogy (Kamener, 2012; Osborne et al., 2003; Osborne & Dillon, 2008; Tytler, 2007). "Teachers are central to a high performing education system . . . An excellent teacher - with strong professional skills, motivation and commitment - can account for up to 30 per cent of the difference in achievement between students" (Gonski et al., 2018, p. 56). The Australian STEM report suggests that we will require "strong STEM teaching at all levels . . . [and] a core STEM education for all students - encompassing inspirational teaching, inquiry-based learning and critical thinking" (Office of the Chief Scientist, 2014, p. 20). The outlined purposes, goals and requirements of an effective Science education places teachers in a position which requires them to expand and change their teaching beliefs, develop their skills and approach planning and assessment in new ways. This indicates the need for Science teachers to have the ability to deliver course content with "confidence and inspiration" (Office of the Chief Scientist, 2014, p. 21).

The 2018 *Report of the Review to Achieve Educational Excellence in Australian Schools* (Gonski et al., 2018) acknowledges that improved teaching will require "different types of expertise and greater collaboration compared with traditional education models" (p. 56). Rennie et al. (2001) comment that traditional teaching methods that emphasise learning as comprehension and factual recall cannot contribute to the goal of inquiry-oriented, student-centred learning activities which lead to scientific literacy. But also, that this reform teaching style requires more sophisticated teaching skills and content knowledge than traditional methods. Many teachers may need to refine their pedagogical skills to enable such activities and learning to take place. An inquiry-based approach with reflection on the nature of science is considered to be one of the most effective methods for enabling student understanding. However, researchers have found that many teachers lack adequate understanding of what this involves (Johnson, 2006; Johnson et al., 2007; Johnson et al., 2012; Rennie et al., 2001).

Teachers' ability and willingness to implement reform education practices is influenced by their self-efficacy beliefs (Margot & Kettler, 2019). Margot and Kettler found that the beliefs that teachers have about their own skills determine their confidence and thus their effectiveness in implementing innovative pedagogy and curriculum. Teachers beliefs and values regarding reform practices also have an impact whereby, teachers who value inquiry-based, STEM education as a valuable way to learn has an impact on their delivery. "A dynamic teacher with a positive attitude

toward STEM seems to be the single most important factor for implementation fidelity and STEM program success" (McMullin & Reeve, 2014 as cited in Margot & Kettler, 2019, p. 11). Although many teachers perceive that some changes are beneficial to student learning, many feel that reform pedagogy approaches require changes which can be difficult to implement (Margot & Kettler, 2019). Teachers also believe that such methods are more time-consuming and may not be as effective for content understanding, therefore are less effective at preparing students for testing and future-years curriculum (Johnson, 2009; Margot & Kettler, 2019). Teachers need support to consider their beliefs and values and develop their skills and confidence. The National STEM Strategy (Education Council, 2015) suggests that:

> Quality teaching is the key to lifting student engagement and performance in STEM education. Teachers need to be equipped with the skills and confidence to support STEM learning. The rapidly changing nature of technology, and the importance of real-world approaches to science education makes this particularly challenging. (p. 8)

2.4 TEACHER KNOWLEDGE AND SKILLS

"The question of what makes a good teacher has been asked by practitioners, policymakers, and researchers for decades. However, there is no guiding framework about which qualities are important for teachers" (Kim, Jörg, & Klassen, 2019, p. 163). In this section, some models of the different categories of knowledge and skills which teachers require are presented. One of the most influential models is one presented by Shulman (1986) which included a type of knowledge base called Pedagogical Content Knowledge (PCK). This concept has been adapted and built upon over the last 30 years. The different models of PCK have different ideas about what constitutes PCK and these differences and similarities are presented in order to synthesise a set of categories and a conceptual model of effective teaching knowledge and skills for use in this study. Through the use of the conceptual model both during the study and in data analysis it is hoped to be able to further refine and perhaps add to or elaborate on the relationships between the categories of teacher knowledge and skills.

The Australian Professional Standards for Teachers (AITSL, 2013) is also presented as an attempt by governing bodies in Australia to encapsulate the skills and knowledge required of teachers. These Standards are compatible with the teacher knowledge categories put forward by PCK researchers however some of the differences, issues and limitations are discussed. There is

clearly a set of knowledge and skills required of effective teachers and there is a suggestion that effective, experienced teachers are able to fluidly move between these elements. Researchers also suggest that further study is required to refine our conceptions of teacher knowledge and skills and particularly how these elements can be developed. The crux of this study revolves around helping Science teachers to become aware of their teaching behaviours, skills and knowledge and thus develop and build their professional expertise in line with the goals of STEM education, as previously discussed.

2.4.1 Pedagogical Content Knowledge (PCK)-based models

Much research has been done to try to identify effective teaching skills and knowledge. The OECD reports that "many features […] characterise expert teachers, which include extensive pedagogical content knowledge, better problem solving strategies, better adaptation for diverse learners, better decision making, better perception of classroom events, greater sensitivity to context, and greater respect for students" (Guerriero, 2014, p. 3). Shulman (1987) suggested a set of categories of teacher knowledge which have formed a useful foundation for further exploration of the extensive understanding required by teachers. Shulman's categories were: Content knowledge; General pedagogical knowledge, including classroom management strategies; Curriculum knowledge, materials and programs to be delivered; Knowledge of learners; Knowledge of educational contexts, including the particular group, classroom and community; Knowledge of educational ends, purposes and values; and Pedagogical Content Knowledge, a special form of professional understanding beyond understanding the content.

Researchers before and after Shulman (1987) have suggested other elements of teacher skills and knowledge, however, Shulman was the first to suggest the category of PCK. He believed it to be the blending or transformation of content knowledge and pedagogy into understanding for teaching and learning.

> PCK can be described as how teachers engage in the business of teaching their subject by accessing what they know about their subject, the learners they are teaching, the curriculum with which they are working and what they believe counts as good teaching in the context of the situation in which they are operating. (Rollnick, Bennett, Rhemtula, Dharsey, & Ndlovu, 2008, p. 2)

According to Shulman, PCK includes the most useful strategies and representations of ideas and concepts in their learning area, including explanations, examples and demonstrations as well as knowledge of how students will interact with the content being taught. Over time these ideas have been expanded and adapted, which means that there is no one particular definition of the construct of PCK and how it fits with other knowledge types (Gess-Newsome, 1999; Park & Oliver, 2008; Van Driel, Verloop & de Vos, 1998). While further studies and reorganisation of Shulman's ideas are useful in terms of considering what effective teachers know and do, it has not made it any easier to clarify PCK.

Most researchers agree with Shulman (1986) that the central ideas of PCK are the transformation of subject matter knowledge and that it encompasses understanding of common learning difficulties and preconceptions of students (Cochran et al., 1993; Magnusson et al., 1999; Park et al., 2011; Park & Oliver, 2008; Smith & Neale, 1989; Van Driel et al., 1998). Effective teachers require some general pedagogical skills and knowledge (GPK) which can be seen as transferable to any learning area and class. They also require a level of subject content knowledge (SCK). Many researchers have put forward other elements of effective teaching which are thought to make up or contribute to pedagogical content knowledge (PCK) as shown in Table 2.1, these elements are described in the following sections.

Table 2.1 A Comparison of the Suggested Elements of PCK as Presented by Various Researchers

Knowledge (and beliefs) about:	Shulman (1986)	Cochran et al. (1993)	Magnusson et al. (1999)	Park & Oliver (2008)	Lee & Luft (2008)	Kind (2009)	Park et al. (2011)	Townsend (2015)
Science topics/ Content knowledge	✓	✓			✓	✓	✓	✓
Orientations and Purpose	✓		✓	✓	✓	✓		✓
Students' Understanding	✓	✓	✓	✓	✓	✓	✓	✓
Curriculum	✓		✓	✓	✓	✓	✓	✓
Teaching strategies and resources	✓	✓	✓	✓	✓	✓	✓	✓
Assessment			✓	✓	✓			✓
Environmental/Educational Contexts	✓	✓				✓		
Well-adjusted emotional attributes/ Self efficacy				✓				✓

This research was used to construct a conceptual framework for use in this study as shown in Figure 2.1. It synthesises the researcher's conception of the elements of effective teaching based on the literature. It presents GPK and SCK as separate required knowledge areas which contribute to a transformed type of knowledge labelled PCK. PCK is shown as being composed of or influenced by five types of skills and knowledge. All of which is further shaped by personal attributes.

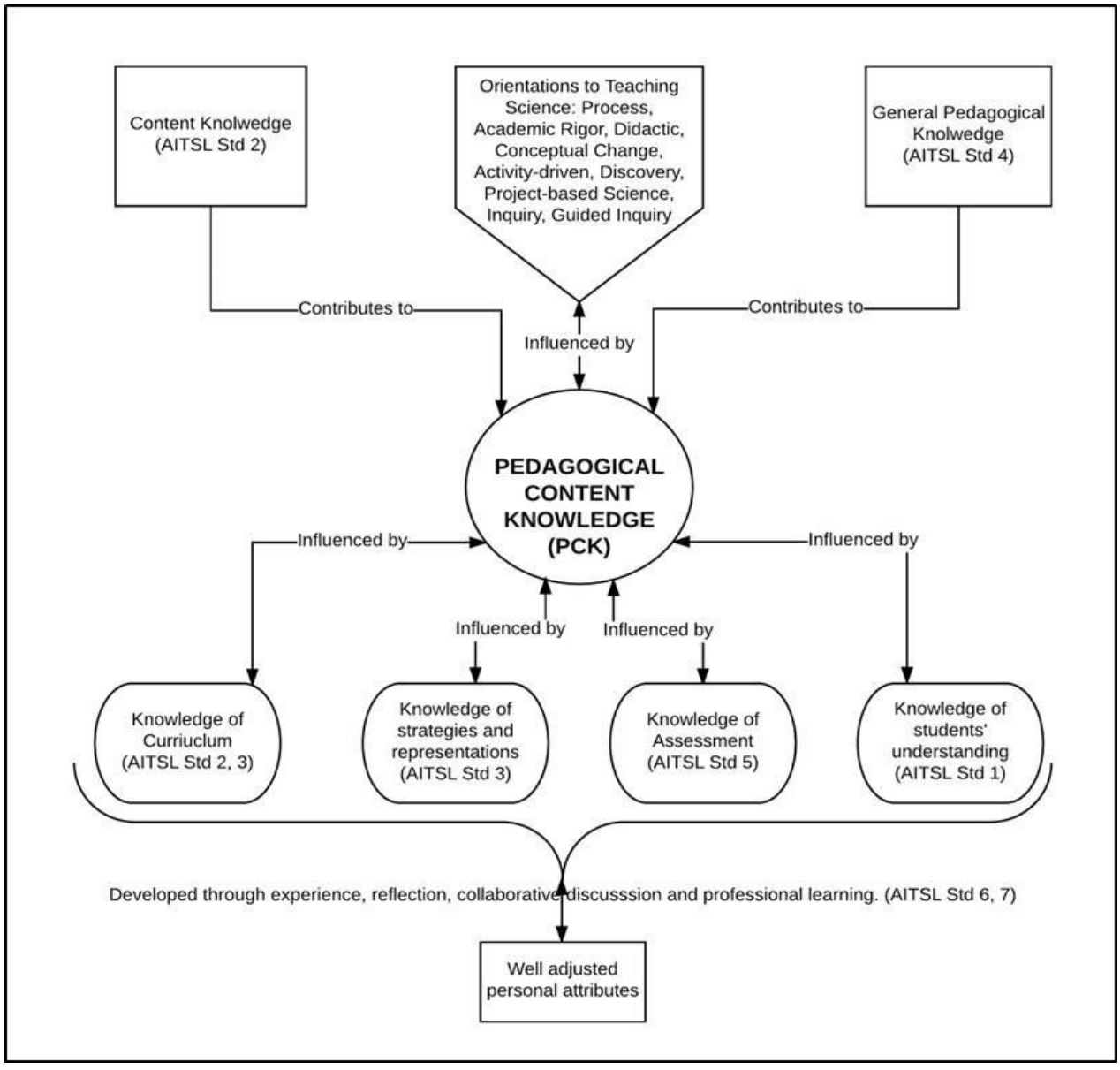

Figure 2.1. A conceptual framework used to represent the elements and contributing knowledge types to PCK mapped to the AITSL standards (also in Appendix A). Based on Shulman (1986), Kind (2009), Magnusson et al. (1999), Park and Oliver (2008) and Townsend (2015).

2.4.2 Science/Subject Content Knowledge (SCK)

Science content knowledge involves teachers having a deep understanding of the science topics and subject matter to be taught. Gess-Newsome (2015) describes it as "the academic content of the discipline" (p. 32). Shulman (1986) believed that content knowledge "requires going beyond knowledge of facts or concepts . . . the teacher need not only understand that something is so; the teacher must further understand why it is so . . . [and] understand why a given topic is particularly central to a discipline" (p. 9). Grossman, Wilson, and Shulman (1989) point out that good teachers also know "things about their content that make effective instruction possible" (p. 5). Lee, Brown, Luft, and Roehrig (2007) add that it includes an understanding of the nature of science, scientific literacy and relationships between scientific topics. A more recent OECD report by Guerriero (2014) refers to "teaching as a knowledge-rich profession with teachers as 'learning specialists.' [Teachers are expected to] regularly update their knowledge base to improve their practice and to meet new teaching demands" (p. 3). Throughout this study, the acronym SCK is used to represent Subject Content Knowledge and more specifically Science Content Knowledge, in some studies and models it is also called Subject Matter Knowledge (SMK).

Studies have found that teachers' SCK has a strong influence on teaching and student learning (Kleickmann et al., 2013). Banilower et al. (2010) state that "effective instruction requires skilled and knowledgeable teachers and research supports the idea that teacher understanding of content is important. Teachers with stronger content knowledge are more likely to teach in ways that help students construct knowledge" (p. 5). However, the relationship between teacher SCK and student achievement is difficult to examine. Measuring and analysing content knowledge is complex and using students' achievement as a measure of teacher effectiveness is problematic (Grossman et al., 1989). Studies have led to some findings which suggest that SCK is less central to effective teaching than expected and that the relationship between teacher knowledge and student achievement is not linear and that there may be a threshold of knowledge which makes a teacher effective (Gess-Newsome et al., 2019; Grossman et al., 1989).

It seems to make sense that teachers who have a strong knowledge of the content to be taught will be much more capable of making relevant links, devising strategies, representations and analogies for concepts and will be capable of directing students learning in a much more confident and competent way (Shing, Saat, & Loke, 2018). Grossman et al. (1989) point out that

it is clear that SCK affects the style of instruction which a teacher chooses to use, where less confident SCK leads to a more didactic style. A number of researchers also make a clear link between the transformation of SCK and another aspect of PCK, being knowledge of students' understanding (Grossman, 1990; Shing et al., 2018; Shulman, 1986). Kleickmann et al. (2013) point out that SCK and understanding students' misconceptions and prior knowledge will impact on "students' learning and motivation" (p. 90). SCK has an integral role in PCK and effective teaching (Rollnick et al., 2008). However, both Rollnick et al. and Kleickmann et al. state that while PCK relies on good SCK, having content expertise alone is not enough and that effective teaching relies on well-developed PCK.

2.4.3 General Pedagogical Knowledge (GPK)

A teacher's subject matter knowledge is crucial for understanding the content to be taught, however, teachers must also develop good GPK. A lot of teacher training, professional development time and educational research has been dedicated to this aspect of teacher knowledge (Cochran et al., 1993; Hattie, 2008). An OECD report (Guerriero, 2014, p. 5) lists the aspects of GPK as being: Knowledge of classroom management; Knowledge of teaching methods; Knowledge of assessment methods and purposes; Structure and lesson planning; Adaptivity and dealing with different learning groups; Knowledge of learning processes and strategies; and Knowledge of individual student characteristics. This list captures elements of GPK but also describes knowledge and skills from other factors influencing PCK, demonstrating how the elements of PCK are intertwined.

GPK can be considered as teaching skills and knowledge which can be used in any classroom, for any subject. A review of several studies about effective science teaching, undertaken by the researcher, shows there to be a lot of agreement about what is thought to be generally effective teaching and learning strategies, which could be considered as GPK. GPK strategies which repeatedly emerge as improving student learning are shown in Table 2.2.

Table 2.2 General Pedagogical Strategies Considered to Lead to Effective Teaching and Learning.

The use of social interaction such as discussion, discourse and sharing ideas	Bautista & Schussler, 2010; Blumenfeld et al., 1991; Driver et al., 1994; Grossman, 1990; Hand, Lawrence & Yore, 1999; Johnson, 2006; Johnson et al., 2012; Jones, 2008; Millar, 2006; Norris & Phillips, 2003; Osborne et al., 2003; Pearson et al., 2010; Prain & Hand, 1996; Rennie et al., 2001; Rosaen et al., 2008; Tytler, 2007; Yore et al., 2003; Yore & Treagust, 2006
The use of relevant contexts	Alonzo et al., 2012; Blumenfeld et al., 1991; De Boer, 2000; Driver et al., 1994; Hand et al., 1999; Johnson et al., 2012; Millar, 2006; Norris & Phillips, 2003; Osborne et al., 2003; Prain & Hand, 1996; Rennie et al., 2001; Rosaen et al., 2008; Tytler, 2007; Yore et al., 2003
Effective questioning	Bautista & Schussler, 2010; Gess-Newsome et al., 2019; Johnson et al., 2012; Rosaen et al., 2008; Tytler, 2007; Wise & Okey, 1983; Yore et al., 2003
The use of wait time	Bautista & Schussler, 2010; Grossman, 1990; Wise & Okey, 1983; Yore et al., 2003
"Focusing" or providing learning intentions	Bautista & Schussler, 2010; Osborne et al., 2003; Rosaen et al., 2008; Wise & Okey, 1983
Encouraging reflection	Abd-El-Khalick et al., 2004; Bautista & Schussler, 2010; Driver et al., 1994
The use of manipulatives	Abd-El-Khalick et al., 2004; Johnson et al., 2012; Norris & Phillips, 2003; Pearson et al., 2010; Tytler, 2007; Wise & Okey, 1983; Yore et al., 2003
Providing a positive classroom environment and relationships	Osborne et al., 2003; Rennie et al., 2001; Rosaen et al., 2008; Tytler, 2007

Using a range of teaching strategies including direct instruction and student-focused methods	Alonzo et al , 2012; Donnelly, 2007; Gess-Newsome et al., 2019; Grossman, 1990; Osborne et al., 2003; Rennie et al., 2001; Tytler, 2007; Wellington & Osborne, 2001; Wise & Okey, 1983; Yore & Treagust, 2006

2.4.4 Other teaching skills and knowledge contributing to PCK

Beliefs and Orientations towards teaching science

Shulman (1987) described one category of teacher knowledge as "knowledge of educational ends, purposes, and values, and their philosophical and historical grounds" (p. 8). Others refer to this element as a teacher's knowledge and beliefs about the purposes and goals for teaching science (Magnusson et al., 1999; Park & Oliver, 2008; Smith & Neale, 1989). Lee and Luft (2008) describe this as instructional goals, for example encouraging understanding of natural phenomena, building scientific literacy, seeing real-life applications and developing integrated understanding. Magnusson et al. (1999) lists several different teaching and learning goals and approaches a teacher may employ such as process-oriented, conceptual change, didactic, activity-driven, discovery, project-based, inquiry and guided inquiry. Kind (2009) explains that teachers adopt different teaching approaches for different reasons depending on their learning goals and purposes. Schneider and Plasman (2011) suggest purposes such as learning about the nature of science, developing curiosity, preparation for future learning, building confidence and appreciation of science. They also add the importance of a constructivist approach. Beliefs and attitudes towards STEM education and reform teaching practices could also be added here.

Townsend, McKinnon, Fitzgerald, Morris and Lummis (2016) put it as teachers having "knowledge of one's orientations towards teaching (knowledge of and about the subject, beliefs about it, and how to teach it)" (p. 4). While techniques, goals and purposes can be learned by teachers, Grossman et al. (1989) found that it is the beliefs of teachers which are very "powerful and influential" (p. 20) when it comes to choosing what and how to teach. Importantly, they also suggest that "beliefs depend heavily on affective and personal evaluations [and] beliefs are more debatable than knowledge" (p. 19). A teacher's beliefs and instructional goals guide many of the other teaching decisions and elements of PCK and therefore plays a central role and can be described as their orientation (Grossman, 1990; Woolfolk, Hoy, Hoy & Davis, 2009). Gess-

Newsome et al. (2019) suggests that it influences PCK, acting as a 'filter' or 'amplifier', this is also the view of the researcher in this study and thus it has been placed above PCK and having a different influence to the other elements in the conceptual framework (Figure 2.1).

Knowledge of students' understanding

This was one of the key factors of PCK identified by Shulman (1987) who stated that teachers need knowledge of learners and their characteristics in order to transform SCK in an effective way. Cochran et al. (1993) expand on this by including knowing about "their abilities and learning strategies, ages and developmental levels, attitudes, motivations, and their prior knowledge of the concepts to be taught" (p. 7). Gess-Newsome et al. (2019) support this and add that it incorporates knowledge of differentiation requirements and information about relevant personal and community contexts. Magnusson et al. (1999), Kind (2009), Lee et al. (2007) and Townsend et al. (2016) state that teachers will need to be aware of Science concepts or topics that students find difficult to learn as well as knowledge of misconceptions or alternative conceptions and how to overcome them

How students learn will depend on what students know about a topic and areas of difficulty, their diversity and learning styles, developmental level and need, and their interest (Lee & Luft, 2008; Park & Oliver, 2008; Park et al., 2011; Smith & Neale, 1989). Students come to Science class with their own ideas (Bybee et al., 2014), their preconceptions sometimes act as impediments for scientific understanding and at other times serves as building blocks towards coherent scientific knowledge. Ideal teaching should identify and understand these. Research shows that "teachers need an understanding that goes beyond knowledge of science content to include knowing how students typically think about concepts, the questions teachers can ask to figure out what their particular students do and do not understand about a specific topic, and the experiences they can provide to help move student understanding forward" (Banilower et al., 2010, p. 33). Good teachers will ensure that the content and activities used will take into consideration the specific students they are teaching, allowing for differentiation and suitable instructional strategies (Grossman, 1990; Shing et al., 2018).

Knowledge of science curriculum

Shulman (1987) discussed the need for teachers to have "curriculum knowledge, with particular grasp of the materials and programs that serve as 'tools of the trade' for teachers" (p. 8). This involves knowledge of the mandated curriculum goals and objectives and requires an understanding of curriculum across year levels and topics as well as what are considered core concepts (Gess-Newsome et al., 2019; Lee & Luft, 2008; Lee et al., 2007; Magnusson et al., 1999; Park et al., 2011; Townsend, 2015). Kind (2009, p. 14) also calls this "curricular saliency – awareness of the importance of a topic to the whole curriculum." The other part of this is knowledge and beliefs about specific programs and resources when teaching particular topics (Grossman, 1990; Park & Oliver, 2008; Schneider & Plasman, 2011).

Knowledge of instructional strategies and resources

Having knowledge of commonly used strategies and subject matter representations was first suggested as one of the two key elements making up PCK by Shulman in 1986. A teacher's knowledge and use of various strategies, explanations and resources represent the intersection between their content knowledge and pedagogy. This category includes knowledge of subject-specific and topic-specific teaching strategies (Cochran et al., 1993; Magnusson et al., 1999; Park et al., 2011). Effective teachers will have a variety of strategies which allow them to deliver appropriate learning activities in a particular context (Lee et al., 2007). These include subject-specific instructional strategies such as models, illustrations, analogies, explanations, examples and demonstrations as well as simulations, investigations and experiments (Kind, 2009; Townsend, 2015).

Lee et al. (2007) point out that an element of this is knowledge of resources. Lee and Luft (2008, p. 1352) suggest that it includes "materials, activities, multimedia, local facilities, laboratory technology, and texts." Grossman (1990) suggests that experienced teachers will have a 'rich repertoire' of effective strategies. An effective teacher must judge whether and when a representation or resource will be useful to support and extend the comprehension of students in a particular teaching situation (Park & Oliver, 2008; Townsend, 2015).

Knowledge of assessment

Knowledge of Assessment includes knowledge of what to assess and methods through which learning can be assessed (Magnusson et al., 1999; Park & Oliver, 2008). Townsend (2015) and Gess-Newsome et al. (2019) state that assessment includes formative and summative types and should be continuous and be used to adjust teaching and learning plans. Teachers should be aware of scientific literacy, and later educational needs to inform their decision-making in this element. They should be aware of different forms of assessment, their importance, advantages and disadvantages (Lee et al., 2007). Lee and Luft (2008) include student discussion and questioning techniques as well as the need for immediate feedback in Knowledge of Assessment. Kind (2009) states that assessment does not just include externally imposed forms of assessment and points to the move by some schools towards assessment for learning (AfL) which integrates instruction, assessment and feedback (Black & Wiliam, 1998). The relationship between high-stakes and large-scale international external assessment such as university entrance exams and PISA and TIMSS on teachers' PCK has not been investigated.

Knowledge of environmental and educational contexts

One of the separate categories of teacher knowledge put forward by Shulman (1987) was knowledge of educational contexts, which is seen as knowledge of the particular students, class or school as well as characteristics of their broader community and cultural backgrounds (Cochran et al., 1993; Shulman, Grossman, 1990). This includes "knowledge of the school climate, parental concerns, legal issues, and the social context of the community" (Cochran et al., 1993, p. 11). As Grossman (1990) puts it "teachers must draw upon their understanding of the particular contexts in which they teach to adapt their more general knowledge to specific school settings and individual students" (p. 8). Kind (2009) discusses the notion of educational context as being part of the orientations and purpose of teaching. This category has been discarded in more recent PCK research, which may be because as well as being part of one's orientations it could be seen as part of a teacher's knowledge and understanding of their students.For this reason, the researcher chose not to give it a separate category in the conceptual framework, instead considering that it was represented within other categories.

Well-adjusted emotional attributes and self-efficacy

Townsend et al. (2016) suggested that another element of PCK is well-adjusted emotional attributes. His results found that it was important for the development of PCK and that improvement in a teacher's PCK can benefit their personal attributes. Based on the work of Kind (2009), Townsend (2015) suggested that teachers require "perseverance, professionalism and an ability to receive and act on well-constructed teaching performance feedback" (p. 96). Decker and Rimm-Kaufman (2008) report that personality characteristics such as flexibility, a cooperative attitude and interest in students are related to teacher success. Bybee et al. (2014) describe essential attributes of effective teachers as having positive perceptions of their students and themselves, good relationships with others as well as enthusiasm for teaching and patience. Townsend (2015) also suggests that teachers need the ability to 'rebound' from the high-pressure demands of teaching and a willingness to work with colleagues and adopt a reflective approach in order to develop their own and others' PCK.

Other researchers have also found an affective element associated with PCK which is best labelled as teacher efficacy. This is described as teacher beliefs and perceptions about their abilities to perform particular teaching tasks and influence student learning (Lauermann, & König, 2016; Kayapinar, 2016; Park and Oliver, 2008; Sachs, 2004). It is related to the concept of self-efficacy put forward by Bandura (1994). High levels of teacher self-efficacy have been related to higher student achievement (Whitworth & Chiu, 2015), teachers' persistence in the face of difficulty (Lauermann & Konig, 2016; Sachs, 2004) and tends to be higher in more experienced teachers (Whitworth & Chiu, 2015). A strong sense of efficacy is seen in highly effective teachers as "they believe that they can help nearly all students learn, . . . such teachers also tend to be very positive in their feelings about teaching and are generally confident about their teaching abilities" (Guskey, 1988, p. 5). On top of this, self-efficacy is positively correlated with teacher change and professional development (Whitworth & Chiu, 2015).

Appleton (2006) described similar findings as teacher confidence which was seen as part of an attitude cluster which was critical to a teacher's PCK. Pajares (1992) recognises that a teacher's educational and personal beliefs, as well as self-perception and confidence, play an important role in determining how a teacher employs their knowledge or PCK. Bybee et al. (2014) state that a teacher's "perceptions of self, students and the teaching task are critical to effective instruction" (p. 24). Due to the descriptions of affective, attitudinal and personality characteristics which impact on effective teaching choices, the conceptual framework used in this

study shows this factor as underpinning the other elements of PCK and effective teaching. It is proposed that teacher efficacy has a reciprocal relationship with PCK whereby as one improves so too does the other (Appleton, 2006).

Technological Pedagogical Content Knowledge (TPACK)

In recent years computer technology has changed the way we do many things, including education, as student learning can be enhanced by technology. The findings of a study by Pierson (2001) suggested another component of teachers' knowledge, that of technological pedagogical content knowledge (TPACK). This includes basic technology competency and an understanding of unique technologies to aid teaching and learning in a particular subject or topic. This is seen by some (Abbitt, 2011) as another component which informs and contributes to PCK. TPACK has seen increasing interest from educational technology researchers around the world who are interested in issues related to technology integration (Graham, 2011).

A TPACK framework has been produced containing three domains: technological content knowledge which consists of knowing how technology plays a role within a topic or subject; technological pedagogical knowledge which is the knowledge required of all teachers to use technology generally in the classroom; and technological pedagogical content knowledge which is the subject-specific technology and resources which can be used to enhance subject-specific learning such as simulations, websites, sensors etc. (Abbitt, 2011). In this study, the researcher has chosen not to include this as a separate knowledge base and instead considered it to be part of GPK and Knowledge of strategies and resources when synthesising ideas into the conceptual framework.

2.4.5 PCK use

Cochran et al. (1993) state that PCK is "the manner in which teachers relate their pedagogical knowledge (what they know about teaching) to their subject matter knowledge (what they know about what they teach), in the school context, for the teaching of specific students" (p. 4). Van Driel et al., (1998) state that PCK is a type of 'craft knowledge' that is an integrated knowledge representing teachers' accumulated wisdom with respect to their teaching practice.

This knowledge guides their actions in practice. Townsend (2015) suggests that fully developed PCK is the ability of moving "holistically and fluidly" (p. viii) among the elements of PCK. This requires continuous teacher scanning of the learning environment to assess and reassess the effectiveness of actions and can be observed in highly effective science teachers.

The elements of effective PCK provide a useful conceptual framework for understanding what teachers do and what is required to do it effectively (Townsend, 2015). While PCK is a valued idea, many researchers point to the difficulty of precisely explaining what it is (Loughran, Mulhall & Berry, 2004). Bertram and Loughran (2012) suggest that PCK is mostly used by researchers but it is not well known by practising teachers.

> PCK has long represented the particular and specialised knowledge of teaching particular content that teachers possess and develop over time. But what is looks like, how it might be captured, portrayed or even used by science teachers in any concrete form has long been recognised as a major gap in the literature. (Bertram & Loughran, 2012, p. 1028)

It is hoped that with further research it will provide a tool for practising teachers and teacher education (Abell, 2008). Some researchers propose the development of PCK-based rubrics or a continuum of teacher standards (Townsend et al., 2016).

2.4.6 AITSL Standards

In Australia, a call to represent the skills and knowledge required of teachers saw the establishment of the Australian Institute for Teaching and School Leadership (AITSL) as a body to promote teacher excellence through a set of standards and associated resources and professional development tools. The Australian Professional Standards for Teachers (the Standards) (AITSL, 2013) outline a set of seven standards within three Domains of Teaching. The Standards consist of skills and knowledge across the range of teacher requirements. They are further described at four career stages of Graduate, Proficient, Highly Accomplished and Lead. Pre-service and graduate teachers are required to develop evidence for each of the standards in order to become a registered teacher. Registered practising teachers make use of them to progress their own development, with some systems certifying teachers at higher levels. The Standards can be represented as shown in Table 2.3.

Table 2.3 The Australian Professional Standards for Teachers (based on AITSL, 2013)

Professional knowledge	1. Know students and how they learn	● Physical, social and intellectual development and characteristics of students ● Understand how students learn ● Students with diverse linguistic, cultural, religious and socioeconomic backgrounds ● Strategies for teaching Aboriginal and Torres Strait Islander students ● Differentiate teaching to meet the specific learning needs of students across the full range of abilities ● Strategies to support full participation of students with disability
	2. Know the content and how to teach it	● Content and teaching strategies of the teaching area ● Content selection and organisation ● Curriculum, assessment and reporting ● Understand and respect Aboriginal and Torres Strait Islander people to promote reconciliation between Indigenous and non-Indigenous Australians ● Literacy and numeracy strategies ● Information and Communication Technology (ICT)
Professional practice	3. Plan for and implement effective teaching and learning	● Establish challenging learning goals ● Plan, structure and sequence learning programs ● Use teaching strategies ● Select and use resources ● Use effective classroom communication ● Evaluate and improve teaching programs ● Engage parents/carers in the educative process
	4. Create and maintain supportive and safe learning environments	● Support student participation ● Manage classroom activities ● Manage challenging behaviour ● Maintain student safety ● Use ICT safely, responsibly and ethically
	5. Assess, provide feedback and report on student learning	● Assess student learning ● Provide feedback to students on their learning ● Make consistent and comparable judgements ● Interpret student data ● Report on student achievement
Professional engagement	6. Engage in professional learning	● Identify and plan professional learning needs ● Engage in professional learning and improve practice ● Engage with colleagues and improve practice ● Apply professional learning and improve student learning
	7. Engage professionally with colleagues, parents/carers and the community	● Meet professional ethics and responsibilities ● Comply with legislative, administrative and organisation requirements ● Engage with parents/carers ● Engage with professional teaching networks and broader communities

While the scope of this study was not to look at the Standards in an in-depth way it is useful to consider them against the models of PCK-based effective teaching. Inspection of the Standards reveal that they seem to encompass many of the PCK-related elements and knowledge areas. They clearly make reference to SCK, Knowledge of students, Knowledge of assessment and Knowledge of curriculum. GPK and Knowledge of strategies and resources are implied across most of the Standards as is Knowledge of educational/environmental contexts. The Standards differ in their addition of organisational and non-teaching requirements. Finally, the standards do not make explicit reference to teachers' knowledge of orientations, beliefs and goals of teaching, however, it could be inferred that this is part of the professional knowledge of teachers. Nor do the standards refer to any affective requirements of teachers.

2.5 TEACHER DEVELOPMENT AND REFORM

2.5.1 Research into, and Development of, Teachers' PCK

Although PCK is recognised as an important and useful concept, little is known about how teachers develop effective PCK (Kind, 2009; Townsend et al., 2016). PCK is not commonly known about by many science teachers (Kind, 2009). In a study exposing secondary science teachers to PCK theory, Loughran, Mulhall, and Berry (2008) found that participants came to see PCK

> as a way of looking into how they might develop their own professional knowledge of practice. In that way, they are applying a more sophisticated view of learning about teaching in their own practice that appears to help them challenge the more traditional science teaching as 'the delivery of facts' so common in schools. (p. 1317)

This is the basis of this study, where it is hoped that the initiative used will help teachers become more aware of their practice and how they can improve using PCK as a guide. Townsend et al. (2016) contend that the development of fluid, effective PCK takes time and requires planning and a systematic approach with support. It is thought that experienced teachers will have better PCK as they have a greater range of strategies and more confidence and understanding of students (Shing et al., 2018).

Townsend (2015) suggests that as teachers develop a high level, integrated version of PCK, an observer would see teachers continuously scanning the teaching and learning environment and making in-the-moment decisions. They would also have improvements in constructivist teaching strategies as well as employing illustrations, models, examples and analogies to represent specific content. As well as this, teachers' understanding of SMK and student learning difficulties would improve. Teachers would be more aware of their personal teaching orientations and generally gather more knowledge about each of the other elements such as assessment and effective feedback strategies. Teachers would have improved confidence to teach science and it can be assumed that there would be improved student outcomes.

Kind (2009) puts forward three key factors required for good PCK: possession of good SMK; classroom experience; and, emotional attributes such as good levels of personal self-confidence, provision of supportive working atmospheres, and collaboration. There is evidence that good content knowledge is the main requirement for PCK development (Ball, Lubienski, & Mewborn, 2001; Friedrichsen et al., 2009). However, Lee et al. (2007) have found that a high level of conceptual understanding does not necessarily lead to effective PCK.

Magnusson et al. (1999) makes four recommendations for enhancing PCK development: help teachers to examine their pre-existing ideas and beliefs to understand their orientation toward the subject as well as alternative conceptions; address subject matter knowledge; situate learning experiences in a meaningful context (i.e., the classroom); and use a model comprised of components of PCK to guide them. Henze, Van Driel and Verloop (2008) found that the development of PCK in experienced science teachers was limited mostly by their perspectives and orientations to teaching. Efforts to help teachers make significant changes and incorporate new strategies and representations must help them to acquire new knowledge and beliefs (Kind, 2009; Magnusson et al., 1999).

Researchers have found that guidance and reflection are essential to the development of PCK, time in the classroom alone is not sufficient to make progress (Schneider & Plasman, 2011). For practising science teachers, presenting them with opportunities to discuss their beliefs about science as well as alternative theories of student learning and associated evidence-based instructional practices will help teachers to reflect on their science orientations and selection of instructional practices thus improving their PCK (Lee & Luft, 2008; Morine-Dershimer & Kent, 1999; Townsend, 2015; Van Driel & Berry, 2012). Cochran et al. (1993) suggest that "peer coaching, cooperative classroom activities, analysis of case studies, and team teaching will

facilitate PCK development" (p. 18). Townsend et al. (2016) also suggested that PCK development requires a willingness to work with other teachers and to have a professional and reflective approach.

There are many questions still to be investigated about PCK to determine the quality of teachers' knowledge and to generate models of PCK development (Abell, 2008). More up to date research into what makes for good PCK is required as the construct itself has expanded and changed over the decades since Shulman. Townsend (2015) suggests that PCK growth can be conceptualised along a continuum and that PCK as a conceptual framework can serve as a map for planning professional learning and goal setting. In Australia, many schools and teachers use the Professional Standards for Teachers (ACARA, 2013) as a means for reflecting on practice and to set professional learning goals. The Standards have a close alignment with the components of PCK, however, Townsend (2015) regards the Standards as a somewhat fragmented approach whereas PCK gives a "coherent and interdependent framework" (p. 76). Loughran et al. (2008) suggest that researchers need to focus on how teachers' understanding of PCK influences thinking about teaching and what it means to be a Science teacher. They state that "there is a need to be able to articulate and document what teachers know and are able to do. This is central in coming to understand pedagogical content knowledge" (Loughran et al., 2001, p. 22). Abell (2008) suggests that we still do not know enough about what PCK science teachers have, how they come to have it, or what they do with it. More studies of master teachers are needed to define the target of knowledge growth and learning and development progression (Abell, 2008; Townsend, 2015).

2.5.2 Teacher change processes

Teacher reform initiatives, including those targeting PCK, aim to bring about change in classroom practices, knowledge, beliefs and attitudes, and therefore learning outcomes of students. Many teachers may have the motivation to make changes but lack the confidence, or self-efficacy, to implement new teaching strategies (Jones, 2008). One of the barriers to teachers using effective teaching practices which lead to enhanced student learning and achievement is teachers' own beliefs about their capabilities and the effectiveness of the initiatives (Blumenfeld et al., 1991; De Boer, 2000; Johnson, 2009). Guskey (2003) reports that teacher change programs require more thought about motivational factors and the process through which change occurs.

Korthagen (2004) and Guskey (2003) propose that change in beliefs is more likely to occur after positive evidence from changes in practice have been observed which contributes to motivation and maintenance of the changes.

Some of the elements of effective teaching are related to Bandura's (1994) concept of self-efficacy, where effective teachers are more likely to feel positively about their abilities and relationships. This factor also influences teachers' ability to make changes in their practice (Guskey, 1988; Whitworth & Chiu, 2015). Not only does self-efficacy make teachers more likely to participate in development activities but it has been found that by implementing new practices effectively and participating in the right development initiatives teachers can also increase their perceived self-efficacy, this concept is as important today as when it was first proposed. Guskey (1988) discusses the reciprocal effect of self-efficacy, effective teaching and teacher development as follows:

> teachers who express a high level of personal efficacy, like teaching, and feel confident about their teaching abilities are, indeed, highly effective in the classroom, these teachers also appear to be the most receptive to the implementation of new instructional practice. (p. 11)

In 2004, Korthagen suggested that "if we wish to promote teacher learning, we will have to take their thinking, feeling and wanting into account" (p. 391). In more recent research Korthagen (2017) dismisses traditional models of teacher development based on presenting theories about teaching, hoping to promote change in practice. He calls this a "theory-into-practice approach" and states that it does not work as teacher behaviour is complex and only partly influenced by thinking, "let alone by theories they have learnt" (p. 389). Abell, Bryan, and Anderson (1998) suggest that to help teachers improve, what is needed is to understand their personal theories, or beliefs, about teaching and learning. This is considered a conceptual change view, it requires finding ways to challenge thinking, this can be done through the use of reflection to develop new understanding and reframe problems. Teacher beliefs are an obstacle to reform, as teachers must decide to integrate new strategies and believe that the change is needed in order to transform their classrooms. Tytler (2007) states that "What is required in order for many teachers to […] change is a new set of beliefs about the nature and purpose of science education" (p. 60).

Most teacher professional development efforts start with attempts to change thinking, beliefs and attitudes in an effort to encourage teachers to change their practices and behaviours or

develop their knowledge (Guskey, 2003; Korthagen, 2004). However, beliefs and attitudes usually come from classroom experience, therefore changes at this level are only likely to occur when there is positive evidence seen in student learning outcomes. Guskey (2003) and Korthagen (2017) propose a model which suggests that teacher change is experientially based, teachers need to adopt changes in practice and when the teacher sees evidence of improvement in their students then they will begin to change their beliefs and attitudes, which will reinforce the teacher development efforts. This model is based "on the idea that change is a learning process for teachers that is developmental and primarily experientially based" (Guskey, 1986, p. 7). In this way, a constructivist learning approach is applied to teacher development.

Regardless of the approach, behaviour change is supported and motivated by situating new learning in relevant contexts and providing positive social influences (Kwasnicka, Dombrowski, White, & Sniehotta, 2016). Bandura (1994) after much research put forward a model of behavioural change which suggests that change occurs through social modelling, where there is a sense of relatedness and trust and individuals aim to maintain positive social identity. Kwasnicka et al. (2016) report that social support and encouragement improve maintenance of behaviour change. Other motivators include "behaviour enjoyment, satisfaction with behavioural outcomes, self-determination or an experience of behavioural congruence with beliefs and values, all of which often develop after initiating a new behaviour" (Kwasnicka et al., 2016, p. 290).

Whitworth and Chiu (2015, p. 3) suggest that "it is critical to understand what factors contribute to teacher change" and have an impact on student learning, especially considering the cost and resources expended on teacher professional development. It is hoped that through the reflective practices employed in this study, participants may experience some of the factors which can lead to changes in beliefs and feelings and therefore improved teaching outcomes.

2.6 TEACHER PROFESSIONAL DEVELOPMENT

The research makes it clear that teachers need to be supported throughout their career to develop skills, knowledge and confidence to adopt new reforms. This is particularly important as the demands of teaching are changing. Effective teacher professional development is essential and must be supported. One of the most common issues regarding teacher learning is time and commitment of resources (Jensen, Sonnemann, Roberts-Hull, & Hunter, 2016; Rogers et al., 2007). Kamener (2012) states that schools need "to develop a culture in schools that is open to

broad, constructive feedback, mentoring, monitoring of classroom performance and ongoing professional development" (p. 3).

2.6.1 Models of professional development (PD)

It is widely recognised that the “single most important factor in student achievement is teacher quality” (Marginson et al., 2013, p. 86). Alonzo et al. (2012) comment that “of all the factors that education leaders can control, the quality of teaching has perhaps the greatest potential effect” (p. 1212). Kamener (2012) points out the importance of quality teaching to student outcomes but states that it is a complex issue comprising individual teacher qualities and effective on the job performance and development. This literature review has discussed some of the individual qualities and knowledge required of effective teachers, it is important to consider what contributes to effective PD.

Guskey (2003) examined the characteristics of effective PD and found that the most common element was the enhancement of teachers’ content and pedagogical knowledge. High performing systems recognise the need for PD to focus on specific discipline skills especially in STEM-related subjects and in the move towards more student-centred learning (Marginson et al., 2013). Yoon et al. (2007) suggest that PD needs to be sustained, content-focused and directly related to improving teachers’ knowledge and instructional strategies. Studies have found that PD spread out over time tends to be more effective in changing teacher practice (Whitworth, & Chiu, 2015). Guskey (2003) states that effective PD and PCK enhancement needs time and resources and that it is "clear that time must be well-organised, carefully structured and purposefully directed" (p. 749). It should also be regularly evaluated for impact on teacher effectiveness and student achievement.

Teachers are more likely to adopt PD when they feel they have some ownership of it and motivation is increased when it builds on prior knowledge and aligns to personal interests and beliefs (OFSTED, 2010; Polly & Hannafin, 2010). Korthagen (2004) suggests an approach which focuses on the level where the teacher is at, making it relevant to their concerns and needs. Magnusson et al. (1999) advocate that teacher learning needs to be situated in meaningful contexts, that is, in the classroom using new strategies and technologies and it needs to be supported. Jones (2008) suggests that one of the best models for PD would be an in-school model which minimizes time away from the classroom, allows for meaningful collaboration and

is purposeful and addresses teacher goals. One model consists of cycles of collaboration, enactment and reflection, where teachers may use videotape, journaling and individual and collaborative reflection.

A report by Kamener (2012) suggests that an effective performance and development system would include: "objective, constructive feedback on individual teaching quality, gathered from multiple sources; […] clear development plans for all teachers; [and] effective professional development programs tailored to meet individual teachers' needs" (p. 2). A report produced by OFSTED (2010) about effective systems suggests that successful school leaders demonstrated a high level of trust in their staff and involved them in identifying and implementing improvements which led to positivity to change. Some researchers (Jensen, Hunter, Sonnemann, & Cooper, 2014; Jensen et al., 2016; OFSTED, 2010) in this area suggest the use of external, peer, self and student reflection and feedback for 360-degree performance management. Effective implementation of this would require effective reflection activities, support, collaboration, professional learning and initiatives using technology.

2.6.2 Reflective Practice and Video Technology

The conception of teaching as a reflective practice is widely embraced “the teacher is a reflective practitioner who continually evaluates the effects of his/her choices and actions on others (students, parents and other professionals in the learning community) and who actively seeks out opportunities to grow professionally” (Rich & Hannafin, 2009, p. 52). The reflection - action process is considered a highly effective dimension of a teacher’s development (Jones, 2008). Teachers can use reflection to consider what needs to change in their teaching and how to implement that change. Korthagen (2017) found that because teachers do not often have time for ‘action-oriented reflection’ they often skip the “deeper understanding of the meaning of the situation under reflection” (p. 395). It makes sense then to give teachers the time and opportunity for critical reflection on their teaching, allowing teachers to adopt reflective practices as a form of PD (Kayapinar, 2016).

In recent years, video technology has become prominent for use in pre-service teacher programs for modelling teaching strategies and observing practice. In a study conducted by Sherin and van Es (2005) teachers were prompted to analyse three aspects of their teaching videos: (a) student thinking, (b) the teacher’s role and (c) classroom discourse. It was found that

this provided teachers with an opportunity to develop their ability to notice and interpret classroom interactions. Harlin (2014) also found that it enabled pre-service teachers to "spot things" that they wanted to change in their teaching and this led to changed habits. Video can also be used to learn classroom strategies by watching others model them and it allows teachers to practice and evaluate their own use of the techniques (Chavez, 2007). Tripp (2010) and Tripp and Rich (2012b) state that there is limited research about how video analysis influences change but they suggest that video encourages change because it helped teachers to: a) focus their analysis; b) see their teaching from a new perspective; c) trust the feedback they received; d) feel accountable to change their practice; e) remember to implement changes; and f) see their progress.

Video technology allows teachers to reflect critically on their own and others' teaching and lead to changes in their beliefs and practices (Abell et al., 1998; Tripp & Rich, 2012a). Experienced and novice teachers can gain a deeper understanding of their teaching practice and knowledge and beliefs about teaching and learning (McCullagh, 2012). To bring about teaching reform, teachers need to come to an awareness of the changes required in their own teaching. "Video may support reflection and help teachers to reframe their experiences by challenging taken for granted assumptions and seeing opportunities for alternative approaches" (Loughran, 2006, as cited in McCullagh, 2012, p. 139). Researchers have found that through the use of video and guided reflection teachers became more aware of student thinking and the focus of their reflections changed (Eröz-Tuğa, 2012; Rosaen et al., 2008; Sherin & van Es, 2005; Tripp & Rich, 2012b; van Es, 2010). Through the use of video and reflection most teachers began to acquire targeted content knowledge and elements of a conceptual change orientation toward science teaching (Smith & Neale, 1989).

Video technology may also enable teachers to develop better reflection abilities (Blomberg, Sherin, Renkl, Glogger & Seidel, 2014). Video reflection activities have the ability to extend the quantity and quality of classroom observation and help teachers develop their observation, analysis and reflection skills (Marsh & Mitchell, 2014). Blomberg et al. (2014) found differences in the way that expert teachers reflect on their teaching compared to novices. Experts are able to reason about objectives or classroom situations that they perceive, whereas novices tend to describe what they see. One element which helped teachers to develop their reflection and noticing skills was the ability to slow it down, to review the video several times and share excerpts with others for collaborative discussion (Rosaen et al., 2008). Halter (2006) even found

that the effect of video analysis can persist over time and the video does not need to be used for every reflection task.

Korthagen (2004) points out that while there is an emphasis on reflection for teachers "it is not always clear exactly what teachers are supposed to reflect on when wishing to become better teachers" (p. 78). There is much consensus that change in teacher thinking is unlikely to occur without purposeful, systematic inquiry about one's beliefs and practice (Bryan & Recesso, 2006). However, the use of video analysis is often neither purposeful nor systematic and Bryan and Recesso suggest that the use of a lens (e.g., a rubric) enables users to focus on specific elements of the teaching/learning events. Griffin (2003) developed a written framework which focused on helping teachers, "(a) use the language of their profession; (b) connect theory to practice as they explain their practice; (c) connect their practice to the standards of their profession; and (d) describe how their reflection/analysis would affect their actions in the classroom and school community" (p. 208). Deaton's (2012) research found that the use of video analysis along with a reflection framework:

> … can be a systematic and purposeful methodology for examining ones' own teaching practice. Through self-awareness, […] teachers become aware of their own beliefs and knowledge about teaching and learning and the environment they create in their classroom. They can become aware of multiple factors that impact on their teaching practice. (p. 2)

Some researchers have discussed issues with the use of video in classroom reflection, including participants becoming overly self-critical of their appearance or voice rather than their teaching (Bryan & Recesso, 2006; Pailliotet, 1995). Eröz-Tuğa (2012) found that in the first feedback sessions with teachers using video they focused on things like tone of voice and body language and overlooked critical issues such as teaching inaccuracies and time management etc. However, by the second session teachers' reflections were much more expressive and accurate. For some, watching themselves on video may be confronting and stressful (Snoeyink, 2010). Others may be reluctant to engage in self-criticism at all or to reveal areas requiring development, particularly if they feel they are being judged (Bryan & Recesso, 2006). However, Coffey (2014) found that many student teachers watched their video more than once and found that the overall activity was a positive one: it was motivating, simple and helped with development and reflective skills.

Video technology has emerged as a useful tool to aid teacher PD through enabling teachers to critically reflect on and attend to their skills, knowledge and beliefs. For example, Townsend (2015) suggests an approach to use video-camera technology to records the entire 360-degree view of the learning environment in order to gather data on students and teacher reactions to instructional strategies. Teachers can then self-reflect on the data gathered with assistance from a rubric describing PCK components, leading to changes in thinking and practices. Polly and Hannafin's (2010) work suggests the use of technology for self-evaluation alongside peer evaluation to help teachers develop their knowledge and skills. Abell et al. (1998) also support self-reflection using video and state that it can be aided by peer reflection and collaboration. While much research has been done in the past about the use of video with pre-service teachers more work is required to look at its effectiveness with practicing teachers.

2.6.3 Professional Learning Communities (PLCs) and Video Clubs

Collaboration and Professional Learning Communities (PLCs)

Teachers can benefit from various PD experiences but one of the key factors for successful PD is the chance for collaboration (Yore & Treagust, 2006). Blomberg et al. (2014) also state that learning is a social process and much can be learned from a collaborative approach. This can be achieved through collaborating with teams from their own school or seeking out opportunities to collaborate with other like-minded teachers elsewhere (Johnson, 2009). Whitworth and Chiu (2015) state that PD is more effective when there is 'collective participation' which leads to change-focused discussions and conversations and holds teachers more accountable. A study conducted by Parsons and Stephenson (2005) found that during collaborative sessions a wide variety of aspects of practice were discussed from basic classroom strategies through to questioning, demonstrations and explanations. In 1996, Showers and Joyce found that not only did teachers enjoy the chance to collaborate but found it helped them to maintain the practice of new strategies and skills in their classroom. Since then it has been shown that one of the key agents for change and support is collaborative partnerships, however, lack of time for collaboration is one of the greatest barriers for teachers (Jensen et al., 2016; Johnson, 2006; Jones, 2008).

A report from OFSTED (2010) found that "across high-performing systems, learning communities have emerged as a cornerstone program for effective professional learning" (p. 33).

Professional learning communities (PLCs) are seen as a "means of supporting and improving teacher knowledge and skills leading to increased teacher efficacy for meeting students' needs" (Dogan, Pringle, & Mesa, 2016, p. 2). Dogan et al. defines a PLC as a group of teachers who "commit to a common vision of improving student learning, teachers work collaboratively to find solutions to problems of practices and improve their teaching practices, and teachers evaluate the success of their efforts to improve their pedagogy based on student achievement" (p. 2).

Dogan et al.'s (2016) review of relevant studies shows evidence that PLCs enhanced other PD programs and were effective on their own. It makes sense that forming collaborative teams or PLCs helps teachers to be more accountable for their change goals and enables a greater degree of reflection through discussion of their teaching and practice with others (Jensen et al., 2016). Participation in a PLC was linked with changes in knowledge and practice and particularly encouraged a shift towards more student-centred and inquiry-based approaches (Dogan et al., 2016).

Van Driel and Berry (2012) suggest that PLCs could be effective for developing teachers' PCK understanding. They found that PD aimed at the development of PCK cannot be purely an exercise of information input. They need to be closely aligned to professional practice and should include opportunities to enact and reflect, individually and collectively. Studies about PCK development (Kyle, Linn, Bitner, Mitchener, & Perry, 1991; McNicholl et al., 2013; Townsend, 2015; Van Driel & Berry, 2012) reflect the importance of forms of PD for teachers that are built on collaboration, collegial interactions, and the fostering of relationships. McNicholl et al. (2013) found that the opportunity for Science teachers to seek help from colleagues was seen as one of the most valuable forms of PD. "Being able to explain difficult scientific concepts to pupils lies at the heart of what is perceived to be good science teaching" according to McNichol et al. (2013, p. 165). Guskey (2003) adds, "Educators at all levels value opportunities to work together, reflect on their practices, exchange ideas, and share strategies" (p. 749).

It has been suggested that PLCs can be used to support other PD programs and on their own. In Finland there has been success in using PLCs for mentoring purposes, called Peer-Group Mentoring (PGM). This model is based on a constructivist view, using 'dialogue and knowledge sharing' to help both novice and experienced teachers to construct knowledge and benefit from support (Geeraerts et al., 2015). Dogan et al. (2016) also found that PLCs have a positive impact on affective characteristics, such as "confidence, self-efficacy, leadership skills, collegiality, a sense of accountability, change in culture of professional practice and empowerment" leading to

greater respect, trust and collaboration (p. 10). Ellis et al. (2017) suggest that teacher networks also help to reduce stress. However, Sherin and Han (2004) found that group members matter when putting together effective PLCs.

Video Reflection and Video Clubs

Over 10 years ago Rich and Hannafin (2009) found that collaboration was essential to reflecting on practice through video, as honest and objective self-evaluation can be difficultSome studies have used a "video club" PLC approach, where a group of participants, usually pre-service or beginning teachers, determined set objectives and then shared video excerpts to analyse and discuss. This was found to be immensely valuable and led teachers to gaining greater insights into their teaching and towards students' thinking (Sherin & van Es, 2005; van Es, 2010). Teachers who met with colleagues and peers to discuss their video felt that viewing and discussing their videos were the most valuable components of their PD (Borko et al., 2008; Tripp & Rich 2012a). Group discussions about video-aided reflection helped teachers to clarify, examine and challenge their teaching assumptions and practices and resulted in optimal learning (Grainger, 2004; Miller, 2009; Thomson, 1992).

This early work shows that collaborative video analysis not only allowed alternative views for reflection but also allowed teachers to share what they do in the classroom and learn from each other (van Es, 2010). Sherin and Han (2004) suggested that a video club model may provide an agent for reform as it changes the focus of discussions and improves colleagueship by developing support and trust (Sherin & Han, 2004; Tripp & Rich, 2012b).). This was explained as "Teachers repeatedly appreciated the input of their peers, supervisors and colleagues" (Tripp & Rich, 2012b, p. 684). However, bringing groups together for this purpose requires time and works best when there is a facilitator and shared goals (Borko et al., 2008; Rich & Hannafin, 2009; van Es, 2010). Further studies are required to investigate the role potential of video-club PLCs with experienced teachers. Townsend (2015) also makes another suggestion for the use of video reflection and video-clubs to help connect teachers in remote and regional areas. These virtual PLCs may allow such teachers to participate in effective PD activities.

The main focus of the current study is the trialling of a method of teacher PD which may help teachers to reflect on their teaching choices, knowledge and skills and therefore better develop their teaching. The research regarding video-based reflection and the establishment of

PLCs in the form of a video club provides strong evidence for their benefits and will be used during this study to help teachers notice their behaviours and consider their beliefs, knowledge and skills and better target their own growth and development. Throughout this work the terms PLC and video club will be used interchangeably to discuss this aspect of the study.

2.7 CONCLUSION

A report from the Office of the Chief Scientist (2014) suggests that

> Quality teaching is the key to lifting student engagement and performance in STEM education. Teachers need to be equipped with the skills and confidence to support STEM learning. The rapidly changing nature of technology, and the importance of real-world approaches to science education makes this particularly challenging. (p. 8)

School science education is important in influencing young people to become economically productive science and technology specialists, producing scientifically literate and informed members of society and, perhaps most importantly, instilling a love of learning about the world around us. The main goals of science education indicate three main interrelated approaches; namely scientific literacy; teaching about the nature of science; and an inquiry-based approach. The drivers of curriculum policy come from current research and are based on international trends and a constructivist perspective. The Australian curriculum is designed to allow teachers to implement relevant student-based effective pedagogy. However, there is some criticism that it is too broad and alongside national testing places undue pressure and work on teachers.

Effective teaching has been suggested to be student-centred, inquiry-oriented and placed within contexts which are relevant, interesting and applicable to students. Within these broad pedagogical directions, there are many strategies which can be incorporated as ways to reform teaching to match up with the best-practice vision. This study focuses on models of effective teaching skills and knowledge based on PCK. The ideas about PCK as first suggested by Shulman (1986) and further refined by Magnusson et al. (1999), Park & Oliver (2008), Kind (2009), Townsend (2015) and others have been used to synthesise an effective teaching framework to guide teachers' reflection and help them to develop and change their teaching. This conceptual framework is shown in Figure 2.1. It combines components of PCK and the Australian Institute for Teaching and School Leadership (AITSL) standards for teachers (AITSL, 2013).

In order for teachers to feel confident and see a need for changes, they must have experiences that change their beliefs about their own teaching and what works. This can be achieved through effective PD, which allows time for reflection and collaboration. It is the researcher's belief that if teachers were to use video technology to record, analyse and reflect on their own teaching using PCK as a 'lens' this would enable them to notice things in their own teaching which are effective or need to change. This would be most effective if teachers were to form a PLC allowing for collaboration and discussion.

The benefits of video technology in a reflection-action process seem to be numerous, as it has been shown to help teachers develop better 'noticing' and reflection skills. Teachers have found that they become better at focusing on student interactions and thinking, and therefore implement more student-centred activities. By becoming aware of what works and where they could improve, teachers can set goals using a PCK framework and monitor their improvement. Teachers do not necessarily need to make large-scale pedagogical change to become more effective but can begin with changes to just a few elements making up effective PCK with full-scale development seen through the fluid and holistic movement through the elements of PCK in-the-moment. Through experiencing and observing success and progress with some strategies they may feel more confident to develop these into larger-scale change and see the value for their students.

In the next chapter, the method used in the implementation of a PD initiative utilising video technology and a video club to help a group of practising, experienced Science teachers is presented. The research questions and study rationale are discussed in greater detail and the qualitative, participatory action research and case study methodology used is considered. The participants and school setting are described along with the methods of data collection, including the video club process used. Ethical considerations involved in such a study and the limitations, validity and reliability are also described.

Chapter 3: Research Design

The Literature Review in Chapter 2 clearly shows that teachers, particularly in STEM areas, face pressure to achieve improved student outcomes and embrace innovative teaching strategies. This requires that teachers develop a range of effective, integrated pedagogical and content knowledge skills as outlined in the PCK-based Teaching Conceptual Framework, which is based on work done by Shulman (1986), Magnusson et al. (1999) and others (Kind, 2009; Park & Oliver, 2008; Townsend, 2015). In order for teachers to develop an understanding of what is required in their teaching and thus change their beliefs and behaviours they need access to effective, personalised PD which focuses on developing reflective practice and supports individual goals (Kamener, 2012; Polly & Hannafin, 2010; Yoon et al., 2007). Self-tracking video use and collaborative discussion through PLCs, known as a 'video club' is seen as one such process with the potential to help teachers reflect on, analyse and make changes in their practice (Abell et al., 1998; Bryan & Recesso, 2006; Chavez, 2007; Deaton, 2012; Eröz-Tuğa, 2012; Rosaen et al., 2008; Sherin & van Es, 2005; Smith & Neale, 1989; Tripp & Rich, 2012a; Tripp & Rich, 2012b; van Es, 2010).

This chapter gives an overview of how a qualitative, ethnographic case-study methodology was used to evaluate the use of a video club process alongside a PCK-based teaching framework to enhance teacher reflection and PD. It gives an overview of the theoretical underpinnings of the methodology used as well as information about the context, participants and tools. The analysis, ethical considerations and limitations are also discussed.

3.1 STUDY RATIONALE

This study sought to explore and understand individual experiences rather than confirm or test hypotheses. The thinking and rationale behind this research project are shown in Figure 3.1. The thought processes and aims which led to undertaking this study help to understand the theoretical underpinnings and methodological choices made in this study. It shows the subjective thought processes that anchored the rationale, guided the research questions and identified data to inform the study. The subjective driver for the study was a personal desire to understand how to be a 'better teacher' and the assumption that all teachers 'want to improve and be better at what

they do.' This can be achieved by gaining insights into the behaviours, skills and insights that characterise excellent science teachers. To have practical value the researcher recognised the benefits of situating the investigation within a 'real world' setting and using a video club model of collaborative professional learning as an organising framework for teacher development.

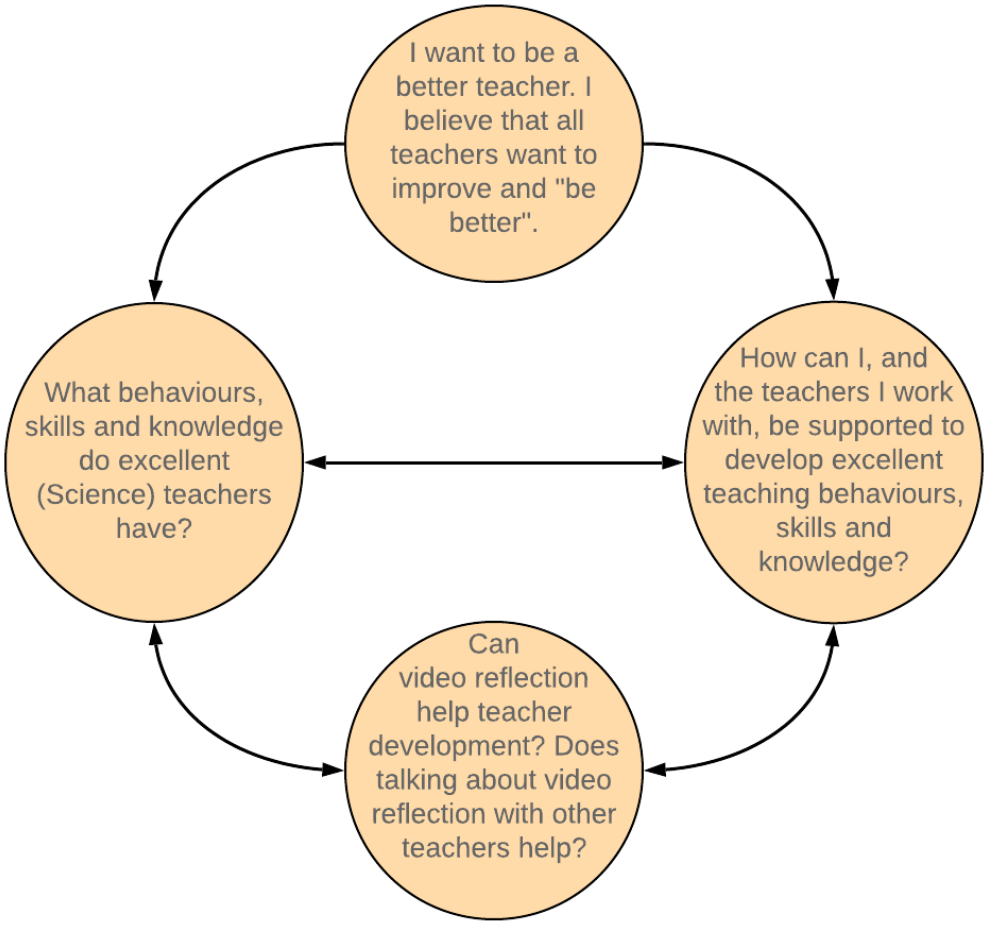

Figure 3.1. Beliefs and thought processes leading to the study rationale and theoretical approach used.

3.2 RESEARCH QUESTIONS

The following questions sought to address the aims of the study as outlined in Chapter 1.

1. How useful is a video club model and pedagogical content knowledge (PCK) - based teaching framework as a means for professional development and teacher capacity building for practising, experienced teachers?

2. In what ways have practising, experienced teachers changed their beliefs, thoughts and behaviours, and teaching practices through the use of a PCK-based teaching framework and participation in a collaborative video club model of professional development?

3. What can be learned about effective teaching skills and knowledge through experienced teachers' participation in a collaborative video club?

3.3 RESEARCH APPROACH

Based on the rationale outlined in Figure 3.1 and the Research Questions, particular theoretical and methodological approaches were used. The paradigm used for this study was an interpretivist, qualitative design. A qualitative paradigm was chosen because teacher effectiveness is highly complex and what is considered 'good' is multidimensional, highly varied, situated and subjective and cannot necessarily be measured by numbers of particular behaviours or actions, or through student achievement. Teacher effectiveness is made up of several components, most of which are subjective and will be different for individual teachers in different contexts. Qualitative research takes the view that reality is constructed by individuals within their own context, and qualitative researchers seek to understand that meaning and individuals' experiences. They are interested in the insider's perspective and are concerned with process rather than simply outcomes or products (Bogdan & Biklen, 1997; Merriam, 1998).

In order to learn about participants' thoughts and feelings, an embedded ethnographic approach was considered suitable as it employs a strong focus on exploring the nature of a social phenomenon, as opposed to testing a hypothesis. Ethnography, an approach used in qualitative research refers to the study of social interactions, behaviours, and perceptions that occur within groups, teams, organisations, and or communities (Anderson, 1989; Gordon, Holland, & Lahelma, 2001; Lichtman, 2010). The aim of ethnography is to provide rich, holistic insights

into people's views and actions, as well as their context through the collection of detailed data (Creswell & Miller, 2000; Hitchcock, Hitchcock, & Hughes, 1995; Lichtman, 2010). Hence, ethnographic data consists of rich, thick descriptions of the researcher's observations, participants experiences and is often presented in the participants' own words (Merriam, 1998). Data analysis in ethnographic research involves explicit interpretation of the meanings and functions of participants' actions, speech and interactions (Creswell & Miller, 2000).

Alongside the ethnographic approach, the researcher integrated a Participatory Action Research (PAR) approach. Bogdan and Biklen (1997) explain PAR as research that is done on a program with the researcher and participants collaborating for the purpose of improvement. It is believed that this type of research helps to develop confidence and allows people to understand themselves better, increases awareness of problems and raises commitment (Hitchcock et al., 1995; Lichtman, 2010; Seale, 1999). Action research is often used to identify real-world, practical problems and tries to develop and validate solutions to them. The methods tend to emphasise collaboration and research within the workplace and what is learnt is put to immediate use (Willis, 2008). Webb (2000) states that action research includes projects undertaken with the view to improving education-related experiences for students, teachers, the extended school community or the wider community.

Although their roots are different, the compatibility between ethnography and PAR has been demonstrated by their use in educational research for many decades (Hitchcock et al., 1995; Gordon et al., 2001; Lichtman, 2010). Their compatibility is confirmed in so far as both approaches place participants' perspectives as central to the research, both utilise qualitative methods primarily, and both are respectful of the groups they work with. Further, when these approaches are combined each adds something important to the other. PAR gives ethnography a posture for doing research that is more democratic and action-oriented than traditional ethnography (Lichtman, 2010; Seale, Gobo, Gubrium, & Silverman, 2004). Ethnography provides PAR authenticity as a research approach. However, the differences between these approaches cannot be overlooked; for instance, ethnography is fundamentally oriented towards cultural analysis whereas PAR pursues activism as its fundamental orientation. In this study, the researcher believed that combining these approaches could strengthen the study for the reasons outlined above.

In all forms of qualitative research, the researcher is the primary instrument of data collection and analysis (Merriam, 1998; Suter, 2012). In this case, having the researcher as an

embedded participant, it allowed greater understanding of contexts, background and relationships as well as greater sensitivity to participants' thoughts, feelings and needs, the processes involved and support required. It also enabled on-going data collection and analysis. The chosen methodology described in the following sections aligned with the rationale and the qualitative approach that drew on both ethnography and PAR.

3.4 RESEARCH METHODOLOGY

In keeping with the principles of ethnographic PAR, a case-study design was employed to conduct the research. Willis (2008) reports that a case study allows the researcher to take a holistic approach to studying a phenomenon in its natural setting. According to Yin (2014) "A case study is an empirical inquiry that investigates a contemporary phenomenon (the 'case') in depth and within its real world context, especially when the boundaries between phenomenon and context may not be clearly evident" (p. 16).

Case study research is often conducted to identify or find solutions to specific issues and problems of practice (Merriam, 1998; Lichtman, 2010; Hitchcock et al., 1995). In this study, the issue was how to best support teachers in increasing their STEM teaching capabilities and practices. Merriam (1998) points out that a case study "is a particularly suitable design if you are interested in process" (p. 33). This involves monitoring and describing both the context of the study and the implementation of a particular program or process, as was done in this study. Merriam (1998, p. 27) states further that a case is "a single entity, a unit around which there are boundaries" and may be selected due to a particular concern or hypothesis surrounding it. The case used in this study was the implementation of an innovative PD program within a secondary school Science teaching department which involved six individual teachers who serve as sub-cases.

Yin (2014) points out that for case studies some theory development as part of the design phase is desired. In this case, prior research and understanding of PCK and aspects of effective teaching, as well as the use of video reflection and a video-club model, were used. This background research influenced the questions asked, observations made and the way data was analysed. As Merriam (1998) suggests "our analysis and interpretation-our study's findings-will reflect the constructs, concepts, language, models, and theories that structured the study in the first place" (p. 48).

Interpretive case studies contain rich, thick descriptions which are used to develop conceptual categories or extend the theoretical ideas held prior to data gathering. These can be used to inform further qualitative or quantitative studies. “Case studies can bring about discovery of new meaning, extend the reader’s experience, or confirm what is known,” according to Merriam (1998, p. 30). Merriam explains further that a case study design can also be used in order for those involved to gain insight about a process which can directly influence practice as well as future research.

3.5 THE SETTING, PARTICIPANTS AND RESEARCHER

3.5.1 The research setting

This research was conducted within a Western Australian independent K-12 school where the researcher worked as the Science Department Head of Learning Area. The ethical considerations associated with this context are discussed in a later section. This setting was chosen as the researcher sought to bring about gains for the individual teachers working within the department and the team as a whole so that they may be more willing and able to implement ‘best practice’ teaching methodologies.

The department was well resourced in terms of finances, textbooks, practical resources and ICT. Some of the goals of the department in the previous years had been to implement more inquiry-based activities, improve literacy for science as well as scientific literacy and incorporate ICT and STEM activities. The school improvement plan during the study focused on the improvement of teaching and learning, with Assessment for Learning (Black & Wiliam, 1998) being a key area of PD at the time of the study. Throughout the study, the department was facilitated with time and provision of teacher relief for teacher-participants to meet and work collaboratively as a means of PD, which also facilitated data collection.

The secondary school (Year 7 to 12) had student numbers of approximately 260. This allowed small class sizes of no more than 26 students in Year 7 to 10 and an average of approximately 10 students in senior science classes. Post-compulsory (Year 11 and 12) science classes offered were Chemistry, Physics, Biology, Human Biology, Integrated Science and

Psychology. The school had a high engagement with science, with nearly all students participating in at least one science course in post-compulsory years and many choosing two or three sciences. Anecdotally, students reported seeing the value in studying science with a high proportion going on to study science-related courses at a tertiary level. Students across all year levels had a high level of achievement as seen in standardised testing and competitions, national and state achievement standards and the rigorous programs delivered.

3.5.2 Participants

This study used non-random, purposeful sampling (also called judgement sampling) (Palinkas et al., 2015; Suter, 2012). Following the researcher's decision about what the study sought to explore she identified the individuals in the Science department of interest as potentially representing information-rich cases, and canvassed their willingness to participate following an ethics approved recruitment protocol (described later). A Total Population Sampling technique ("Total Population Sampling," n.d.) was deployed, involving the entire population (i.e., six teachers including the researcher), all of whom met the criteria of being experienced secondary school Science teachers. The Total Population Sampling technique was feasible given the small number of individuals employed in the Science department, and their expressed willingness to participate.

Teachers in the Science department were identified as proficient and well-informed with the phenomenon of interest, deemed willing to participate in the study and communicate their experiences and views. The teachers represented a range of specialist science teaching areas and years of experience. The teacher-participants had worked together as a team for approximately 10 years and on average had approximately 17 years teaching experience. They regularly worked collaboratively and enjoyed professional discussions about teaching strategies, goals, activities, students' misconceptions and their own difficulties. They viewed their participation in the study as advancing the ways in which they worked as a team. Prior to the study they met formally twice per term but they also shared an office space allowing informal discussions on a daily basis.

Following an ethics approved research protocol the teachers were formally invited to participate in the study and provided with full details of what was involved and their rights and expectations, which complied with the standards as outlined in the Ethics section (see Appendix B). Respectful of the sensitivity when working with video data, in this study the researcher

facilitated the gathering of video data but the participant-teachers had control over its use and it was made clear that it was not to be used for purposes other than their own reflection. In reporting and presenting data, codes and pseudonyms were used to protect participant privacy; any information which may allow teachers to be identified was omitted where possible or permission was gained from the teachers involved.

3.5.3 The researcher

The researcher is a secondary Science teacher with over 15 years teaching experience. She has worked in the Science department under study for 10 years, at least 5 of those as the Head of Learning Area. The researcher had developed excellent communication and supportive relationships with all members of the department. The teacher-participants felt comfortable and confident to make suggestions, ask for help and discuss issues with each other and with the researcher. The researcher regularly led team meetings and professional development sessions and had the experience required to lead the discussion sessions, having gained the trust of the team members allowing encouragement and modelling of the process. The researcher shared an office with the majority of team members and was well placed to make observations and provide support in implementing the process.

3.6 DATA COLLECTION METHODS AND RESOURCES

Data collection occurred over three school terms. Overall there were five data sources which consisted of responses to an initial questionnaire, three video club meeting transcripts and responses to a final questionnaire as well as observations. In this section, the specific data collection techniques and instruments will be described. An overview of the activities and timeline is shown in Figure 3.2.

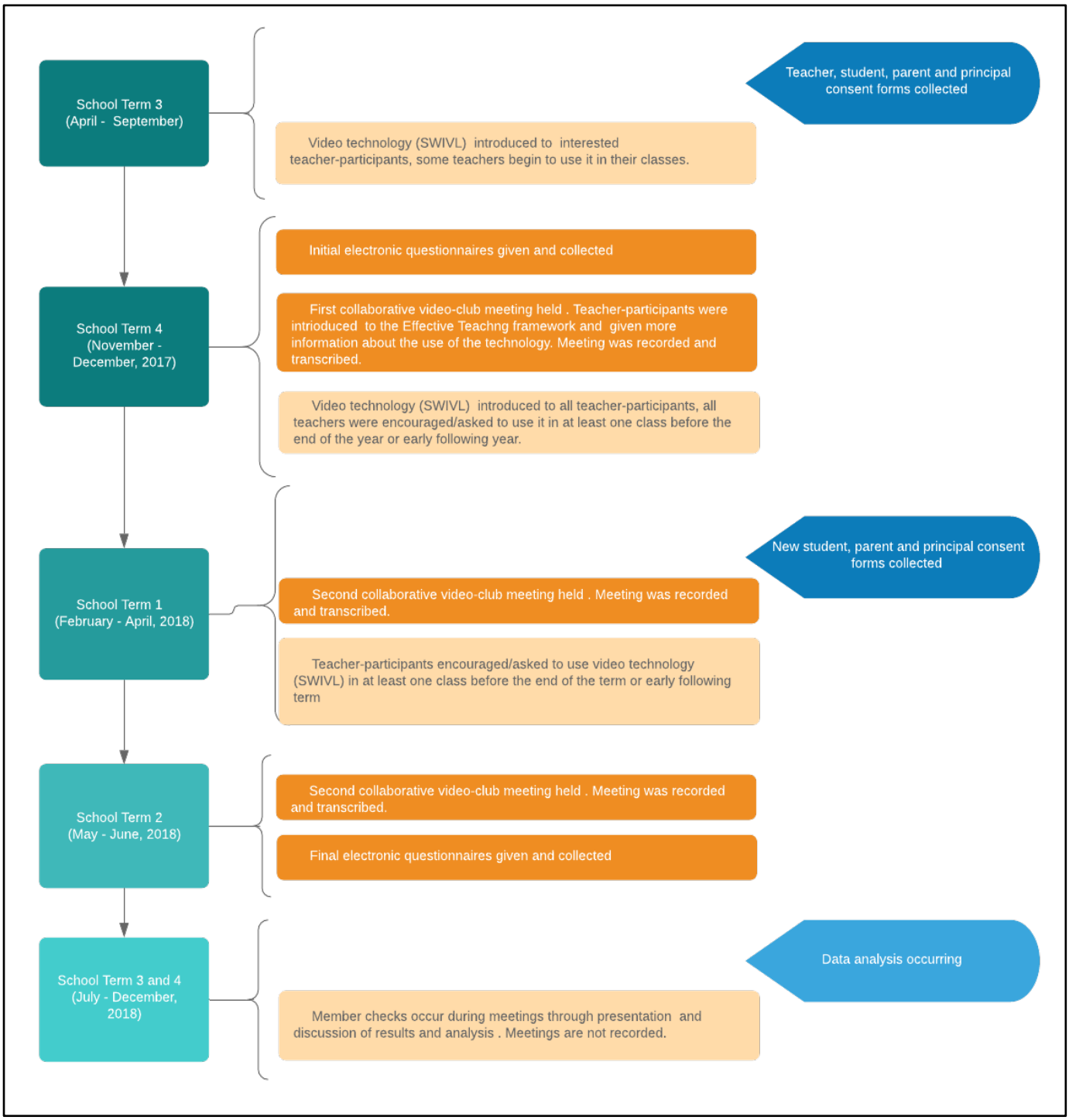

Figure 3.2. Timeline of data collection activities.

3.6.1 Resources and Instruments used

Resources (details found in Appendix C)

- SWIVL device and software
- iPad
- Audio recording equipment
- Portal for dissemination of questionnaires

All data was stored electronically on a secure password protected computer.

Data Collection Instruments

- Initial electronic self-administered questionnaire (Appendix D).
- Final electronic self-administered questionnaire (Appendix E).
- PCK-based teaching framework (Appendix A)
- Optional reflection proforma (Appendix F)

3.6.2 Data Collection Techniques

Initial questionnaire

Teacher-participants completed a pre-study self-administered electronic questionnaire. Questions were designed to gather background and contextual information. It also sought to find out what the teachers thought constituted good Science teaching as well as what they knew about PCK and their thoughts about their own teaching. The responses were automatically collated into an electronic spreadsheet by question and respondent allowing the researcher to gain insight into the responses of each participant as a whole but also to capture all of the responses to a particular question.

The questions were as follows:

Age
Years of teaching experience
Qualifications
Year levels taught
Specialist areas
Q1. In what areas of your teaching do you feel most confident? Explain.
Q2. What do you think good science teachers do?
Q3. What skills and knowledge do good science teachers need/possess?
Q4. What strategies do good science teachers use?
Q5. What do you think sets expert or very accomplished science teachers apart from others?
Q6. What areas of your science teaching would you most like to improve?
Q7. Have you been exposed to the concept of Pedagogical Content Knowledge (PCK)? If yes, what do you know about it and its use?

Video Club meetings

The main data collection during the study came from transcripts of recordings of three PLC sessions, or video club meetings. These meetings occurred over three school terms as shown in Figure 3.2, each meeting was audio-recorded and transcribed, with the data then securely stored on a password-protected computer. During background research, a PCK-based teaching framework (Figure 2.1; Appendix A) was devised for use by participants when considering their teaching as well as by the researcher when guiding video club discussions and analysing results. A reflection guide (Appendix F) was also provided based on this framework. Use of the reflection form was optional and not collected as part of the data but merely used to guide teachers' thinking and inform discussion points. Between each meeting, participants were encouraged to use the self-tracking video technology in at least one of their classes with support from the researcher, video data remained private to the participants. During the video club meetings, observations and memos were also noted by the researcher.

The discussions were unstructured and free-flowing, using open-ended questions and prompts by the researcher, guided by the PCK-based teaching framework, to elicit feelings about the video-club process and encourage teachers to elaborate on their reflections and observations

about their teaching. Bogdan and Biklen (1997) state that this type of open discussion encourages participants to talk openly about their perceptions, feelings and beliefs and allows them to determine the content and direction of the discussion which can lead to unexpected ideas, points and links. This strategy suited this study well since the open-ended questions fitted the purpose of encouraging participants to express their thoughts freely and to interact openly. Some initial coding occurred as each data source became available, providing some direction for subsequent meetings.

The purpose of the first meeting was to discuss expectations and demonstrate how the technology worked. The PCK framework was introduced and the video club discussion aspect was modelled, with teachers sharing how they felt about the process. In the second meeting, the participants were encouraged to take turns to discuss their reflections, observations and thoughts about the self-tracking video use and their teaching which often led to whole-group discussion about pedagogy and students. The third meeting encouraged participants to discuss their final thoughts and reflections. Of particular interest was the perceived benefits and usefulness of the process.

Final questionnaire

Teachers completed a final self-administered electronic questionnaire which asked them to evaluate the video club process and its professional learning value as well as their thoughts about effective teaching. The questions were designed to assess how the participants felt about each of the aspects of the process as well as its potential use in the future. It also aimed to find out if participants' thoughts about effective teaching and their own teaching had changed. Questions were based on background research, research questions and preliminary analysis of the initial questionnaire and meetings. Again, these results were collected and collated digitally in a spreadsheet format and stored securely by the researcher. Data from the final meeting and questionnaire were coded alongside previous data.

The questions were as follows:
Q1. After watching and reflecting on yourself teaching a number of times, how did it make you feel? What thoughts did you have? What did you learn or notice from watching yourself teach?
Q2. How was the experience of watching yourself teach? As an overall experience, was it positive or negative?

Q3. After taking part in the series of collaborative discussions about the use of video reflection, how did it make you feel and what thoughts did you have? What did you learn?
Q4. Was participating in the collaborative discussion sessions an overall positive or negative experience?
Q5. What are your thoughts about the use of a video club model as a form of professional or performance development?
Q6. Did any of the discussions, observations or reflections surprise you? Explain.
Q7. Can you suggest any changes or improvements to the use of the video club model and PCK as a form of PD to make it more useful?
Q8. The Pedagogical Content Knowledge (PCK) framework helps to outline what teachers do and know, how did this framework impact on your reflections on your teaching and what effective science teachers do?
Q9. Have your thoughts about effective science teaching changed? If so how?
Q10. How do you think these experiences of videoing, reflecting on and discussing your teaching have changed your teaching and personal goals?
Q11. Any other thoughts?

Members Checks

There were some other unrecorded meetings towards the end of the second school year after all data had been transcribed and data analysis was being completed. Here the researcher presented findings of the emerging themes and possible representations of the relationships between them. The participants were encouraged to give feedback about the findings and all confirmed the themes identified and the emerging links and conclusions. Observations and thoughts were noted and the meetings served as member checks and for triangulation purposes.

3.7 CODING PROCESS AND ANALYSIS

3.7.1 Data collected

The final set of raw data consisted of an electronic spreadsheet containing all participants' responses to the initial questionnaire as well as a similar spreadsheet for the final questionnaire. The three audio recordings of the video club meetings were hand transcribed and tabulated with times and codes for the participants/speakers by an external transcription service and checked for accuracy by the researcher. Some notes and observations made by the researcher throughout the study were also used.

After the collation of the initial questionnaire and the first meeting transcript, data analysis began and then as each new data source was collected, further refinement of the analysis took place. This technique is called constant comparison; Anderson (2010) states that this allows the researcher to treat the data as a whole and for emerging and unanticipated themes to be identified.

3.7.2 Open content analysis

Open coding took place as each data source was read carefully identifying repetition of ideas, words and phrases. Longer responses in the questionnaires and during discussion required interpretation to identify key ideas, as recommended by Bogdan and Biklen (1997). These repeated ideas, words and phrases became the initial coding categories. This allowed the researcher to begin to identify broad themes. As each new set of data came in, the same process was followed to identify areas which consistently came up as areas of reflection, discussion, tension or importance (Bogdan & Biklen, 1997).

A series of spreadsheets were developed with one for each emerging theme. Short sections of the coded dialogue and questionnaire responses were extracted so that the overall context and meaning remained intact as much as possible (Dey, 2003). Each of these chunks of data could be thought of as a "databit" (Dey, 2003, p. 9). The databits along with their associated information such as the speaker, timestamp, keywords and all codes allocated to it, were placed into each of the relevant spreadsheets according to the codes or themes allocated to it. In doing so most databits were placed in multiple spreadsheets.

An iterative inductive approach was used to look for overlaps and redundancies as well as commonalities alongside the PCK-based teaching framework used. This allowed for the themes to be narrowed down into a final list of conceptual categories. Analysis of the content of each spreadsheet allowed a description of each theme to be built up. These were compared against background research described in Chapter 2 and the PCK-based teaching framework. By placing participant quotes in the spreadsheets in longer form with meaning intact allowed a fuller picture of the feelings and thoughts of the participants about each theme to be constructed. This suited the ethnographic, case study methodology of this study and its research questions.

3.7.3 Axial coding

Further analysis was conducted to begin to identify relationships between the themes and their categories. Open axial coding aims to look for hierarchies, causal relationships and other links between themes in order to expose deeper issues and build up a broader idea of the interactions at play (Bogdan & Biklen, 1997). This was done by further analysing the databits and exploring how they overlapped or linked across different themes. Careful reading and interpretation of the data within themes and categories enabled the researcher to distinguish common feelings and thoughts of the participants. Relationships were identified where certain ideas or themes were often referred to together and this was also true where relationships were not clearly seen. It was also possible to see clear causal links through participants' responses in the final questionnaire.

This study used qualitative methodologies to build a picture of how the participants felt about the initiative being implemented and evaluate its usefulness. Coding and analysis were also employed to explore elements of effective teaching. In order to evaluate changes in the focus of the discussions and judge the importance of the elements of effective teaching, some numerical analysis was undertaken. This technique was discussed by Dey (2003) as shown below.

> It may seem strange, in a qualitative analysis, to introduce numbers as a means of data reduction. However, whenever we make a qualitative judgement about the data by assigning a category to the data, we also create numerical data. For we can enumerate the qualitative decisions we make and relate them to the cases we are analysing. We can count the number of times we have assigned any category to the data. Only prejudice

> would prevent us from using this information if it can help us to identify patterns within the data. (p. 207)

It was possible to use the number of databits assigned to each theme to give a picture of how frequently participants referred to each theme, both overall and in each data source, and thus give a potential indication of its relative importance. This was particularly important when looking at how participants' thoughts and feelings changed over the course of the study. However, it was recognised that due to the nature of the study the information gained from this was limited.

3.8 ETHICAL CONSIDERATIONS

Ethics approval was granted by the ECU Human Research Ethics Committee.

3.8.1 Informed consent and approval

This study involved voluntary participation. Teachers within the department to be studied were verbally invited to participate and information was provided about the purpose and use of the study as well as expectations and the use of data (including ownership of video and audio collected). A teacher information letter and invitation to participate, containing ethics details, was provided which was signed and collected (see Appendix B).

Additional considerations were included because although the focus of the videos was the teachers, students were also included in the videos. Thus, prior to data collection permission was sought from all students and their parents or guardians (Appendix G). Participation was voluntary and any students who did not give written informed consent were moved to a location in the classroom where they would not be filmed, allowing normal classroom activities to proceed uninterrupted. In most cases filming only occurred in classes where consent had been provided for all students. All permission forms were collected and collated by the researcher who provided electronic lists to individual teachers to see which students had permission and which did not. All forms were filed and locked away securely.

This research took place in an independent school so informed consent was obtained from the school principal at the beginning of the study and from the new school principal mid-way through the study (Appendix H).

3.8.2 Risk concern

Teachers who elected to participate had the right to withdraw at any time. It was made clear through discussion and modelling that the purpose of the study was not one of judgement but rather to provide an opportunity for growth of the teachers involved. The process was modelled and supported by the researcher who was also a participant to demonstrate the safe, non-judgemental nature of the activity.

Merriam (1998) suggests that interviews and open discussion carry with them the risk of participants feeling embarrassed and compelled to reveal things they may not like to, which may have long-term effects. However, it is also suggested that it may be a positive experience, where they gain valuable self-knowledge. “Most people who agree to be interviewed enjoy sharing their knowledge, opinions, or experiences” (Merriam, 1998, p. 214). During this study, open discussion was encouraged and there was a risk that participants may have felt uncomfortable; however, the researcher was sensitive to this and the results suggest that this was not the case.

Because the researcher was the line manager of the participating teachers, there was the possibility of some perceived power issues, however, this does not seem to have negatively influenced the findings and will be discussed further in the limitations. The researcher closely followed the guidelines in the National Statement 4.3 (The National Health and Medical Research Council, 2018) referring to people in unequal relationships. The researcher was able to ensure the reflective, capacity-building purpose and voluntary nature of the study was understood. Some teachers felt discomfort with the techniques to be used particularly the use of video of their own teaching. However, given time and modelling of the video reflection process by the researcher, within a safe environment all teachers involved became willing to try it and enjoyed the experience.

3.8.3 Privacy

The small nature of this study in this setting did bring some ethical considerations to do with privacy which were difficult to control. While attempts have been made to protect participants' privacy and confidentiality and to preserve the anonymity of participants through the use of pseudonyms and the removal of identifying information from reported findings, identification may be possible for those close to the school setting. Merriam (1998) explains, "At the local level, it is nearly impossible to protect the identity of either the case or the people involved" (p. 217). It was widely acknowledged by the participants and other school staff that the process was one of growth and support rather than assessment and so the risk was judged to be low in impact, with little to no harm to participants. In addition, every attempt was made to present results accurately, using member checks, with an effort to protect privacy and to maximise the benefits for participants as suggested by Merriam (1998).

The guidelines for using video in classroom research developed by the Edith Cowan Institute for Educational Research was closely followed and the researcher explained how the video data was to be used. The participants had the option of recording their classes using their own device (iPad), with the intention that video footage remained private to the teacher. However, all participants opted to have class recordings captured on the researcher's device and at the conclusion of a filmed lesson the researcher downloaded the video footage from the SWIVL platform and transferred it to a secure location to be shared with the teacher. The original footage was deleted from the iPad and SWIVL software/cloud. This was done with the participants' consent and the privacy of the footage was respected and maintained.

All documents and data collected during the study were stored securely in a digital or hard-copy form by the researcher at all times. Classroom video was kept securely by the individual teacher with the understanding of its intended use. Data transcripts were thoroughly checked by the researcher to ensure accuracy and the online method of questionnaire collection ensured that responses were accurate and kept with the correct participant.

3.9 RESEARCH LIMITATIONS AND TRUSTWORTHINESS

Webb (2000) states that PAR, such as this study which are aimed at improving education-related experiences, has limitations due to their reliance on subjective judgements, risk of bias

and being context specific. The goal of qualitative research is not generalizability (Hitchcock et al., 1995; Seale, 1999) instead the focus is on possible transferability to other similar settings by providing details about the context. In this section, the limitations and delimitations of the context and research design are described. A discussion of potential sources of bias and issues regarding the trustworthiness of the data collected is undertaken.

3.9.1 Limitations and delimitations

This study was undertaken within a specific setting which places limitations on the scope of the findings. The case-study nature of the research involved a small sample size and involved participants with particular relationships and expertise within a particular school setting, all of which placed limitations on the nature of the findings. The delimitations placed on the study included the involvement of participants who were experienced, secondary school Science teachers teaching in a small regional independent school. The involvement and relationships with the researcher will also have influenced the group and findings due to the position of perceived power of the researcher to the rest of the group.

A limitation also exists in the nature of the data collected and the timing of the study. The data was collected within three school terms, which is a relatively short time period to assess real and lasting behaviour and pedagogical change. Also, the data collected only assessed how teachers felt about their teaching strategies and skills, based on self-observation and reflection. It did not measure their skill level, effectiveness, student engagement or achievement. However, these issues could form the basis of future studies.

3.9.2 Bias

The risk of bias was high due to a number of factors. Participants may be biased both positively and negatively when reflecting on and evaluating their own teaching. Collaborative discussion sessions may have reflected some bias due to the small, close-knit nature of the group and the supportive, positive relationships developed. Finally, the pre- and post-questionnaire data may have represented bias due to teachers wanting to present positive responses perhaps due to

the perceived power difference of the researcher but more likely due to the close, positive relationships between participants and the researcher.

The relationships formed may also have influenced the objectivity of the researcher during discussion sessions and analysis, as explained by Merriam (1998), “Because the primary instrument in qualitative research is human, all observations and analyses are filtered through that human being's worldview, values, and perspective” (p. 22). To minimise bias, participant voice was used in addition to researcher observation. Participants were encouraged to discuss the process openly and honestly and these discussions were used for analysis. Member checks, where the emerging results and findings were presented to the participants, were also conducted as part of the collaborative discussion sessions and at the end of the study.

3.9.3 Issues of trustworthiness

In such a qualitative study, reliability and validity are more aptly discussed as trustworthiness, credibility and dependability (Creswell & Miller, 2000; Hitchcock et al., 1995; Lincoln, & Guba, 1986; Seale, 1999). These were addressed through the research design of using ethnographic, PAR and the use of a number of participants to form a ‘case’ and the collection of multiple sets of data over time in order to build up a set of comprehensive and reliable findings.

Most researchers agree that issues to do with validity such as trustworthiness and credibility is a strength of qualitative research, particularly ethnographic and PAR designs, as the researcher’s observations and data is closer to reality than would be the case if a quantitative measure is used (Merriam, 1998). In this study, the use of discussion transcripts and the researcher’s observations alongside questionnaire responses improved the trustworthiness of the findings. PAR and the embeddedness of the researcher allowed an insider-perspective and elicitation of in-depth understanding of the participants’ thoughts, feelings and changes throughout the study.

As discussed, the reliability of a qualitative case-study is not important as the goal is not generalizability. Reliability refers to whether the findings can be replicated, this is difficult in studies such as this due to the changing nature of human behaviour and interpretations of the reality of a situation (Merriam, 1998, p. 205). The findings are limited to the setting where and when the research was conducted and therefore while it may be possible to replicate some of the

findings it will be dependent on the particular context. It is suggested that researchers produce working hypotheses as a guide for others in similar situations (Merriam, 1998). In this case, details of the context and methods are given in order to leave the generalizability to the reader to decide the findings' transferability.

3.9.4 Triangulation

Triangulation helps to achieve internal validity, reliability and minimises the effects of bias (Merriam, 1998). In this study, triangulation was achieved through the collection of data from multiple participants in several different formats, including research observations and participant input, over a period of time. The discussion sessions allowed participants to speak freely and express themselves without constraint. The questionnaires allowed teachers to comment privately and give their considered, individual opinions. The researcher acted in the role of embedded participant-observer and the observations were also used to triangulate findings. During the video club meetings as well as after pertinent interactions with the participants, observations and memos were noted by the researcher to aid triangulation and validity (Marshall, & Rossman, 2014; Suter, 2012).

The emerging themes and categories were analysed alongside background research and the conceptual framework prepared which further justified the set of findings. After the key themes had been identified and links were beginning to be established a meeting was held to gain member checks where the findings were presented to the participants and feedback was invited. While this meeting was not recorded, observations and brief notes were made by the researcher.

3.9.5 Other Issues

It was envisioned that there may be difficulty in using the video technology both from a technical point of view and in the readiness of teachers to adopt it and how it might impact on their students and teaching as they got started. However, this did not seem to be much of an issue as the use of the SWIVL was very straightforward, but its set-up and use was facilitated by the researcher as requested by the participants. The resources and technical support at the school also facilitated ease of use of the equipment. Behaviour issues were not a major concern at the school

and students quickly became used to the equipment in their classrooms and classes carried on as usual.

Return of consent forms by students and parents was initially difficult as they were required from virtually the entire secondary cohort to give teachers the freedom to film any class they preferred. Forms were initially handed out to students in class and collected back by the classroom teacher which was an inefficient process. It was made much easier when the forms were included in the start of year information pack which parents collected and signed as required in person. This resulted in the majority of the forms being returned. The teachers involved were provided with release time from teaching for meetings where necessary, which reduced some of the burden on teachers. However, there were still fewer meetings than anticipated due to the busy schedules of teachers and not all teachers could attend all meetings.

Therefore, while the process was made relatively easy and efficient this may be another limitation for the extrapolation of findings to other school contexts where some of these things may not occur.

3.10 SUMMARY

In this chapter, I have outlined the qualitative ethnographic, PAR approach and methods used to collect and analyse the data. A case study methodology was adopted with data collected from a single case of a secondary school Science teaching department which consisted of six teacher-participants. Participants in the department were asked to film video of themselves teaching and then to privately reflect on their videos, they then gathered on multiple occasions to discuss the video-reflection process and what they learned about their teaching.

The data collected came in the form of questionnaire responses, discussion transcripts and researcher observations. The different forms of data collection and background research allowed for triangulation of findings which minimised the effect of bias and improved trustworthiness of the findings. Documents were analysed using open coding to find key words, phrases and ideas which allowed the identification of codes, themes and categories which fit within the ideas discussed in the background research. Further open axial coding was then used to identify relationships between these themes and categories. The methodology employed was open to some ethical issues and bias and these were discussed in this chapter along with the limitations of

the research design and the findings. In the next chapter the data and findings are presented as a set of themes within three main categories along with presentation of responses and discussion points from each data source in participants' own voice.

Chapter 4: Findings

This study employed a PAR, case-study design to evaluate the use of self-tracking video and a video club with a small group of experienced Science teachers. The data consisted of questionnaire responses at the beginning and end of the study for each participant as well as transcripts of three video club meetings. Each of the data sources provided insight into the participants' thoughts and feelings at the start, throughout the study and at the end. Qualitative data was collated and analysed using open axial coding and categorisation to identify themes. This chapter presents the findings from the data collected.

In this chapter, the identified themes and their categories are presented first to give the reader an overall view of the triangulated findings. These themes are presented early on as they will be used when describing and summarising the actual data. This is followed by a profile of the participants and the setting. The data is presented chronologically with responses to the initial questionnaire presented using direct quotes from participants as well as summaries of their responses and then a visual representation of the common concepts. Each video club meeting is then described, and again direct quotes from participants are presented to give insight into the topics being discussed. The main concepts from each meeting are then compared to see the progression between meetings. The final questionnaire data is then presented in a similar manner to the initial questionnaire.

4.1 OVERVIEW OF THEMES IDENTIFIED

The questionnaire responses and video club transcript excerpts presented in this chapter were read to identify key ideas and words which allowed themes to emerge, such as discussions about "students", "knowledge", "organisation/preparation", "feelings" etc. During subsequent readings and comparison, these themes began to resemble ideas presented in the PCK-based Teaching Framework and this was used more closely to guide the coding process and the identification of the emerging themes. The final result was twelve themes within three categories as shown in Table 4.1 along with a short description. These themes will be referred to during the presentation of findings from each questionnaire and meetings later in the chapter.

Four of the identified themes pertained to the way teachers discussed their PD. This included the way that they discussed the self-tracking video use and the collaborative discussions amongst other formal PD activities and their personal goals. A number of themes emerged which closely resembled some of the aspects of effective teaching as put forward by PCK researchers as discussed in Chapter 2 and represented in the PCK-based Teaching Framework. Three final themes were originally grouped into the teacher skills and knowledge category, however further exploration suggested that they were more aligned with enduring characteristics of the teacher and their approach to both the teaching and learning of students and their approach to their own professional learning. These themes were discussed in such a way that implied that they were more fixed and difficult to 'learn' or 'change' and actually develop with time and experience in the classroom.

Table 4.1 Overview of Themes Identified from the Data

TEACHER DEVELOPMENT THEMES	**Theme 1** – Goal setting and behaviour modification	Teachers discussed how the study processes helped them to develop and set goals as well as monitor goals they had already set for themselves. They commented that they became more aware of their behaviours and noticed things they were happy with and things they wanted to change.
	Theme 2 – Professional development	Responses and discussion showed that the self-tracking video use and video club enhanced teachers' formal professional development programs and provided stand-alone value for professional development and capacity building. Teachers had ideas about how it could be used in the future to complement other programs but also to replace certain initiatives in the school.
	Theme 3 – Supportive professional learning community (Video Club)	Teachers' discussion and responses showed that the video club process increased and improved their collaborative discussion and sharing and also solidified positive relationships amongst staff. The quality of discussions was deepened so that teachers were not inclined to only discuss the "what" and "how" of teaching and assessing but also the "why" and helped them to consider their beliefs about teaching and learning.
	Theme 4 – Self-reflection and video use	Teachers reported that self-reflection was improved and more meaningful through the use of self-tracking video. Their discussion and responses showed that the video use was relatively simple and valuable. The participants commented that they became more reflective generally and were likely to reflect on the teaching choices before and during a lesson as well as after even when the video technology was not in use.
KNOWLEDGE AND SKILL	**Theme 5** – General pedagogical knowledge (GPK)	Background research described GPK as the general understanding teachers possess and can learn in order to present material for learners. Teachers discussed general teaching strategies, capabilities and classroom logistics. This encompasses things such as lesson planning and structure, organisation, giving instructions, providing skills practice, classroom management, layout, and seating plans, teacher movement around the room, distribution of resources, managing student interactions, managing transitions, checking on student

		learning, behaviour management, managing classroom discussion, use of questioning and wait time, organising group work and more. GPK was one of the main components of the PCK-Based Teaching Framework.
	Theme 6 – Science content knowledge (SCK)	Science content knowledge can be taken to mean the depth and breadth of knowledge of the different topics within science. This includes how different content areas are interrelated as well as how they link to real-world applications and contexts. Teachers often discussed their own content knowledge concerns but also how this element was important for effective teaching and learning. SCK was one of the main components of the PCK-based Teaching Framework.
	Theme 7 – Knowledge and interpretation of curriculum	Teachers are expected to have knowledge of the mandated curriculum. In this study there was some discussion and responses about knowledge of "what to teach" from the syllabus documents, including earlier learning, future learning and learning in other areas (science and other areas). This was depicted as relating to a teacher's PCK on the PCK-based Teaching Framework.
	Theme 8 – Knowledge and use of strategies and representations	This theme refers to the explanations, examples, stories, diagrams, models, and activities used by teachers to deliver learning outcomes. During the meetings participants discussed their use of strategies, examples and explanations. This was depicted as relating to a teacher's PCK on the PCK-based Teaching Framework.
	Theme 9 – Knowledge and application of assessment	The findings show that the participants discussed assessment, particularly questioning and their use of feedback techniques, quite a bit. This was depicted as relating to a teacher's PCK on the PCK-based Teaching Framework.
APPROACH TO TEACHING AND LEARNING THEMES	**Theme 10** – Orientations and beliefs about teaching and learning	Teachers discussed their thoughts and beliefs about effective pedagogy and how they approached student learning. It was discussed as something that teachers wished to improve, develop and change but that it can be very difficult and many were not sure if "progressive" methods are effective. The background research suggests that this as an element associated with Pedagogical Content Knowledge (PCK).
	Theme 11 – Understanding of students	Background research revealed knowledge of students' understanding as an important aspect of effective teaching. During the study, participants discussed making learning relevant and interesting for students, differentiating for different abilities, being interested in students and thoughts about student thinking and learning.
	Theme 12 – Personal attitude, confidence and self-efficacy (Positive Feelings)	Teachers' responses and discussion often had an affective, attitude or personality dimension, which supported some of the suggestions presented in the background research. It showed the need for teachers to have a positive approach towards relationships with students and their learning, a positive attitude towards their teaching activities and also their own development and learning as teachers. It relates to passion, motivation, interest, willingness to try new things and make learning enjoyable, and helps with collegial relationships.

4.2 SUMMARY OF DATA COLLECTED FROM EACH PHASE OF THE STUDY

4.2.1 Initial questionnaire

The initial questionnaire gathered participant details. The teacher-participants had teaching experience ranging from seven years to more than 30 years and taught Science across the entire secondary school with different specialist areas. Five of the participants, including the researcher, taught Science classes at year eight to ten as well as at least one senior school class in the areas of Physics, Chemistry, Biology, Human Biology, Psychology and Integrated Science. One of the teacher-participants was a year seven specialist Science and Maths teacher. Participants had an excellent working relationship with all other members of the team, they had worked together as a department for more than seven years. They met regularly both formally and informally to discuss teaching programs, curriculum, assessments and students. A summary of the teacher participant details is shown in Table 4.2.

Table 4.2 Overview of teacher participant details (pseudonyms have been used)

Name	Age range	Teaching experience (yrs.)	Highest Level of Education	Year levels taught	Previously exposed to PCK concepts?
Aidan	40-50	15-20	Masters (Education)	7-12	Yes
Sacha	30-40	15-20	Post-graduate diploma (Education)	8-12	Yes
Beck	30-40	10-15	Bachelor (Education)	8-12	Not sure
Kelly	40-50	15-20	Post-graduate diploma and certificate (Education)	8-12	No
Dale	30-40	5-10	Post-graduate diploma (Education)	8-12	Maybe
Chris	50-60	30+	Bachelor (Education)	7-8	Yes

The initial questionnaire also had five questions (Question Two - Six) regarding skills, knowledge and behaviours of ‘good’ Science teachers and PCK. An overview of the responses to each question are shown below.

Question Two: “What do you think good science teachers do?”

Responses to this question show the importance of understanding and relating to students. Participants included ideas such as makes students “curious” (Dale) and “enjoy their learning” (Chris). Other responses also recognise a teacher’s beliefs and orientations, and all participants’ responses infer the need to have a positive approach to the teaching and learning of Science as seen in the responses below.

> “They inspire students to love learning about science and the world around them. They make the content achievable by pitching it the level where they are at and supporting them to develop their understanding. Learning should be enjoyable and students should be able to see how it applies in the real world. They should make students feel safe to try and get things wrong but also confident that they can achieve.” - Sacha

> “provide experiences that change students' thinking towards a scientific conception” - Aidan

> “Ask questions. Be ok with not knowing all the answers but be prepared to find out. Be interested in your student's lives, know how to explain difficult Science concepts to differing abilities, have a plan and be organised.” - Kelly

> “Impart a good understanding of science in a way that they understand and makes the information they are gaining relevant to them.” - Beck

Question Three: “What skills and knowledge do good science teachers need/possess?”

Most participants’ responses identified good SCK as essential, in some cases this was explicitly stated while in others the responses identified skills and knowledge which require good content knowledge. These include giving good explanations, making the learning relevant and engaging for their students and being able to cater for individual students in their classes.

> “Confident understanding of the content including past knowledge of students and upcoming content in certain subjects. Helps to develop relevance to what students are learning.” - Beck

> "They should be able to explain things in many ways and know or think of good learning activities such as prac work/demos/group activities which help students to understand." - Sacha

As in the answer from Beck (above) many of the responses referred to teachers' attributes such as confidence and passion and their approach to students and their own development. This shows that teachers realise the importance of an affective element to teaching.

> "They should also love learning and be passionate about their teaching area and doing the right things for students." - Sacha

> "Well organised, life long learners, confidence in your own ability, embrace technology, have a go attitude, be prepared to get your hands dirty" - Kelly

Question Four: "What strategies do good science teachers use?"

All participants' responses refer to a variety of strategies and an ability to cater for individual students. Strategies included science specific strategies such as predict, observe, explain; use of demonstrations; inquiry learning and use of diagrams and analogies. Other strategies would be classified as GP. For example:

> "POE, science inquiry, think/pair/share, jigsaws, don't sit down, differentiate the curriculum" - Kelly

> As can be seen in the response by Kelly (above), most participants implied a constructivist or conceptual change approach and referred to inquiry techniques as represented in the response by Sacha.

> "Excellent demonstrations which challenge students' ideas, good questioning techniques, practical work which consolidates understanding, good examples, analogies, diagrams; showing students ways of representing info; inquiry and applied tasks (hard to do!)" - Sacha

Question Five: What do you think sets expert or very accomplished science teachers apart from others?

The participants' responses identified three main ideas. Most referred to understanding and catering for their students such as, "the ability to relate students interests to the concept/content that is being learnt" (Dale). They also inferred a depth and breadth of Science content knowledge as being necessary. For example, "knowing their area, being enthusiastic about their subject, knowing the bigger picture in terms of key concepts" (Chris). And finally, most participants also implied positive teacher attributes as seen in the responses below

> "self-awareness and personal reflection skills" - Aidan
>
> "Knowledge of the students and what they need and are likely to get right and wrong. Passion, interest and breadth of knowledge, confidence, great relationships with students." - Sacha

Question Six: What areas of your science teaching would you most like to improve?

A range of responses were given including use of technology, differentiation, use of questioning techniques and improving science content knowledge. Some responses reflected a desire to incorporate more student-centred and perhaps 'innovative' learning activities as seen below.

> "developing student independence in learning" - Aidan
>
> "develop more strategies for allowing students freedom to explore concepts on their own." - Dale
>
> "Encouraging students to learn for themselves and construct and apply their knowledge. Use of inquiry and self-directed learning. Integrated projects and learning. Making learning more authentic and meaningful." - Sacha

Figure 4.1 gives an indication of the themes in the responses to the pre-study questionnaire. This visualisation represents the topics in varied sizes which is indicative of the number of databits allocated to each topic from the questionnaire data.

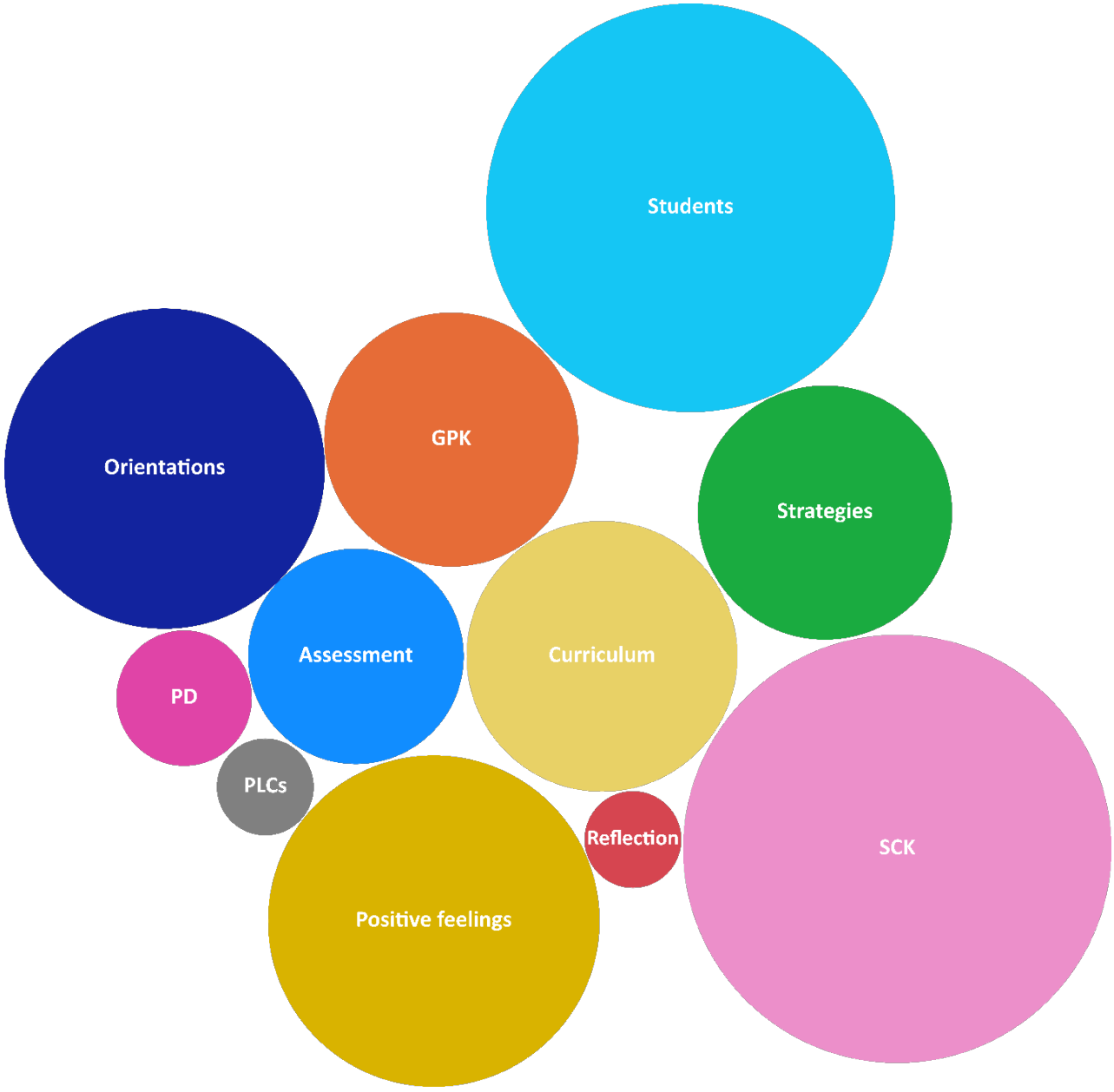

Figure 4.1. Representation of themes presented in the pre-study questionnaire.

4.2.2 Video club meetings

Three video club meetings were held, and each was recorded and transcribed. Due to the researcher being an embedded participant and full-time teacher at the school, she was able to make observations, notes and memos from the meetings as well as other interactions with the participants regarding the study, as summarised below.

General observations

The participants were keen to use the technology but they did need regular reminders and prodding to use it in their classrooms. While the technology (SWIVL) was easy to use and set-up, the busy nature of teaching meant that the participants did not often initiate its use and they appreciated the logistical aspects being managed by the researcher. Some teachers asked for hard deadlines in order to 'make them do it' and all preferred that the researcher manage the video data on their behalf.

The participants often sought out the researcher either in person or by email to discuss or give their initial thoughts and observations after first using the technology. These communications mostly consisted of surprise or discomfort at seeing themselves, with comments about their accent, hair, dress, mannerisms and other physical observations. The researcher was able to support them and encourage them to view their video a second time or be less critical of themselves, some discussion also occurred between participants outside of the meetings as well. This set-up enhanced the support available and most participants admitted to viewing their videos more than once. The supportive, positive relationships between the participants, including the researcher were evident in the meetings as well.

Meeting 1

Table 4.3 Video Club Meeting One Details

Timing of meeting	Mid-Term 4
Duration of meeting	15 min
Number of participants present	6
Number of attendees who had used SWIVL prior to meeting	2
Purpose(s) of meeting	Introduce the technology to be used (SWIVL, iPad and software) and the PCK-based effective teaching framework as well as discuss the expectations of participants.
Meeting structure	The concept of PCK was introduced along with the PCK-based teaching framework. Elements of PCK were discussed, led by the researcher. The researcher spoke about the technology use and expectations of the study.

The participants were positive about the PCK-based Teaching Framework and could see the relevance of the different aspects to their own teaching and what they felt about effective teaching. It led to some constructive and interesting discussion but this was limited due to the purpose of the meeting being mostly for the researcher to give information.

The findings showed that all participants felt worried about using the technology and were uncomfortable with the idea of watching themselves teach. Some felt that their students were not going to cope with it or that the technology would not work properly. The two participants who had already trialled it were able to explain the ease of its use and how, upon watching themselves, they were able to get past their discomfort and begin to notice many good things about their teaching. The comment below illustrates this sentiment.

> "… the things that I saw were nice mostly...there are things I know that I am still doing but at least I'm conscious..." 00:00:00 - Sacha

The positive experience of early adopters allowed them to provide support and encouragement to other participants. Some of the beneficial aspects pointed out were goal setting and monitoring as well as improved reflection as seen in the response below.

> "I feel like I talk too much at the start of a lesson. 'Yes, I spent too long at the beginning of the lesson talking...other things I know I've picked up on are that I need to stop telling and I'll start asking more." 00:00:00 - Sacha

At the conclusion of the meeting participants were asked to use the technology prior to the next meeting to be held early the following school year.

Meeting 2

Table 4.4 Video Club Meeting Two Details

Timing of meeting	Mid-Term 1
Duration of meeting	30 min
Number of participants present	5
Number of attendees who had used SWIVL prior to meeting	4
Purpose(s) of meeting	Discuss participants' reflections, thoughts, and feelings after having used the self-tracking video technology.
Meeting structure?	The researcher asked each participant in turn to contribute their thoughts and feelings leading to whole-group discussion using the PCK-based teaching framework as a stimulus.

The participants who had used the self-tracking video at the time Meeting 2 was held had similar feelings about its use, to those expressed by the early adopters. They agreed that it was easy to set-up and use as this was facilitated by the researcher. They all felt nervous and uncomfortable about watching themselves teach, however, they were able to move past this and were happy to see many good things happening in their classrooms as well as areas for improvement. Participants were able to encourage and support each other, including the participant who was yet to use the video technology; this sharing of experiences helped co-participants build rapport. They seemed to enjoy discussing the process and their observations. At the conclusion of the meeting the participants were again encouraged to use the technology at least once prior to the next meeting in the following school term. The overall tone of the meeting was very supportive and positive and the discussion was free-flowing and open.

The participants discussed their feelings about having used the video-technology. They all expressed that they had found it difficult to watch their video at first. As the comments below show, they were uneasy at first and were likely to focus on personal physical attributes; this shared experience allowed the teachers to feel more comfortable because everyone felt the same way.

> "You just came in and set it up for me which was handy. It was a bit…it was really hard to actually get in to actually going and watching the video."
>
> … "that's what I found as well." 00:02:09 Beck/Sacha
>
> even just getting up the nerve to even record it was really hard…...just getting over watching yourself and listening to yourself...Oh my gosh, was my hair really like that, and all those weird things. ….once you kind of get over that bit…. 00:02:21 Beck
>
> "I watched it just about twice. The first time was the not so nice time I guess because you're just looking at yourself as a person, but yeah. I quite liked it once I watched it the second time and it really emphasises the goods and the bads that you do. And it's nice that you notice both really, really quickly. I liked that I do that." 00:03:52 Dale

After the initial discomfort, the participants were able to appreciate the experience of reflecting on their teaching and were able to see many positive aspects. This included participants noticing their practice, as described by Dale: "positive praise and good manners and emphasising the point of my lesson" (Dale). Participants were also impressed with their ability to provide "a really good explanation or answer to a question" (Sacha) or "finding a way to rephrase your question so that struggling kid can actually answer it" (Dale) and being able to come up with things "in the moment" (Sacha). Some participants were also pleased to see "that we actually discussed and it wasn't [. . .] me just standing at the front and actually talking the whole time" (Beck).

These reflections allowed participants to support each other and encourage the one participant who was yet to use the technology. It should also be noted that similar supportive discussions had taken place between individual participants and the researcher immediately after they had first used the technology, outside of the meetings. The quotes below show that the experience led to positive feelings for some.

> "after watching it I'm like, "Sick! I knew exactly what I wanted to teach," because that's the point that I got across, so I was super happy with that. I was like really happy with that." 00:05:11 - Dale

> "like I always know after a lesson that was good, that was bad. But I guess I just liked watching because then you can finetune it and not be general and say that was a bad lesson. Because even a bad lesson you still have good points." 00:07:55 - Dale

As suggested through the quotes presented thus far the participants were positive about the use of the SWIVL. They also commented that it brought their goals and PD aims into sharper focus as reflected in the comments below. It gave them things to work on and allowed them to examine their personal behaviours. The participants were keen to use it for further observation.

> "I've made that change and yeah, that was the biggest one in terms of what I thought was really bad and I try not to say yes so much. And I keep doing the good things you know, like the positive praise and good manners and the emphasising the point of my lesson." 00:05:11 - Dale

> "one of my goals this year was to work on my questioning and I know in the video that I watched that I recorded I just was not happy with the way my questioning was going. .... And so, I need to put more effort into consciously working on my questioning style." 00:14:05 - Beck

> "because I am so teacher-directed and I stand up front and I write notes or I dribble crap for so long. I really don't allow myself that time to spend it individually with the students who I know need it. I know I need to check in and do that sort of thing. So, I really like to analyse that." 00:14:51 - Kelly

> "just be interested to see how the differentiation is going because I know that I've got like so many levels . . . I'd like to see that, see if that's working." 00:19:37 - Chris

One further aspect of the discussion around using the video technology was the feeling that even just discussing its use and the prospect of using it and being part of the study had made the participants more reflective. The comments below show that with a focus on reflection and their teaching the participants were encouraged to think more about their choices and behaviour.

> "I think even just talking about SWIVL made me move around the room more and being more conscious of my body positioning" 00:06:00 - Kelly

> "I agree though, I find now that I'm often considering my teaching because of the SWIVL, like just in a different way. I reflect more before and during. Like you always

> reflect after a lesson a little bit of like what went right, what went wrong, that was a really awesome activity or lesson. And then, or, oh geez, that was really poorly planned or I wasn't ready for that part. That's what I reckon during- I'm more reflective during a lesson." 00:06:56 - Sacha

For most the use of the SWIVL led to goal setting as shown in the quote below.

> "I realised like for that particular lesson I wasn't overly prepared... And so, I've been trying really hard to make sure that I'm super prepared." 00:04:16 - Dale

One of the key points of reflection which began to emerge was participants' beliefs and orientations towards teaching and student learning.

> "The other thing I found really good with it was not just…because I know before I'd reflect but it was kind of almost like a superficial reflection, like that was a good lesson, that was a bad lesson. What I would do better, you know, the next time kind of questions. But it was more on like techniques and you know, like my actual teaching style that I was reflecting on instead of . . ." 00:09:55 - Beck

Participants discussed their approach to teaching and pedagogical choices which was not commonly a feature of regular departmental meetings outside of the study. They commented on their desire to make changes and their goals to be more innovative. They were also open about their difficulties and issues with making these changes. These ideas are shown in the quotes below.

> "I really would love to try and do more, sort of not every lesson but problem-based or project-based activities " 00:10:23 - Sacha

> "I think that's my goal in a way as well [...] just try to change it up and make it- make things somewhat less teacher-directed and more often and more student-thinking oriented. And sometimes that is just a really good question in class. [...] I know that if I want my aim to be to ask good questions, I have to think of some good questions and go in prepared with that plan. And that sort of you know, if you were differentiating you'd want to know, what could I ask those good kids before." 00:25:33 - Sacha

> "normally I have a really set way of teaching middle school science, like I have the . . . [theory/prac/IT-based/discussion lessons] This time I've been trying to do it so it's more like . . . [student centred]
>
> . . . it's because I'm not comfortable with this way of teaching because my content knowledge isn't near like you guys" 00:21:55 - Dale

Science Content Knowledge (SCK) was not often explicitly discussed as a point of reflection, however, it can be seen or implied through many of the other comments made. This is also true for discussion about curriculum, it seems that these points are almost taken for granted, or fixed. The participants did refer to curriculum pressures when considering implementing more innovative or student-centred pedagogy as shown below.

> "you know how much content you have to get through. So, you're going, 'Well, if I don't deliver it then you're kind of stressed.'
>
> . . . It takes longer.
>
> . . . You've got one day on [. . .]. You can't let them go and play around with the door.
>
> [lots of agreement]" 00:11:42 - Dale/Beck/Dale

Many of the observations show that teachers were reflecting on their teaching skills and choices out of an interest to help their students to learn. Much of the discussion reflected this interest in doing their best for their students as shown below.

> "as experienced teachers we have this whole bag of stuff ... which means that we're good at teaching not just generally but teaching Science as well. And that comes with those things of knowing the individual kids in your class and what they need and how you can further them along or add to what they need to know or help them, assist them." 00:06:56 - Sacha

At the conclusion of the meeting, participants were positive about the use of the SWIVL and were keen to continue using it in their classes. The participant who had not yet used it was encouraged by the other participants such that she asked the researcher to help set it up in an upcoming class. All of the participants requested the researcher to help remind them and to set up

the equipment. The participants seemed much more comfortable with the process to be used and were buoyed by the comfortable and supportive discussion.

Meeting 3

Table 4.5 Video Club Meeting Three Details

Timing of meeting	Mid-Term 2
Duration of meeting	30 min
Number of participants present	6
Number of attendees who had used SWIVL prior to meeting	6
Purpose(s) of meeting	Evaluate how the participants had found using the self-tracking video over a number of occasions with different classes and discuss its usefulness as a form of professional development to be used alongside, or instead of, other programs.
Meeting structure?	The researcher guided the discussion by prompting participants to express their views. Again, the PCK-based teaching framework was used as a stimulus and initial data analysis also informed the discussion direction.

In this meeting it was fairly clear that the participants no longer had any issues with the use of the self-tracking video, there was limited discussion of being nervous or uneasy about watching themselves. Instead, the participants were focused on discussing their observations and thoughts regarding their strengths and weaknesses and their beliefs and orientations, as captured in the excerpt that follows.

> "I've got this faint goal that as a teacher I might be able to influence their thinking, help them develop a scientific conception whatever it is we're teaching." 00:09:12 - Aidan

Science content knowledge (SCK) was discussed in the context of how it impacted their GPK, the strategies and representations used, and the assessment techniques employed. A discussion between Aidan, Dale and Sacha shows the types of observations and supportive discussions that took place.

> "you would know when you're doing electricity (to Dale), you would know the questions to ask the kids… when you did chemistry even though you're organised, perhaps there's

> questions that you don't know that are worth asking. […] You're probably knocking yourself a bit more than you need to...” 00:17:04 - Aidan

> “that's the difference between [...] surface learning and then deep learning. You know what I mean? Just somebody who is teaching outside of their specialisation can go in and teach the basics, this is what you need to know sort of thing. And then, but in your chemistry classes (to Aidan), you go for the deep. And that's fine. You sort of hope that they get that surface stuff along the way.” 00:17:19 - Sacha

The participants also commented on the need for good SCK when implementing more student-centred and inquiry-based learning as seen below.

> “the types of integrated learning that I have seen that worked is where you maintain that specialisation . . . You can't replace the knowledge that's behind the content knowledge by being just a good teacher.” 00:14:43 - Aidan

> “I guess I'm coming to more and more the realisation that content knowledge is really super important. I mean of course we know that, yeah, it's just so much easier to do the things you're talking about, progress their knowledge and find other ways to get them to think about things and relate it to stuff. It's really hard to do that when your content knowledge isn’t as good.” 00:13:57 - Sacha

Most of the discussion focused on reasons to use the self-tracking video (SWIVL). Most of the participants discussed the benefits of using the SWIVL for personal reflection and for setting and monitoring their own goals. In this third meeting, some teachers expressed that they would like to continue to use the technology but in a more focused way to evaluate their progress and work on specific things as seen in the quotes below.

> “It makes you think about what you're doing so if I'm going to think about what I'm doing, I want to be pretty specific about it.” 00:11:27 - Aidan

> “I actually want to SWIVL again because I kind of have my personal thing that I want to look for.” 00:08:40 - Dale

> “I'm keen to keep going … And just to go back and to think about how it be useful for me as a teacher. So, I'm keen to keep going whether you're collecting data or not. But I want

> the opportunity to be specific about it. And if I can weave that into other stuff we have to do, I probably prefer to do it that way than just be another thing." 00:18:25 - Aidan

A large portion of the discussion was around the use of the technology alongside other PD initiatives occurring. The PD consisted of Assessment for Learning (AfL) workshops (Black & Wiliam, 1998). As part of this PD, teachers at the school had been paired with another teacher. Study participants had been paired with a non-study participant, for the purpose of conducting classroom observation activities. The school was also encouraging "Learning Walks" (AITSL, 2013) where groups of teachers were encouraged to move around a few classes within a set time period to observe classroom activities and this was part of a wider push for "open" classrooms and forming PLCs.

The reflections and thoughts represented below show that participants could see the potential benefits of using the SWIVL technology to work on goals set through the formal PD program and to provide an alternative to the classroom observations and learning walks. They also believed that the use of video technology could potentially enhance teacher learning through PLCs. The participants suggested that the SWIVL could be used by individual teachers to check their own progress as they worked on particular goals and techniques and then they could share their progress with others in their PLC either by inviting other interested teachers to come and see the technique in the classroom or by sharing small sections of video. This could then lead to discussion about how the implementations went and be a way of receiving feedback. These ideas are reflected in the quotes below.

> "And then you're still doing that stuff for AfL [...] I know for myself I was using it as well when we're doing like the, I looked at the questioning techniques and stuff like that. And so that was handy to have that available as well as, so I think they kind of, I don't know, overlapped each other nicely." 00:19:28 - Beck

> "why don't we say like I say I'm going to work on this [technique] and I'm going to try it and I'm going to SWIVL […] and I'm going to see what works, what doesn't work, …. and then at a date in the future where I'm comfortable then people would come to my room to look at that technique" 00:00:11 - Aidan

> "I'd be quite happy if a teacher had said they're working on [a technique]. And that's something that I'm interested in. Then maybe [. . .] I go watch that technique. That's what I'm going to watch - is that specific teaching technique. It's encouraged that teacher to

look at something specific. It's encouraged them to play around with it to see what works and doesn't work. It's encouraged me to have a look at it and then the teaching reflected to me initially I tried this and I did that. And that didn't work so well. I've done this. This is how I like to run it now. [Agreement]" 00:00:46 – Aidan with agreement from others

"when they're using SWIVL to look at their own goals and development of their techniques or skills or whatever. You could almost be putting together a little library of snippets. So if you get in the meeting you can show techniques like instead of talking [Sacha] . . . yeah your little group could say well we have this little library of five minute videos of somebody trying something in their class [Dale] . . . Especially with the AfL where it's only 5 or 10 minutes [Sacha] . . . I prefer the video than have people come into my class. [agreement]" [Dale with agreement from others] 00:25:13 – Sacha and Dale

The other point of discussion regarding the value of the initiative was in its potential to be used to gain insight into student thinking and perform a diagnostic or feedback role. As some participants became more confident and comfortable with the technology they began to consider how they could use it to 'listen in' to student conversation or as a method of formative assessment. The responses below show how the participants were keen to use the technology to benefit their teaching through evaluating student learning and encouraging student reflection. They also represent participants orientations and thoughts about learning and the role of the teacher and may reflect a move toward a more student-centred approach.

"And SWIVL you would just record what you're doing and then I guess reflect well does this kid know that?" 00:10:33 - Dale

"you're doing some diagnostic stuff where the kids are doing some learning stuff where you ... are doing formative assessment of seeing what they know and then the end of it of it being good then to engage the kids in some reflection of their learning and have that on the SWIVL." 00:04:43 - Aidan

"I would love to, yeah use the SWIVL where I can gauge their level of understanding of that [IDEA/TOPIC] initially and see what their conversations are and my conversations with them as they're doing those activities. Because not all of them make the leap just because they've drawn the graph or whatever. And then what I can do to steer them in the right way of thinking." 00:09:39 - Aidan

> "[It's like] having another person in the room overhearing student discussion. [Looking at] the way that they questioned each other and interrogated each other and their own understanding of what was happening in the prac work. … And how cool it would be if I could hear that at the end of the task like that where….? And then you really would know, oh well they obviously haven't picked, understood that concept but they've really understood that one or they're really keen on that idea." 00:06:55 - Sacha

> "I love that idea of that kids develop their own conceptions based on their own experience and then me trying to manipulate the experience to change their conception. That's the part I like. And so, I would love that to be my focus and then say what I'm going to do is look at lessons where I know kids are either bringing or developing their own conceptions. ... they're the ones I'd like to work on with the SWIVL. And then even, I'd love to have me going asking kids' the questions about those conceptions that go around as they're doing activities." 00:02:41 - Aidan

Participants were also aware that the technology could be used for other purposes and were keen to explore that. They discussed it potential for use in evaluating student understanding through "listening in" on their conversations and discussions or listening back to their responses to questioning, in this way it may become beneficial for student assessment purposes.

> "there are so many things that SWIVL could do but we don't currently use it for and I'm kind of keen to look at it but you can have the extra markers so there's one on each bench to the kids ... it can actually do a whole lot of analysis for you in terms of your questioning or which kids you actually spoke to." 00:28:17 - Sacha

Again, the talk amongst participants was very positive about the use of the SWIVL technology and its benefits to teaching and learning. The discussion and responses made it clear that the benefits of the use of the technology was sometimes subtle and could be felt even without watching their videos.

> "The SWIVL does highlight for us... It reminds that we're teaching." 00:10:43 - Aidan

However, even though participants appreciated the value of using the SWIVL and found it easy to use, they still required support from the researcher to organise setting it up. Some discussion also pointed out the need for time to be made for it and it not to be 'just another thing' they have to do.

"I think it's definitely beneficial but while ever, there isn't time made for people to do this. It's really a difficult thing." 00:11:35 - Sacha

"It's just actually ridiculous how easy it is to start and how I can never remember." 00:27:12 - Dale

"it's very easy for you [to set up the SWIVL] you just grab and go.

"It doesn't mean you're going to remember to do it anyway."

"That's the problem [agreement]" 00:27:25 – Sacha with agreement from others

Comparison of themes from each meeting

The coded data bits were used to look at how the topics or themes discussed during the subsequent video-club sessions changed. This was done by extracting the number of databits allocated to each theme from each meeting in order to give an indication of the overall content of each meeting and how the discussion focus may have changed. This data is shown in Table 4.3.

Table 4.3 shows that the discussion focus of meeting one was quite different from the discussion focus of meeting two and three. The purpose of meeting one was mostly dissemination of information and the meeting was quite short. However, it does suggest that over the course of the study and the meetings the participants became more inclined to talk about their goals, self-reflection and professional development. The teacher-participants also made reference to their approach to teaching and learning including greater discussion about their beliefs and orientations as well as their awareness of students and their own feelings and attitudes. There were less obvious changes in the way teachers talked about their GPK, SCK and other elements of their PCK.

Table 4.6 Number of Times Each Theme was Assigned Within Each Meeting Transcript

	Themes	Video club Meeting One	Video club Meeting Two	Video club Meeting Three
Theme 1	Goal Setting and Behaviour Modification	3	20	17
Theme 2	Professional Development	1	3	18
Theme 3	Supportive Professional Learning Community (Video Club)	4	5	10
Theme 4	Self-Reflection and Video Use	6	31	29
Theme 5	General Pedagogical Knowledge (GPK)	3	28	17
Theme 6	Science Content Knowledge (SCK)	4	11	8
Theme 7	Knowledge and Interpretation of Curriculum	0	3	0
Theme 8	Knowledge and Use of Strategies and Representations	6	13	5
Theme 9	Knowledge and Application of Assessment	1	4	13
Theme 10	Orientations and Beliefs about Teaching and Learning	2	20	11
Theme 11	Understanding of Students	2	18	13
Theme 12	Personal Attitude, Confidence and Self-Efficacy (Positive feelings)	7	28	17

4.2.3 Final questionnaire

Following the third meeting it was clear that participants had become comfortable with using the technology and felt that it had value and was beneficial in a range of ways. They were then asked to complete an electronic questionnaire in their own time to clarify their thoughts about the process and any changes that had occurred. On the whole, the participants found the experience positive and beneficial. They valued the ability to reflect on their teaching and also to discuss their reflections with each other. Their responses referred to the orientations and beliefs about teaching and learning as well as their understanding of students' needs. Very few final reflections were about curriculum, assessment or strategies and representations.

Question One: After watching and reflecting on yourself teaching a number of times, how did it make you feel? What thoughts did you have? What did you learn or notice from watching yourself teach?

Most of the participants commented that watching themselves led to positive outcomes such as feeling re-energised, realising many good teaching skills and behaviours and becoming more comfortable with the process. Their observations included their ability to respond to their students effectively, their positive approach and attitude while teaching and their use of pedagogical skills as well as being able to see things from a different perspective leading to the identification of goals for improvement. These goals included logistical aspects such as awareness of the classroom space and the impact of this on students and general pedagogical skills.

> “It made me feel re-energised for improving the quality of my teaching. It made me consider the students more in terms of their physical position and how that impacts on their engagement with my teaching. I learnt that there are areas in my class room that I don't visit, practicals are difficult to disseminate equipment in my room and that it's hard to see details in what I am showing from the back of the room.” - Kelly

> “My first impressions were actually good. It made me realise that I do a lot of good things like I smile and laugh and have a good relationship with the students and an engaging style. This made me happy. It also made me realise that I was able to provide good explanations and answers to questions, even in the spur of the moment or off the top of my head. My students are generally engaged and seem to enjoy class and are doing the right thing. I also realised that perhaps sometimes I talk too much and do too much explaining and need to redirect students or give enough info to get started and then encourage them to think for themselves more.” - Sacha

> “It emphasized the good aspects of my teaching and also highlight the things I needed to do better - for instance I found that there was too much dead time in my lesson, this was easy to fix for future lessons” - Dale

> “I couldn't believe how [...] I sounded, how many miles I walked and how many questions I answered. I also was amazed at my multitasking! I was pleased that my passion for teaching was in evidence, that I had differentiation going on and was asking higher order questions.” - Chris

> "Felt more comfortable viewing myself teaching. Nice to get the students' point of view for the class." - Beck

> "It made me hypersensitive to some of the things I do when teaching that I don't want to do" - Aidan

Question Two: How was the experience of watching yourself teach? As an overall experience, was it positive or negative?

Overall, every participant answered that the use of the video was "positive", some gave more information as seen in the quotes below. They acknowledged the discomfort felt at first but that it was a growth experience and beneficial. This supports the observation made by the researcher during the meetings.

> "Positive in the sense it was a growth experience" - Aidan

> "I was nervous at the start but found it very beneficial" - Chris

Question Three. After taking part in the series of collaborative discussions about the use of video reflection, how did it make you feel and what thoughts did you have? What did you learn?

Participants appreciated the chance to discuss their reflections with others which allowed them to see that they had similar experiences. Their responses point out that while they could reflect on their videos and gain insight that way the PLC discussions were seen as valuable. The discussion encouraged them to feel positive about their experiences and observations and to also discuss their teaching goals at a deeper level.

> "Self-reflection is wonderful, but sharing this with a group can be of assistance to others. I enjoyed the process." - Kelly

> "Was great that some of the reflection was similar with others." - Beck

> "It was great to hear that other teachers had similar experiences and the discussions were so supportive and non-judgemental. Having watched our videos it led to us having much more in-depth conversations about the nature of teaching, the way we teach, what students

do and do not know, what works etc. In other department meetings it is often just communication about upcoming assessments or topics etc without getting into the deeper parts of our teaching. It was also great to hear the other teachers reflecting deeply on what was occurring in their classrooms." - Sacha

"I think everyone liked using the video reflection - it is a quick way to get an unbiased look at how your lesson went with respect to what you were actually trying to teach." - Dale

"It essentially inspired me to improve my teaching. It taught me there is a difference between my ideal and my practice." - Aidan

"I enjoyed talking about the experiences." - Chris

Question Four: Was participating in the collaborative discussion sessions an overall positive or negative experience?

Again, all of the participants confirmed that the experience of discussing their reflections with their colleagues was "positive" without supplying extra information.

Question Five: What are your thoughts about the use of a video club model as a form of professional or performance development?

All responses reflected that the participants thought the video club model was beneficial and would be useful for a wider range of teachers to use alongside other PD. They compared its use with other PD models in use such as classroom observations and peer mentoring and felt that this could replace or help such activities. They also discussed the possibility of sharing video with each other.

"I think this would be more helpful than many other PD sessions we currently do" - Beck

"I think it has a lot of value. It could continue to be used in a similar manner with a broader range of teachers and teachers could set specific goals to look for etc." - Sacha

> "We also discussed it's use to create a library of teaching moments to be used for reflection and discussion with a supportive group. I think it would need to be managed well and be the responsibility of particular people to help integrate it with current PD approaches." - Sacha

> "I think this is very rewarding and productive" - Aidan

> "I think it could only help to improve teaching in a school. Less invasive than having another teacher come into your classroom, particularly for the students. Yes, it is time consuming but overall very helpful." - Kelly

> "Great idea, once the person being shown is made aware and it is only small sections of the lesson" - Dale

> "informative and useful" - Chris

Question Seven: Can you suggest any changes or improvements to the use of the video club model and PCK as a form of PD to make it more useful?

Some participants offered no suggestions and others reflected ideas which came up in meeting three where teachers could use it in a more focused and specific way, perhaps aligned with other PD initiatives. For example:

> "It would be great to tie into our work on AFL - teacher could pick a "task" then video it and the whole staff could watch it being implemented and then decide if they would like to use it." - Dale

> "Probably be more planned in the lesson I am video, rather than a random lesson. Pick a particular skill I want to improve and film that over a period of time." - Aidan

Question Eight: The Pedagogical Content Knowledge (PCK) framework helps to outline what teachers do and know, how did this framework impact on your reflections on your teaching and what effective science teachers do?

Throughout the meetings the PCK-based teaching framework had not been discussed explicitly, however it was used to guide discussion and participants had been exposed to it. Most of the participants' comments implied that it helped them to organise their thoughts and guide their reflection as seen in the responses below.

> "It made me think about my orientations to teaching and what I was trying to achieve. It also made me realise the importance of good content knowledge. Also, how as experienced teachers we are able to employ all of the different elements in an integrated way and when we discuss our teaching each of these things play a role." - Sacha

> "My reflections were more based around what was done during the lesson that was good, and what was done in the lesson that could be improved. And if it could be improved, how could this happen - did it require a new approach to teaching or a more in depth understanding of the content." - Dale

> "Gave me a schema to reflect on my skills, place them in context." - Aidan

Question Nine: Have your thoughts about effective science teaching changed? If so how?

Many participants reflected that their ideas had not really changed but had been 'reinforced' or 'refreshed' and reflect ideas put forward in the pre-study questionnaire as seen below.

> "I'm not sure. I appreciate more the importance of science content knowledge but also personal attributes and knowledge of the students in front of you. There is no one correct methodology or orientation as this should change but that students need to be given more responsibility for their learning and teachers should be there to inspire, motivate and guide." - Sacha

One participant had a more positive outlook on incorporating inquiry-based learning responding:

> "Yes, structure is good, but it is better to find a way to tie it into inquiry as well" - Dale

Question Ten: How do you think these experiences of videoing, reflecting on and discussing your teaching have changed your teaching and personal goals?

Participants' responded that the use of the video and participating in the PLC helped them to recognise positive aspects of their teaching and to observe and reflect on areas they wanted to improve. This allowed them to monitor their progress with their goals and set new goals. This supports observations and responses made during the meetings

> "Made me more aware of strengths and weaknesses. More able to find areas to focus on for personal goals and to see improvement/document improvement or working toward/achieving the goal." - Beck

> "Re-energised my enthusiasm for Science teaching to a higher standard" - Kelly

> "My teaching goals are to continually learn - either different ways of doing things or to embrace new ideas so as not to become stale and ineffective. I enjoyed the SWIVL as it showed me that I after 30 or so years in the classroom my passion for teaching is still there. I am embracing new ideas and giving new things a try." - Chris

> "Not a lot. Gave me more focus." - Aidan

Some participants found using the video and participating in the discussions useful in helping them to move towards more student-centred and inquiry-based teaching and learning.

> "I try to put the learning back on the students and not provide so much information and answers all the time. My personal goals are to provide learning experiences where students not only construct ideas and knowledge but they develop thinking skills, collaboration skills and they apply their learning more often. I would also like to help teachers to continue to use this technology in a beneficial way." - Sacha

> "I have always been a very structured teacher and I have always wanted to be more inquiry based, being able to chat to other teacher about their own reflections showed how they do it in a more inquiry-based manner" - Dale

Other responses

The participants were also asked if anything in the study surprised them (Question 6) and for any other thoughts (Question 11). While for some of the teachers the outcomes were expected, others were surprised by how positive the experience was and how it actually helped to build confidence and relationships between the participants as seen below.

> "The positive observations surprised me because I didn't really like the idea of watching myself. I was also surprised by how receptive most of the other teachers were. It's also interesting that for everyone it made us more conscious of what we were doing whether the SWIVL was there or not. Generally, the positive and in-depth nature of the conversations and discussions were a good surprise." - Sacha

> "some teachers are not very confident in themselves, and it was nice to see that some of them gained confidence after watching themselves." - Dale

Some of the participants also felt that the video club initiative increased their self- reflection even without using the technology regularly.

> "Just the act of videoing the class made me reflect on my teaching even before I actually watched the video" - Aidan

Finally, on the whole the self-tracking video use and video club PLC was considered to be a beneficial process.

> "Very good, I would like to keep viewing my lessons -but I keep forgetting to set it up!" - Dale

> "Everyone should swivel as a way to develop their teaching" - Chris

The following figure (Figure 4.2) represents the themes presented in the post-study questionnaire data, similar to Figure 4.1.

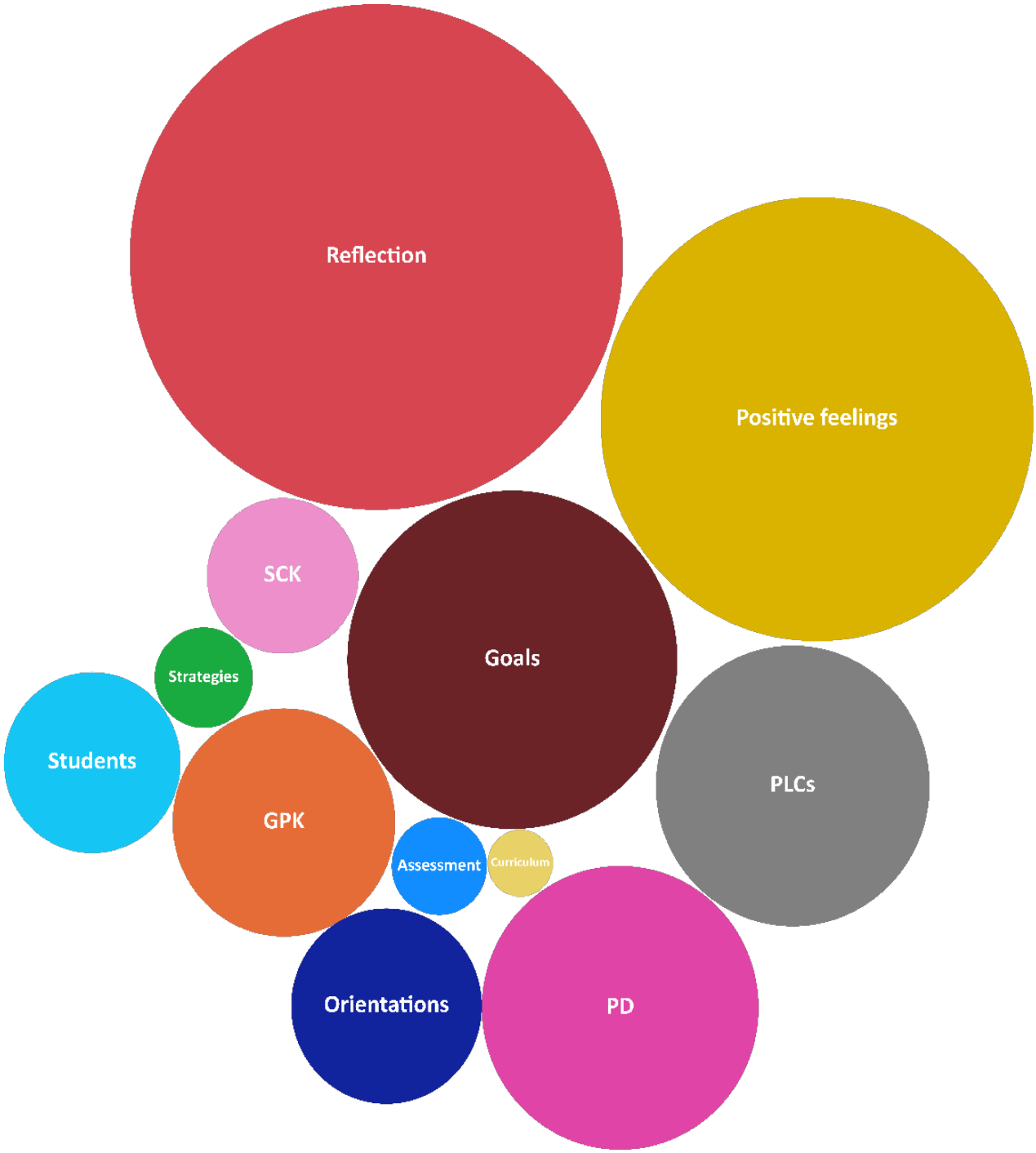

Figure 4.2. Representation of themes identified in the post-study questionnaire.

4.2.4 Data Collection Issues

Some of the issues during data collection included not all participants being able to attend all meetings and encouraging them to find the time to use the video technology. Although the school was supportive in providing time and teacher relief for meetings to take place, fewer

meetings occurred than expected. The busy nature of teaching and schools meant that a significant amount of time was required between meetings to enable teachers to use the technology and finding meeting times which suited the participants was difficult. Although, the study ran for a significant amount of time it was not really enough to evaluate the extent and effect of behaviour and thinking changes of the teachers. Finally, while there was some concern from the ethics committee that teacher participants may be affected by the position of power of the researcher as the teachers' line manager this did not seem to adversely affect the amount and quality of discussions or responses. During the coding and analysis, there were few problems; although the amount of data was manageable, the process may have been improved through the use of a software package to facilitate coding and analysis.

4.2.5 Chapter Summary

The purpose of this study was to trial a PD method with a group of experienced practicing Science teachers. It aimed to explore how the use of self-tracking video and video club meetings might build the reflective practice and professional discussions of the teachers involved leading to improved teaching and learning. It also aimed to tease out ideas about effective teaching from experienced teachers and how this aligns with previous research about PCK with a view to creating an effective teaching framework for use by teachers and others. Findings from the data collected, which consisted of questionnaire responses and video club meeting transcripts were open-coded using a constant comparative method. Twelve themes were identified, and further open axial coding was completed to reveal relationships between the themes.

The 12 themes were subdivided into three categories. The Teacher Development themes consisted of Goal setting and behaviour modification; Professional development; Supportive professional learning community (Video Club); Self-reflection and video use. The Teacher Knowledge and Skill themes consisted of General pedagogical knowledge (GPK); Science content knowledge (SCK); Knowledge and interpretation of curriculum; Knowledge and use of strategies and representations; and Knowledge and application of assessment. There were also a set of themes which could be classed as Approach to Teaching and Learning themes, these were Orientations and beliefs about teaching and learning; Understanding of students; and Personal attitude, confidence and self-efficacy, or positive feelings. A lot of what the teachers discussed and included in their responses fell into the categories put forward by previous researchers in this

area. These findings will be analysed in greater detail in the next chapter, where a set of key findings related to the research questions will be presented.

Chapter 5: Discussion

This study was designed to explore a professional development initiative implemented with a group of practicing, experienced Science teachers. Self-tracking video (SWIVL) and video club meetings, along with a PCK-based teaching framework, were used to encourage critical reflection and discussion about pedagogy and promote meaningful collaborative discussion practices. It was thought that this may lead to more innovative and effective teaching practices which embrace a more student-centred, inquiry approach. The data included three meeting transcripts and an initial and final questionnaire. In the previous chapter, the data collected was presented and the analysis methods were explained. The themes identified were described along with verbatim quotes and summaries from the questionnaires and each meeting. In this chapter, the findings are discussed with reference to the research questions, along with a discussion of the limitations of the study.

5.1 SUMMARY OF THEMES IDENTIFIED

The coding and data analysis led to the identification of 12 themes within 3 categories as shown in Table 5.1 and discussed in Chapter 4. Many of the identified themes align with concepts associated with effective teaching as presented in the background research and synthesised in the PCK-based teaching framework. These were arranged into two categories of Knowledge and Skills and Approach to Teaching and Learning. Other themes were associated with Teacher Development. The themes and categories as well as the participants' responses overall enabled each of the research questions to be considered and a set of findings to be identified.

Table 5.1 Summary of themes identified from the data

Teacher Development	Goal Setting and Behaviour Modification Professional Development Supportive Professional Learning Community (Video Club) Reflection and Video Use
Knowledge and Skill	General Pedagogical Knowledge (GPK) Science Content Knowledge (SCK) Knowledge and Interpretation of Curriculum Knowledge and Use of Strategies and Representations Knowledge and Application of Assessment
Approach to Teaching and Learning	Orientations and Beliefs about Teaching and Learning Understanding Students Personal Attitude, Confidence and Self-Efficacy

5.2 DISCUSSION OF FINDINGS REGARDING RESEARCH QUESTION 1

RESEARCH QUESTION 1

How useful is a video club model and Pedagogical Content Knowledge (PCK)-based teaching framework as a means of professional development and teacher capacity building for practicing, experienced teachers?

Through the video club discussions and questionnaire responses, participants expressed their thoughts and feelings about self-reflection and video use; being part of a PLC in the form of a video club; goal setting; and professional development. The data suggests that the process was beneficial in a number of ways. Three key findings for research question one have been identified and are discussed below. The results show that the initiative was positive and beneficial for all participants and improved their self-reflection, goal-setting and complemented other professional development activities. The video club activities also enhanced pedagogical discussions and collegial relationships and there was evidence of increased positive feelings and self-efficacy. Some other issues regarding the use of self-tracking video and a video club were also identified. These findings support and add to background research about professional development, PLCs and video-enhanced reflection.

Finding 1 - The video club model was a positive experience and beneficial for reflection, goal setting and professional development.

It was clear that the use of self-tracking video technology was beneficial for self-reflection, goal setting and as a form of professional development, and that the video club PLC enhanced these effects, supporting findings by Borko et al. (2008) and Tripp and Rich (2012a). Discussion and questionnaire responses showed that the use of the self-tracking video and participation in the video club allowed the participants to reflect on both positive behaviours and areas of change as seen below.

> "It emphasized the good aspects of my teaching and also highlight [sic] the things I needed to do better - for instance I found that there was to [sic] much dead time in my lesson, this was easy to fix for future lessons" Dale – Q1 - Post-study Questionnaire

The participants commented that they were able to 'notice' things that they may not otherwise have considered, as was found by Sherin and van Es (2005). Most of the teachers involved commented that they watched their videos more than once, also seen in Coffey's (2014) study. Rosaen et al. (2008) point out that teachers' reflection and noticing skills are likely to be aided by the to re-watch teaching episodes which is supported by the findings in the current study. The discussion sessions indicated that participants' reflections became more specific and focused on particular skills and student understanding rather than just what was done in the lesson. This has been shown in other studies (Blomberg et al., 2014; Marsh & Mitchell, 2014), where through the use of video reflection, teachers began to focus more on student learning, interrogate their pedagogical choices and begin to adopt a more student-centred approach.

The findings indicate that participants' self-reflection and goal-setting was not only enhanced by the use of the self-tracking video but also by the video club PLC sessions and the PCK-based teaching framework. Abell et al. (1998) suggest that self-reflection can be aided by peer reflection and collaboration. In this study the participants commented that they enjoyed the chance to discuss the process with their colleagues and that the discussion sessions helped the teachers to reflect to a greater degree. Some felt discussing others' experiences and their own future use of the video technology made them more reflective about their teaching generally. Some participants commented that they were more reflective before and during a lesson as seen in a comment by Sacha:

> "I find now that I'm often considering my teaching because of the SWIVL, like just in a different way. I reflect more before and during. Like you always reflect after a lesson [. . . but now] I'm more reflective during a lesson." Sacha - Meeting 2 00:06:56

This point was also observed by Halter (2006) who found that the effect of video analysis can persist over time and that the technology does not always need to be used and Kopcha and Alger (2011) found that teachers reflected on issues raised in discussion long after the meetings. The PCK framework was also of use, although not commonly discussed, as it introduced PCK concepts which some participants used to guide their reflection and helped to provide a shared framework for discussion. As Aidan stated it "gave me a schema to reflect on my skills, place them in context." This supports previous research which suggests that video reflection is more effective with the use of a lens or reflection guide (Bryan & Recesso, 2006; Deaton, 2012; Korthagen, 2004).

Another clear benefit of the use of the self-tracking video was its relationship with teachers' goals. The participants reported that through watching themselves teach, their observations led to the identification of areas for change and goals for improvement. This supports research (Abell et al., 1998; Harlin, 2014; Smith & Neale, 1989; Tripp & Rich, 2012a) which showed that through video reflection teachers were able to critically see things leading to changes in habits, beliefs and practices. Through the video club discussion sessions, the participants encouraged each other to observe and analyse their goals which will be discussed in a later section. Participants also discussed some goals they had set for themselves prior to using the video or during other professional development activities and they were keen to use the video technology to analyse their progress. They appreciated the ability to observe and witness behaviours that they were interested in or had set personal goals about such as questioning, movement around the room and individual student attention. The participants were also able to track their progress with the goals they had set through formal professional development programs. This supports Chavez's (2007) recommendation that video can be used to allow teachers to practise and evaluate new techniques.

Discussions during Meeting 3 along with the final questionnaire responses indicated that the participants felt that the video technology and video club PLC were useful as a form of PD on their own and also to complement other PD activities. Teachers felt that it both enhanced formal professional development programs and could potentially replace some professional development initiatives, with specific ideas for implementation. When asked about the use of a video club for

PD purposes in the final questionnaire, Beck stated "I think this would be more helpful than many other PD sessions we currently do". They felt this model allowed them to work on what they were keen to follow up, it provided them with an opportunity to practise and evaluate new skills, and it was seen as less time consuming and more relevant than other forms of PD. A number of researchers (Jones, 2008; Magnusson et al., 1999) suggest that effective PD is best-situated in-school and even in-the-classroom, with meaningful collaboration and addressing teacher goals. Others (Guskey, 2003; Kamener, 2012; Korthagen, 2004; Polly & Hannafin, 2010) also suggest that it is more effective when teachers feel that they have ownership of their PD and it builds upon prior knowledge and aligns to personal interests and beliefs. It is also suggested that PD needs to be sustained over time (Yoon et al., 2007; Whitworth & Chiu, 2015) and a key factor for success is the chance for collaboration (Yore & Treagust, 2006). The findings of this study show that this model encourages collaboration, allows teachers to have ownership of the direction of their learning and builds on their particular interests and addresses individual goals. It is situated in the classroom and can take place over an extended period of time making it more meaningful.

Through the video club the participants were able to provide alternative points of view, challenge each other's thinking, and encourage reflection, goal setting and commitment to change. This supports findings by Sherin and van Es (2005) and van Es (2010) who also found that collaborative discussion allowed participants to see alternative points of view and challenge their thinking. Participants' responses showed that they appreciated being able to discuss the process and their observations with their colleagues, which is further discussed in a later section. Others (Borko et al., 2008; Rich & Hannafin, 2009; Tripp & Rich, 2012a) have also found that collaboration through a video club was seen as essential to video-reflection. This view is represented by Kelly who stated that "self-reflection is wonderful, but sharing this with a group can be of assistance to others. I enjoyed the process." Blomberg et al. (2014) state that learning is a social process and much can be learned from a collaborative approach. Participants in this study became more willing to use the technology and engage with the process due to the group dynamics showing that forming collaborative teams or professional learning communities (PLCs) helps teachers to be more accountable for their change goals and enables a greater degree of reflection through discussion of their teaching and practice with others as has been discussed by Dogan et al. (2016) and Jensen et al. (2016).

Finding 2 - The video club initiative had a positive effect on collegial discussion and relationships, and promoted confidence and self-efficacy.

The use of the self-tracking video and participation in the video club PLC was a positive experience for all participants as shown in the responses to Question 2 and 4 in the final questionnaire. The final questionnaire responses support findings by Coffey (2014), Borko et al. (2011) and Tripp and Rich (2012a) that such activity is positive, motivating, simple to use and helps teacher reflection and development.

As previously discussed, the use of self-tracking video benefitted participants' self-reflection and goal-setting. This was aided by participating in collaborative video-club discussion sessions about their reflections. However, the use of the video and its effects on teachers' self-reflection also impacted on the quality of the collegial discussions about pedagogy and student learning as was observed by Kopcha and Alger (2011) and Richmond and Manokore (2011). One participant commented that the video club discussions were more focused on pedagogical choices and student assessment and understanding rather than the usual logistics and organisation. In a study by Grant and Kline (2010) the use of video appeared to have helped the discussion between PLC participants evolve beyond generalities and recollections of practice and Sherin and Han (2004) found that video club participants "valued the chance to discuss more substantive issues related to teaching and learning" (p. 166). Borko et al. (2008) also found that discussions within a video club style PLC became more 'productive', talking in a more focused way about teaching and learning, this effect was seen in the current study where teachers discussed their specific concerns, strategies and student understanding. They suggest that this may be due to developing a sense of a professional community of practice, appropriate facilitation, the establishment of discourse norms and encouragement. Throughout the meetings the teachers became more inclined to discuss their beliefs and orientations about teaching and learning and their students' understanding and learning needs, this is elaborated on in a later section.

The supportive nature of the video club discussions enabled the participants to support each other to use the technology and benefit from the process, this has also been seen by Borko et al. (2008) where participants of a video club style PLC offered each other support and encouragement. In the current study all participants were nervous about watching themselves teach at first, however, being part of a supportive PLC allowed them to encourage and support each other (Tschannen-Moran, & McMaster, 2009). This was due to the positivity of other members of the video club. It seems that some participants were more open to the use of the

technology at first and the positive attitude of these 'early adopters' towards their own teaching, learning and professional development helped to encourage others. The data also show that initially the participants tended to focus in a critical way on their voice, appearance and body language in a similar manner to other research (Bryan & Recesso, 2006; Eroz-Tuga, 2012; Pailliotet, 1995). However, the participants were supported to see past this and begin to observe interactions with students and teaching and learning practices as was also noticed by Eroz-Tuga (2012). The role of the researcher was also important in this regard as is discussed in the next finding. While the protocol did not require participants to share their videos with each other, as the project progressed the participants did begin to express that they would be open to this as a form of professional development and were interested in other ways that they could use the technology. This is of interest as it provides insight as to how teachers develop engagement with video-aided reflection activities and with an ongoing supported approach could benefit to a greater degree.

Participants reported that one of the most beneficial aspects of participating in the video club was that it enabled them to recognise their shared experiences which helped to enhance relationships and build confidence (Borko et al., 2008; Tripp & Rich 2012a). In the post-study questionnaire Sacha provided the following response

> "It was great to hear that other teachers had similar experiences and the discussions were so supportive and non-judgemental. Having watched our videos it led to us having much more in-depth conversations about the nature of teaching, the way we teach, what students do and do not know, what works etc. In other department meetings it is often just communication about upcoming assessments or topics etc without getting into the deeper parts of our teaching. It was also great to hear the other teachers reflecting deeply on what was occurring in their classrooms." – Sacha – Q3 - Post-study Questionnaire Q3

As previously discussed, teachers were able to share their thoughts and reflections, encourage and support each other as well as learn from each other (Sherin & Han, 2004; Tripp & Rich, 2012b; van Es, 2010). All of the final questionnaire responses indicate that the participants appreciated the video club as it enhanced their relationships with colleagues and contributed to more positive feelings about teaching. Woolhouse and Cochrane (2010) also found that a similar model helped develop confidence, renewed teachers' enthusiasm, interest and fulfilment in teaching and strengthened friendships among colleagues. Comments from participants in this study included

> "Re-energised my enthusiasm for Science teaching to a higher standard"– Kelly – Q10 – Post-study questionnaire

In the current study the participants already had well established, friendly and comfortable working relationships, perhaps providing evidence to the idea that group members matter when putting together effective PLCs (Sherin & Han, 2004). However, others have also found that teachers appreciated PLCs as a "safe space where they could take risks, discuss problems and explore perceived deficiencies" (Woolhouse & Cochrane, 2010, p. 11). This fostering of a 'community' of practice has been referred to by other researchers as an important aspect of teacher development activities, and especially for building confidence and self-efficacy (Borko et al., 2008; Dogan et al., 2016; Mintzes, Marcum, Messerschmidt-Yates, & Mark, 2013.

Through the use of the technology and collegial support the participants were able to reflect on their goals but also observe their positive behaviours such as the rapport they had formed with their students, and the use of humour, good manners and positive praise. For example

> "My first impressions were actually good. It made me realise that I do a lot of good things like I smile and laugh and have a good relationship with the students and an engaging style. This made me happy. It also made me realise that I was able to provide good explanations and answers to questions, even in the spur of the moment or off the top of my head. My students are generally engaged and seem to enjoy class and are doing the right thing. I also realised that perhaps sometimes I talk too much and do too much explaining and need to redirect students or give enough info to get started and then encourage them to think for themselves more." – Sacha – Q1 – Poststudy Questionnaire

Participants were also pleased to see that they were able to answer questions and give good explanations in answer to students' questions, even when put on the spot. This helped them to feel good about their teaching, and willing to use the technology and encourage others. The results suggest that the use of self-tracking video, with PLC support, can build confidence and positive feelings in experienced teachers, which was also observed by Richmond and Manokore (2011). Professional learning communities (PLCs) are seen as a "means of supporting and improving teacher knowledge and skills leading to increased teacher efficacy for meeting students' needs" (Dogan et al., 2016, p. 2).

There was clear evidence that the initiative enhanced positive feelings. The findings show a relationship between the use of video-reflection and being part of a supportive PLC with positive

feelings and confidence towards teaching and learning (Woolhouse & Cochrane, 2010). Dogan et al. (2016) found that effective PLCs have a positive impact on affective characteristics, such as "confidence, self-efficacy, leadership skills, collegiality, a sense of accountability, change in culture of professional practice and empowerment leading to greater respect, trust and collaboration" (p. 10). The findings in this study suggests that through self-reflection and PLC support, the participants' were able to see positive behaviours as well as identify ways to change and feel motivated to do so through shared experiences and supportive relationships and thus self-efficacy was enhanced (Dogan et al., 2016; Gröschner, Schindler, Holzberger, Alles, & Seidel, 2018; Mintzes et al., 2013).

> "some teachers are not very confident in themselves, and it was nice to see that some of them gained confidence after watching themselves." – Dale – Q6 – Post-study Questionnaire

Guskey (2003) discusses the reciprocal effect of self-efficacy, effective teaching and teacher development

> teachers who express a high level of personal efficacy, like teaching, and feel confident about their teaching abilities are, indeed, highly effective in the classroom, these teachers also appear to be the most receptive to the implementation of new instructional practices… (p. 11)

This reciprocal effect is supported in the current study as through video-aided reflection teachers are able to witness their success and have the potential to experience personal mastery and the video club provides feedback and encouragement, which Bandura (1994) suggests as sources of self-efficacy development.

Finding 3 - While a video club model has many benefits there are other considerations such as time constraints, support in the form of mentoring, and the role of leadership and school culture.

Some of the participants commented that they were keen to continue using the technology but that they would require incentive in the form of time, motivation and leadership support in order to do so. During the meetings the participants commented that it was easy to use the equipment but that unless the researcher reminded them and set it up for them, they were unlikely

to use it. Some responses showed that teachers felt that watching their videos was time consuming but that it was time well spent and more beneficial than other PD time. It should also be noted that time-release was provided in order for the participants to meet and participate in the video club. Research shows that lack of time for collaboration is one of the greatest barriers for teachers (Jensen et al., 2016; Johnson, 2006; Jones, 2008; Rogers et al., 2007; Borko et al., 2008; Guskey, 1986; Rich & Hannafin, 2009; van Es, 2010).

Support and guidance or mentoring are also seen as essential (Borko et al., 2008; Guskey, 1986; Rich & Hannafin, 2009; van Es, 2010). In this study the researcher had an excellent relationship with the participants and the group as a whole was comfortable with each other and willing to share. In the current study the participation in the video reflection activities by the researcher acted as a model for the other participants and contributed to the sense of 'shared experience'. The researcher being a full-time staff member in the department with excellent knowledge of, and relationships with, the teachers involved allowed other participants to access support throughout the study. Outside of the formal discussion sessions participants were able to discuss their concerns and initial feelings of discomfort or surprise after using the technology and the researcher was able to provide timely support to encourage them to focus on both the positive aspects of their teaching and more meaningful observations. A number of researchers have found that the relationship between program facilitators or researchers and participants has an impact on teacher development (Bandura, 1994; Guskey, 1986; Kwasnicka et al., 2016). Guskey (1986) found that the presenter must be seen as "credible, [. . .] articulate and charismatic, and must emphasise the practicality of the new practices" (p. 9). Whitworth and Chiu (2015) point out that there is a gap in the literature about the role of coordinators and learning area leaders.

A final element which was implied through the discussions during the final meeting was the role of the school administration in determining the direction of PD activities and allowing teachers to use an initiative such as the one in this study in place of other activities and to trust staff to have some ownership of their own PD activities. A report produced by OFSTED (2010) about effective systems suggested that successful school leaders demonstrated a high level of trust in their staff and involved them in identifying and implementing improvements which led to positivity to change. The school administration in this case was supportive of this study but participants were unsure about how it would fit with other programs in an ongoing way. The participants discussed how they would like to use the technology to replace other PD initiatives occurring rather than adding this on top. However, this would require support from school

leadership in the form of time and minimising top-down expectations, allowing teachers to direct their own PD activities to some extent. Another important element is the culture of the school environment, in this case it was obvious that the participants were open and comfortable with each other which led to positive results. Kamener (2012) states that we need "to develop a culture in schools that is open to broad, constructive feedback, mentoring, monitoring of classroom performance and ongoing professional development" (p. 3). When a culture of collegiality exists, teachers are more likely to learn and work together to apply changes to their practice and be open to new ideas (Whitworth, & Chiu, 2015; Woolhouse & Cochrane, 2010).

5.3 DISCUSSION OF FINDINGS REGARDING RESEARCH QUESTION 2

RESEARCH QUESTION 2

In what ways have practicing, experienced teachers changed their beliefs, thoughts and behaviours, and teaching practices through the process of being part of a video club and using a PCK-based teaching framework?

The data and themes indicate that some changes in beliefs, thoughts and behaviours, and teaching practices were initiated by the video club program and using a PCK-based teaching framework. Discussion topics indicated that teachers were reflecting on their beliefs and orientations and were considering their use of ‘reform’ practices. Changes occurred for all participants in their reflection and goal setting behaviours and some made other small changes to their practices. While it was possible to gain insight into participants thoughts and feelings about the process it was more difficult to get an idea about how their thoughts about their teaching had changed and the study required a longer time frame and other methods to gauge the extent of changes in behaviour and practices. An extended study would also allow for understanding whether changes were sustained over time. The findings do indicate that the process supports an effective constructivist model for teacher change and development and can promote effective teaching practice.

Finding 4 – Video reflection and video club participation alongside a PCK-based teaching framework initiated changes in teacher beliefs, thoughts and behaviours and teaching practices.

The video club was valuable as the participants found it useful to talk about their reflections, feelings and beliefs. The analysis shows that the nature of the discussions became more meaningful, encompassing thoughts and reflections about pedagogy, participants' orientations and beliefs about teaching and their understanding of students. Their responses and discussion topics reflect a shift in thinking and behaviour. Table 4.3 shows that there was a change in focus of the discussions between meeting one and two after the majority of teachers had begun to use the self-tracking video technology and had been introduced to the PCK-based teaching framework. In meetings two and three the participants began to discuss their reflections, goals and professional development to a greater extent. Other researchers have also found that through the use of video and guided reflection teachers became more aware of student thinking and the focus of their reflections changed (Eröz-Tuğa, 2012; Rosaen et al., 2008; Sherin & van Es, 2005; Tripp & Rich, 2012a, 2012b; van Es, 2010). Some researchers suggest that a video club model may provide an agent for reform as it changes the focus of discussions and improves colleagueship by developing support and trust (Richmond & Manokore, 2011; Sherin & Han, 2004; Tripp & Rich, 2012b). This is one of the key findings of the current study.

Evidence of participants' thoughts and beliefs about adopting a constructivist position was seen in their expressions of wanting to adopt more innovative, inquiry-based practices during the PLC meetings. Smith and Neale (1989) found that through the use of videotape and reflection most teachers began to acquire targeted content knowledge and elements of a conceptual change orientation toward science teaching. Although participants expressed motivation to adopt 'reform' practices and an understanding that it can be beneficial for some students, they also lacked confidence in their ability to do it based on their SCK, this is also seen in findings by Jones (2008) who states that teachers lack content knowledge required for inquiry-based learning activities. They expressed concerns about whether IBL or PBL was as effective for transmitting the required knowledge and covering 'enough' curriculum and that it was more time-consuming. These findings reflect those of many other researchers (Blumenfeld et al., 1991; De Boer, 2000; Dogan et al., 2016; Johnson, 2009; Margot & Kettler, 2019). In the final questionnaire Sacha expressed the role of the PCK-based teaching framework in guiding reflections:

> "It made me think about my orientations to teaching and what I was trying to achieve. It also made me realise the importance of good content knowledge. Also, how as

> experienced teachers we are able to employ all of the different elements in an integrated way and when we discuss our teaching each of these things play a role." – Sacha – Q8 – Post-study Questionnaire

Participants discussed and reported that they had made some changes in their practices as a result of the video club initiative. They focussed on general teaching strategies, capabilities and classroom logistics. This encompassed things such as lesson planning and structure, organisation, giving instructions, providing skills practice, classroom management, layout, and seating plans, teacher movement around the room, distribution of resources, managing student interactions, managing transitions, checking on student learning, behaviour management, managing classroom discussion, use of questioning and wait time, organising group work and more. The project heightened participants' awareness of their choices in the classroom and this led to changes. Previous research by Tripp (2010) found that video reflection encouraged change because it gave teachers focus and a new perspective, made them more aware and accountable, and enabled them to see their progress. Participant responses during this study support these findings, however assessment of the extent of changes in practice was difficult to determine using this method. A review of video-aided reflection studies conducted by Hamel and Viau-Guay (2019) recounts that many reported a change in practice but contain little detail about the actual changes.

Finding 5 - A video club model and the use of a PCK-based effective teaching framework supports a social, constructivist model for teacher development and change.

The data indicate that some changes to beliefs, thoughts and behaviours, and teaching practices were initiated, however such changes were difficult to fully gauge in the short time frame of the current study. Background research led to a review of literature about how teacher change occurs. Tripp (2010) and Tripp and Rich (2012b) state that there is limited research about how video analysis influences change but they suggest that video encourages change because it helped teachers to a) focus their analysis; b) see their teaching from a new perspective; c) trust the feedback they received; d) feel accountable to change their practice; e) remember to implement changes; and f) see their progress. The findings of this study support these ideas as participants changed the way they reflected on their teaching and were more prepared to discuss pedagogy and implement new practices.

The positive impacts of the video club PLC support Bandura's (1994) notion of a social-constructivist model of teacher development and change as requiring social modelling and positive relationships. Kwasnicka et al. (2016) report that learning new practices is best done using relevant contexts and with positive social influences which reinforces maintenance of behaviour change (Whitworth & Chiu, 2015; Showers & Joyce, 1996). In this study the supportive encouragement of trusted colleagues was seen as valuable and participants were able to situate the learning in their own classroom and focus on what was most relevant to them. By forming a collaborative PLC the participants seemed more invested in the process and more accountable for their change goals, enabling a greater degree of reflection through discussion of their teaching and practice with others as described by Jensen et al. (2016) and Richmond and Manokore (2011). Other researchers (Guskey, 2003; Kwasnicka et al., 2016) have found evidence that PLCs can also help participants to remain committed to their goals (Guskey, 2003; Kwasnicka et al., 2016).

The participants did not often explicitly discuss the use of the PCK-based teaching framework during the video club sessions. However, in the final questionnaire, the participants were asked how the framework impacted on their reflections, the responses showed that it made most of the teachers think about the ideas it held a little more and in some cases gave them guidance as to what could be improved or changed. Korthagen (2004) points out that while there is an emphasis on reflection for teachers "it is not always clear exactly what teachers are supposed to reflect on when wishing to become better teachers" (p. 78). A number of researchers (Bryan & Recesso, 2006; Griffin, 2003; Deaton, 2012) have suggested the use of a lens or rubric to support reflection. The results of this study show, that while it was not explicitly discussed, the emerging themes correspond with many of the PCK elements and so teachers were possibly using the PCK-based framework as a scaffold for their reflections and discussion points. It also allowed participants to pick up on those elements which were of most interest to their own development, this indicates that teachers can benefit from a simple reflection guide or effective teaching framework or rubric to guide their PD focus.

Guskey (2003) and Korthagen (2004) refute the view that change will take place just through presenting new ideas and information, as is the case in many traditional PD programs. They propose that teachers require evidence of positive effects derived from a change in behaviour before a change in beliefs and thinking is established. The use of the self-tracking video and video club provides evidence for this, as participants were able to focus on areas of

interest, possibly using the PCK-based teaching framework, and to see the effects of changes they were implementing as part of their own personal goals, programs or other PD which led to thoughts and discussion about their beliefs and orientations. This model is based "on the idea that change is a learning process for teachers that is developmental and primarily experientially based" (Guskey, 1986, p. 7). In this way, a constructivist learning approach is applied to teacher development. The model used in this study corresponds with this approach allowing teachers to focus their activities at their own point of interest and readiness and the positive findings support such a process being used with experienced teachers.

The process also enhanced positivity amongst the participants. Teachers reported finding the process enjoyable and were able to see that it built confidence and consolidated positive relationships. In this case the participants were already supportive and comfortable with each other, however responses indicate that these feelings were reinforced. This indicates that a video club model with the right PLC can enhance teachers' positive feelings and relationships, their self-efficacy, and their willingness to adopt behavioural change. This supports research by Margot and Kettler (2019), Guskey (1988), and Whitworth and Chiu (2015) that behaviour change is most effective when supported by a positive environment and attitude. Kwasnicka et al. (2016) state that other motivators include "behaviour enjoyment, satisfaction with behavioural outcomes, self-determination or an experience of behavioural congruence with beliefs and values, all of which often develop *after* initiating a new behaviour" (p. 290). The outcomes of the current study show that this method has the potential to provide a structure which can support such motivators for behavioural change.

Finding 6 - A video club model and the use of a PCK-based effective teaching framework can promote effective teaching.

When asked if their thoughts about effective teaching had changed throughout the study many of the participants' responded that their ideas had not really changed but that their ideas about effective teaching had been 'refreshed' or 'reinforced'. However, the participants' responses in the initial and final questionnaires indicated that through the study their knowledge and understanding of PCK had developed and that the PCK-based teaching framework provided, helped in some ways. Initial responses showed that some participants were not familiar with PCK ideas and upon introduction to the framework they all appreciated the elements of effective

teaching presented. This is supported by Kind (2009) who suggests that PCK is not commonly known about by many Science teachers. Loughran et al. (2008) also found that exposing teachers to PCK theory helped them to develop professional knowledge and challenge traditional teaching methods. This was seen in the current study where participants discussed their strengths and weaknesses and identified goals. They also discussed their thoughts about 'reform' teaching practices as opposed to traditional methods and the video club PLC model supported the development of professional knowledge and skills.

The PCK-aligned themes which emerged in the data, as discussed in the next section, indicate that the presentation of the PCK-based teaching framework influenced the discussion, responses and therefore participants' thinking. Some participants confirmed that this was the case. Background research revealed that little is known about how teachers develop effective PCK (Kind, 2009; Townsend et al., 2016). A number of researchers (Lee & Luft, 2008; Morine-Dershimer & Kent, 1999; Townsend, 2015; Van Driel & Berry, 2012; Kyle et al., 1991; McNicholl et al., 2013) suggested that an initiative such as the one used in this study, where teachers have the opportunity to discuss beliefs, student learning and teaching practices, and reflect on their orientations and behaviours could improve their PCK. The findings of this study provide evidence to support this notion and justify further exploration of the use of such a model and the development of a PCK-based framework. Van Driel and Berry (2012) suggest that PD aimed at the development of PCK cannot be purely an exercise of information input and Schneider and Plasman (2011) claim that time in the classroom alone is not enough. Richmond and Manokore (2011) and Dogan et al. (2016) found that video-club participants increased their confidence in their SMK and PCK due to having access to knowledge of others and the ability to share their practices and reflections with a supportive community. The findings of the current study suggest that a video club model alongside a PCK-based framework could provide a vehicle for the delivery of information and implementation of change practices.

The following sections outline how effective teaching is likely due to more than just a set of knowledge and skills but is also about teacher attitude, confidence, self-efficacy and their approach towards their students. The improvements in teacher affect, confidence and self-efficacy have already been discussed (Finding 2) and it is clear that these attributes likely enhance teacher effectiveness. Decker and Rimm-Kaufman (2008) relate effective teaching ability with attributes such as having positive perceptions of their students and themselves, good relationships with others as well as enthusiasm for teaching. Not only does self-efficacy make

teachers more likely to participate in development activities but it has been found that by implementing new practices effectively and participating in the right development initiatives teachers can also increase their perceived self-efficacy (Guskey, 1988) as was found in this study.

5.4 DISCUSSION OF FINDINGS REGARDING RESEARCH QUESTION 3

RESEARCH QUESTION 3

What can be learned about effective teaching skills and knowledge through experienced teachers' participation in a collaborative video club?

Finding 7 - The skills and knowledge areas of Pedagogical Content Knowledge (PCK) - based models of effective teaching were supported.

Analysis of the data led to the identification of several themes which corresponded with elements proposed by PCK research and presented in the PCK-based teaching framework. During discussion and in the questionnaire responses participants commented on aspects of GPK, SCK and other elements associated with PCK. While the data set was small, some aspects had a greater focus than others indicating a hierarchy of PCK elements. The PCK-related themes were placed into two categories and these themes and categories are outlined below followed by some other insights into PCK coming from the results.

SCK

In this study, the questionnaire responses both at the beginning and the end explicitly referred to the importance of good science content knowledge as knowing the 'depth and breadth' of different science topics (Gess-Newsome, 1999; Shulman, 1986). At times the participants discussed their science content knowledge concerns explicitly, commenting that a lack of SCK in certain areas held them back from trying more student-centred teaching methods, or made them feel less confident and therefore reverted to a more didactic style. It is clear that SCK has an

influence on teachers' orientations and instructional choices. These findings can be linked to Grossman et al.'s (1989) statement that SCK affects the style of instruction which a teacher chooses to use, where less confident SCK leads to a more didactic style.

Most often SCK was implied when the participants discussed their strategies and their pedagogic justifications, and most participants were impressed with their ability to answer questions or explain concepts, indicating that their SCK was sufficient to do so. However, they did also discuss specific areas which they struggled to clearly articulate to students. They also discussed the importance of SCK when making links across topics and making learning relevant for students. It seems to make sense that teachers who have a strong knowledge of the content to be taught will be much more capable of making relevant links, devising strategies, representations and analogies for concepts and will be capable of directing students' learning in a much more confident and competent way as has also been expressed by Shing et al. (2018).

Participants recognised and appreciated the good SCK of their colleagues in different areas and were pleased to have support in this way through an opportunity to share expertise. Although participants discussed some areas of SCK, it was not discussed as something that they reflected on directly or set goals towards. It is not clear whether the participants noticed or reflected on their own SCK, or whether some of them were uncomfortable talking about this as a limitation or they may feel that it is difficult to address or change. It is likely that teachers are aware of limitations in their SCK even without the use of the technology, however, research about teachers' awareness of their SCK limitations, needs and how they address this is lacking.

GPK

General Pedagogical Knowledge (GPK) was a commonly discussed theme. In Chapter 2 GPK was presented as general skills teachers possess and can learn in order to plan and present material for learners. In the study, participants discussed general teaching strategies, capabilities and classroom logistics as elements they observed, set goals around and wished to make changes to as discussed in Finding 4. This encompassed things such as lesson planning and structure, organisation, giving instructions, providing skills practice, classroom management, layout, and seating plans, teacher movement around the room, distribution of resources, managing student interactions, managing transitions, checking on student learning, behaviour management, managing classroom discussion, use of questioning and wait time, organising group work and

more. These classroom and pedagogical strategies are encompassed within GPK as represented by the OECD (Guerriero, 2014) and other researchers (Gess-Newsome et al., 2019; Grossman, 1990). They also correspond with findings about effective teaching presented in Chapter 2, Table 2.2. The data supports the idea that there are some general skills and capabilities which effective teachers consider important, and that participants were likely to notice and reflect on these skills and behaviours and set goals concerning them.

Assessment

The findings show that the participants discussed assessment, particularly questioning and their use of feedback techniques, quite a bit. Background research suggested that teachers require an understanding about what is to be assessed and knowledge of different types of assessment, particularly informal formative assessment such as questioning, discussion and feedback (Magnusson et al., 1999; Park & Oliver, 2008; Townsend, 2015; Lee & Luft, 2008). Throughout the study the participants were taking part in a whole-school professional development program about Assessment for Learning (Black & Wiliam, 1998) which focuses on formative assessment used to inform and direct learning. Teachers were in the process of setting goals to implement and try new assessment and feedback strategies in their classrooms. The results show that formative assessment was an area of reflection when viewing their videos. Participants did not refer to summative or formal assessment during the study. The findings support the idea that knowledge of Assessment is important for effective teaching and that implementation of video-aided reflection, a video club PLC and a PCK-based teaching framework can serve to strengthen formal PD initiatives as suggested by Chavez (2007) and discussed in Finding 1. The participants of the study also discussed the potential for using the self-tracking video technology for the purpose of monitoring student discussion and discourse to provide insight into their understanding and to provide feedback about teaching and instruction needs.

Curriculum

This theme was the least frequently discussed or referenced, however, there was some discussion and questionnaire responses about knowledge of “what to teach” from the syllabus documents, including earlier learning, future learning and learning in other areas (science and

other areas). Shulman (1986) pointed out that teachers are expected to have knowledge of the mandated curriculum. This includes knowledge of curriculum across year levels and topics and what is considered core concepts (Gess-Newsome et al., 2019; Lee & Luft, 2008; Lee et al., 2007; Magnusson et al., 1999; Park et al., 2011; Townsend, 2015). Some comments inferred that the participants felt pressure to "deliver" a certain amount of content or curriculum outcomes, which impacts on their willingness to use innovative practices which is seen in other research (Bybee et al., 2014; (Johnson, 2009; Margot & Kettler, 2019). The fact that it was not reflected on or discussed to any great extent may be due to the participants in this study being experienced teachers who have a strong grasp of the curriculum and a shared understanding of what is required and therefore it was not a topic of discussion or concern.

Strategies and Representations

Shulman (1986) first suggested that effective teachers required good subject matter representations. This element refers to the subject- and topic-specific explanations, examples, stories, diagrams, models, analogies and activities such as demonstrations, simulations, investigations and experiments used by teachers to deliver learning outcomes (Cochran et al., 1993; Kind, 2009; Magnusson et al., 1999; Park et al., 2011; Townsend, 2015). This theme came up in some of the responses in the questionnaires and was discussed relatively frequently showing that it was something that teachers noticed and reflected on when viewing their video recordings of classes. Their confident repertoire of strategies was a source of positive feelings for some teachers; video enabled these teachers to see that they were using good strategies and particularly when they were differentiating for students. This connects well to Lee et al. (2007) and Grossman's (1990) suggestion that effective teachers will have a 'rich repertoire' of strategies which allow them to deliver appropriate learning activities in a particular context (Lee et al., 2007). The findings in this study support this background research and also suggest a link between SCK, awareness of strategies and teacher confidence.

Teacher Skills and Knowledge Relationships

SCK, GPK, SCK, Knowledge of Assessment, Knowledge of Curriculum, and Knowledge of Strategies and Representations were categorised as Teacher Skills and Knowledge. These

findings support many of the ideas about effective teaching as presented in Chapter Two and the PCK-based conceptual framework. These skills and knowledge areas are interrelated, with GPK and SCK having a greater focus in the data produced in this study, and indicating that they impact on the other three themes as shown in previous studies (Kleickmann et al., 2013).

Finding 8 – Effective teaching is related to teachers' approach to teaching and learning, specifically their understanding and approach towards students, their beliefs and orientations about teaching and learning and their personal attitude, confidence and self-efficacy.

Three more themes emerged which relate to effective teaching and teacher development. These were teachers having an understanding of their students and their needs, the beliefs and orientations teachers have towards teaching and learning, and a third element related to individual teacher attitude, confidence and self-efficacy.

Understanding of students

One of the key factors of PCK identified by Shulman (1987) was knowledge of learners and their characteristics in order to transform SCK in an effective way. Most researchers agree with Shulman (1986) that the central ideas of PCK are the transformation of subject matter knowledge and that it encompasses understanding of common learning difficulties and preconceptions of students (Cochran et al., 1993; Magnusson et al., 1999; Park et al., 2011; Park & Oliver, 2008; Smith & Neale, 1989; Van Driel et al., 1998) and this was included as part of the PCK-based teaching framework. The participants often made reference to the needs and interests of students, including the need to differentiate learning and make it relevant. Their responses showed that knowledge about or Understanding of their Students was seen as particularly important for differentiation and being able to tailor activities towards students interests and contexts.

The results of this study suggest that this element is broader than earlier models suggest and that it is not just about knowing what students understand or know but also knowing the individual students and their interests, abilities and forming relationships with them. This is supported by findings from Bybee et al. (2014) who states that effective teachers will personalise their relationships with students, treating them as individuals. It seems that it is not just an area of knowledge but also an orientation of teachers that believes in a particular approach towards the way that they deal with students. The findings also made it clear that the participants valued an

approach which encourages their students to feel positively about learning by making it engaging and applicable to their lives. For example, Sacha commented that good Science teachers will do the following:

> "They inspire students to love learning about science and the world around them. They make the content achievable by pitching it the level where they are at and supporting them to develop their understanding. Learning should be enjoyable and students should be able to see how it applies in the real world. They should make students feel safe to try and get things wrong but also confident that they can achieve." – Sacha – Q2 – Pre-study Questionnaire

The findings of this study suggest that teachers need to not only have knowledge of their students, as is suggested by previous PCK models, but be interested in them and approach teaching such that they make the learning interesting, relevant and personal.

Beliefs and orientations about teaching and learning

Another element suggested by researchers as being part of PCK is a teacher's Beliefs and Orientations towards teaching and learning. The participants did discuss their thoughts about their own pedagogical choices and beliefs about student learning. Many wanted to embrace more innovative practices but felt limited by their abilities, time pressures and were not sure if inquiry-based teaching was effective for student learning. Responses to the questionnaires expressed that being more open to reform practices was something that participants wished to develop and change but that they believed such practices were difficult and many were not sure if such methods were as effective as traditional teaching (Johnson, 2009; Margot & Kettler, 2019).

This theme could also have been placed in the Skills and Knowledge theme as it can be considered a knowledge base of teachers. The results, however, suggest that it has more to do with a teacher's individual beliefs about what works and that it influences the way that they approach teaching Science. While orientation or style techniques, goals and purposes can be learned by teachers, a teacher's beliefs and instructional goals guide many of the other teaching decisions and elements of PCK and therefore plays a central role (Grossman, 1990; Woolfolk, Hoy, Hoy & Davis, 2009) and hence it has been categorised as a teacher's approach to teaching

and learning rather than a skill or knowledge area. This is similar to Gess-Newsome et al.'s (2019) idea that it acts as a 'filter' or 'amplifier' of other elements of teaching.

Having a positive approach to teaching and learning, including professional development, took some time to emerge from the data but was consolidated during member checks as being one of the most important elements of effective teaching. The responses in questionnaires and during the discussions implied a range of positive characteristics as being required for effective teaching. The way the participants discussed the video-use and video-club also indicates a positive approach being required to embrace professional development activities. This theme supports the suggestions of Townsend (2015) and others (Lauermann, & König, 2016; Kayapinar, 2016; Park & Oliver, 2008; Sachs, 2004; Kind, 2009) that there is an affective element to effective teaching and professional development which is related to self-efficacy and confidence.

Participants expressed the need for teachers to feel positively towards their classes and students. The importance of a positive attitude also presented in the way they feel towards their colleagues and their own professional development and goal setting. The data refers to passion, motivation, interest, willingness to try new things and make learning enjoyable, and helps with collegial relationships. The results also suggest that effective teacher development requires openness to self-development and reflection. This relates to research by Bybee et al. (2014) who describes essential attributes of effective teachers as having positive perceptions of their students and themselves, good relationships with others as well as enthusiasm for teaching and patience. It seems that it is very important for both teacher development and teacher effectiveness, and was borne out by the views expressed by participants in this study.

This is an important finding as it is often overlooked when discussing teacher effectiveness and development, however, it potentially impacts on all other elements of effective teaching. This element has an important impact on teachers delivering effective lessons and the way they relate to students and prepare engaging learning activities. The PCK-based teaching framework used in this study presented this aspect as underpinning the other elements of PCK and effective teaching. It seems that this idea is supported by the results but with even greater influence and prominence than was expected. It also seems that as teachers improve their skills and take part in effective PD, their positive outlook is enhanced, indicating that there is a reciprocal effect, as suggested by Appleton (2006). The importance of this element deserves further study and it seems that schools and departments should prioritise this in order to get the best from their teachers.

Personal Attitude, Confidence and Self-Efficacy (Positive feelings)

Participants' responses and discussion supported the suggestion of an affective element of effective teaching and PCK, however with a broader meaning than that suggested by Townsend (2015). It showed the need for teachers to have a positive approach towards relationships with students and their learning, a positive approach towards their teaching activities and also their own development and learning as teachers. Results showed that these themes had implications and an impact on all other themes identified, however, it also became apparent that this element can be built up in teachers as occurred in this project. These elements can be thought of as 'filters' or 'amplifiers' as suggested by Gess-Newsome et al. (2019) and thus they have been labelled as an Approach to Teaching and Learning that impacts skills and knowledge choices.

Two other themes represented in the PCK-based teaching framework and in the background research emerged. These were initially labelled Knowledge of students' Understanding and Beliefs and Orientations about teaching and learning. A third theme was also identified regarding teachers having a positive outlook and relationships. Closer inspection of the data led to these three themes being categorised not as Teacher Skills and Knowledge but as having more to do with an individual teacher's outlook or personal approach and often influenced the decisions they made. They did not speak about them as something to be "learned" or "developed" but as coming from experience and their own personal beliefs and attitudes and so they were categorised as Approach to Teaching and Learning.

Finding 9 - Teacher skills and knowledge have a reciprocal relationship with their approach to teaching and learning and both were influenced by the video club teacher development initiative.

The analysis reveals some possible relationships and links between the identified themes and categories. Participants discussed how their skills and knowledge impacted on their beliefs and orientations and understanding of students and data showed how their confidence in their abilities influenced their self-efficacy or positive approach to teaching and learning. In this way, teachers' skills and knowledge affected their approach to teaching and learning. There is also a relationship in the reverse direction whereby teachers' understanding of their students, their beliefs and most importantly their confidence, efficacy-beliefs and positive approach impacted on their instructional choices and skills and knowledge.

The teacher development program in place was able to shape each of these other elements as well. Participants with a more positive approach were more likely to commit fully to the

process and embrace the personal development on offer. They were able to support and encourage other participants. They were also more likely to see high level skills and knowledge during video-based reflection. All participants were able to notice and reflect on their interactions with students and this was frequently a source of positive feeling for the participants. They also were able to discuss their thoughts about student-centred and inquiry-based learning, including their doubts and perceived difficulties. These relationships seem to be reciprocal, whereby the participants benefited from positive relationships such that they were willing to participate in the initiative, they were then encouraged by each other and supported to notice positive aspects of their teaching. The combination of these factors likely helped to build more positive feelings and relationships as expressed in the final questionnaire. This increase in confidence and self-efficacy had a positive impact on further development and involvement. It seems that the relationship between the three categories is reciprocal as suggested by Gess-Newsome et al. (2019) and Tschannen-Moran and McMaster (2009).

5.5 LIMITATIONS

The limitations of this study and its findings can be attributed to three main factors. The first is the small case study nature of the research and the particular setting and the participants involved, which limits the extent to which the findings can be extrapolated to other situations. The second limitation is related to this but warrants its own discussion, which is bias throughout the study. The third limitation is the nature of the data collection and analysis methods used. Each of these limitations is discussed in detail below.

5.5.1 The setting and participants

The purpose of this study was to trial a PD initiative with a particular group of teachers to determine its usefulness. The small case study design and use of participatory action research served to look closely at the thoughts, feelings and actions of the participants. As such the purpose of the study was realised. Case study research does not seek to produce findings which are generalisable (Merriam, 1998; Yin, 2014), however, information is provided about the setting and participants so that the reader can determine the extent of the applicability of the findings in other domains (Merriam, 1998; Yin, 2014).

The particulars of the setting and participants were outlined in Chapter 3, however, some points for consideration are outlined here. The participants, alongside the researcher, had very good, supportive, long-term relationships. Although the researcher was the participants' line manager a culture had been developed within the department which encouraged open, honest communication and comfortable working relationships. The school setting was also conducive to discussions about pedagogy and learning rather than about behaviour management or engagement of students exclusively.

The participants and researcher were supported by the school administration to take part in the study through time and resource allocation. The participants were also supported with the use of the technology by the researcher, and by the researcher always being available on-site, as a co-worker. The nature of the classes and students at the school also meant that the use of the technology had very little disruption to the normal teaching and parents and students were generally supportive of its use. These factors provided an environment which was conducive to a positive outcome which may not necessarily be the case in other situations. Other researchers have found that the members of a PLC make a difference (Sherin & Han, 2004) and that without good working relationships and a collegial culture such initiatives are difficult to sustain (Grossman, Wineburg & Woolworth, 2001; Borko et al., 2008). The results can therefore be considered a picture of what may be possible.

5.5.2 Data collection and analysis

There were few issues during data collection and analysis, however, some limitations may have arisen due to the nature of the information gathered; the allocation of codes and subsequent sorting of data into databits for numerical analysis; and the interpretation of the relationships.

While the quality of the data was good, the analysis of some aspects may have been limited by the questions asked in the questionnaires and the direction of the discussion during video club meetings. The researcher was not able to fully assess the role or usefulness of the PCK framework developed, as originally anticipated. The nature of the study and information collected also made it difficult to fully ascertain the level of change and whether teachers had made lasting changes in their behaviour and thinking. This is in part due to the fact that the number of meetings was less than the researcher had planned due to the busyness of teachers and the fact that change takes time. The study would need a longer time frame and perhaps more specific

targets for teachers. The data that was collected allows insight into how the teachers felt and thought about certain aspects of the video club method and effective teaching but does not allow an assessment to be made about their actual skills, effectiveness, student engagement or results, nor does it allow an objective view of their behaviours.

Several iterations of interrogating the data took place until saturation was reached and the codes, themes and categories 'made sense" (Dey, 2003). However, the techniques used including the coding and breaking the data into chunks, labelled as databits relies heavily on researcher judgement and consistency. The method of analysis whereby chunks of data were counted as data bits allowed the qualitative data to be quantitised. These are interpreted as an indication of a relationship, influence or link between those themes as suggested by Dey (2003). These relationships are suggestive only and it is important that it is not interpreted as a causal relationship. One of the main issues with this technique in this study is the limited amount of data being used and the small number of participants, meaning that the links and relationship reported are merely possible relationships requiring much more investigation.

5.5.3 Bias

Perhaps the biggest limitation in this study was the likelihood of bias creeping in during data collection and analysis and interpretation. Possible sources of bias some from the participation of the researcher, the relationship between the researcher and the participants, the relationships between the participants themselves and the use of the PCK-based teaching framework during data collection and analysis.

This study involved ethnographic participatory action research, therefore the role of the researcher was many-fold. The researcher organised and facilitated the use of the video technology as well as convened the collaborative meetings. During the meetings, the researcher led the discussion through the use of prompts and questions to gain insights from each of the participants however the meetings were allowed to flow freely and participants were encouraged to speak openly and honestly and discuss any aspect of the process that was of interest to them. The researcher also provided her own thoughts and reflections about the use of the self-tracking video and her own teaching and it is possible that this will have influenced the reflections of the other participants and shaped the flow of the discussion. It is possible that the participants' high regard for each other and the researcher may have led them to expressing overly positive views.

Another possible issue was the power relationship between the researcher and the other participants. As outlined, the researcher was the line manager of the other participants and there was some concern about the ethics of this. It was made very clear that ongoing participation was optional and that the purpose of the study was for their own personal growth as a teacher and to determine the usefulness of the technology for this purpose. It was confirmed that there would be no judgement or negative consequences through taking part. This was possible due to the long-standing positive relationships and the reciprocal, open sharing norms established. Participants were also put at ease through modelling of the process by the researcher as a participant. While the responses and data collected were likely to have been influenced by the positive relationships and the researcher as a participant it does not mean that the views expressed were invalid or untrue as the researcher's motives and experience using the technology was the same as the other participants and triangulation methods were used to confirm participants' views.

The position and relationship of the researcher with the other participants is also likely to have had an effect during analysis and coding due to the researcher's knowledge of the people involved and insight into their underlying feelings and beliefs. Webb (2000) noted that this is a limitation of action research projects and is also raised by other qualitative research observers (Merriam, 1998). However, perhaps this just makes the analysis more accurate and richer. In order to minimise bias, participant voice was used rather than solely researcher observation or quantitative measures. Member checks were also conducted as part of the collaborative discussion sessions and at the end of the study.

The themes identified are obviously influenced by the background PCK research completed and the PCK framework developed and introduced to the participants. This will have influenced the points of discussion and responses as well as the themes identified. However, this is not seen as a detrimental point as it was the purpose of the study to determine the effect of using such a framework alongside video-based self-reflection and collaborative discussion, the themes identified only serve to support PCK-based models. The discussions and observations were also influenced by the Assessment for Learning professional development being undertaken by all staff at the time of the study, which may have skewed some of their reflections and discussion points.

5.6 SUMMARY

The results indicate that the self-tracking video use and collaborative video-club model were thought to be very informative and beneficial for the teachers involved and helped them with their self-reflection, goal setting and enhanced their professional development activities. It was also seen as a positive experience and helped to build and consolidate positive feelings amongst the staff. Secondly, the results also supported many of the key elements of effective teaching as previously suggested by PCK researchers. However, they indicate that these factors are intricately interrelated and the distinction between PCK, GPK and SCK are not as distinct as many theories have suggested. They also reveal that there is another important dimension of teacher effectiveness which has been largely ignored by previous literature, that of a teachers' approach to teaching and learning. This encompasses their beliefs and orientations, their approach to students and their overall positivity and self-efficacy. In the final chapter, some conclusions about the use of the video-reflection and a video club and elements of effective teaching are proposed. This leads to a discussion of contributions, some recommendations and a final summary.

Chapter 6: Conclusions

The previous chapter discussed the findings from this study in relation to background literature and the research questions, and some of the limitations were presented. In this chapter, some overall conclusions are suggested leading to a discussion of the implications, contributions and suggestions for action and further research. Teacher effectiveness is crucial to delivering the innovative and effective pedagogy required of today's science education, and so it is hoped that the findings and conclusions of this study may go some way to contributing to an understanding of how teacher quality can be developed and what it requires.

6.1 CONCLUSIONS

The video club model implemented was perceived by experienced teachers as a beneficial form of professional development.

> "The positive observations surprised me because I didn't really like the idea of watching myself. I was also surprised by how receptive most of the other teachers were. It's also interesting that for everyone it made us more conscious of what we were doing whether the SWIVL was there or not. Generally, the positive and in-depth nature of the conversations and discussions were a good surprise." – Sacha – Q6 – Post-study Questionnaire

Teacher quality and development is critical to enable effective, innovative teaching which is required to deliver today's expected student learning outcomes (Kamener, 2012; Osborne et al., 2003; Osborne & Dillon, 2008; Tytler, 2007). In-service teachers' professional growth requires reflection-on-action, appropriate PD and professional collegial support (Rich & Hannafin, 2009; Jones, 2008). In this study the use of video-based reflection and a supportive PLC, in the form of a video club, was found to be beneficial for aiding teacher self-reflection, supporting goal setting and tracking their progress of change in practice. This conclusion draws support from previous research about video use and video clubs (Abell et al., 1998; Borko et al., 2008; Chavez, 2007; Eröz-Tuğa, 2012; Harlin, 2014; Rosaen et al., 2008; Sherin & van Es, 2005; Tripp & Rich,

2012a; Tripp & Rich, 2012b; van Es, 2010). The participants considered the initiative worthwhile and were willing to continue to use the technology but reported that they required support in the form of setting up equipment, time for PLC meetings and guidance and direction from the school leadership.

The approach taken in this study aligned with previous research into effective professional development (PD) which suggests that the best models are based in-school or in-the-classroom, foster collaboration and social learning, allow teacher 'ownership' and focus on individual concerns; promote reflection which challenges beliefs and enhances consideration of student learning and is ongoing with support (Guskey, 2003; Jones, 2008; Korthagen, 2004; Magnusson et al., 1999; Whitworth, & Chiu, 2015; Yoon et al., 2007). The video club method used in this study provides a model of PD that meets these criteria and the participants reported that it was an effective form of PD. They felt that the protocol was beneficial as personal PD allowing them to focus on individual goals. They also discussed its use to support other forms of PD such as tracking the progress of skills and practices presented in formal PD or being used to support and facilitate teacher collaboration and sharing practices. Many felt that the process could replace some other forms of PD, freeing up teacher time and making sharing practices more meaningful. As the study progressed participants developed confidence with the video-reflection and developed an openness to sharing their video excerpts with a PLC for the purpose of development of practice.

Figure 6.1 shows a tentative representation of how the video club protocol is related to teacher self-reflection, leading to enhanced goal setting and complementing formal PD activities. It shows the important relationship between self-reflection, goal setting and PD. The findings in this study showed that the video club model was felt to be an effective tool for self-reflection which then benefitted the other elements. For this reason, the video club concept has been placed within the self-reflection element but with links to goal setting and PD. How this is linked to other findings is shown later.

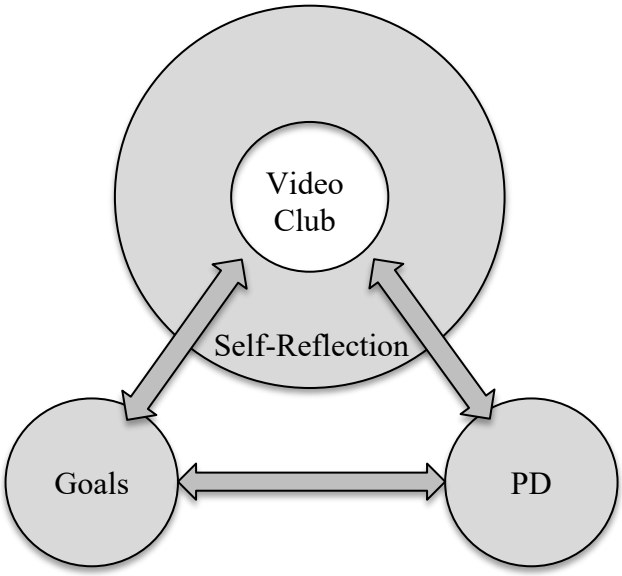

Figure 6.1. Representation of teacher development themes and their relationships.

Student-centred, inquiry-oriented teaching and learning activities are lauded as the ideal teaching practice in many systems around the world (Anderson, 2002; Driver et al., 1994; Marginson et al., 2013; Office of the Chief Scientist, 2014; Park et al., 2011; Rennie et al., 2001). It has been widely recognised that this type of teaching requires more from teachers and many lack the required beliefs, skills and understanding of what is involved (Johnson, 2006; Johnson et al., 2007; Johnson et al., 2012; Park et al., 2011; Rennie et al., 2001). Previous researchers suggest that to help teachers improve, a deep understanding of personal theories, or beliefs, about teaching and learning is needed (Abell et al., 1998; Blumenfeld et al., 1991; De Boer, 2000; Johnson, 2009). This is considered a conceptual change view, it requires finding ways to challenge thinking, which can be done through the use of reflection to develop new understanding and reframe problems. Teachers need support to consider their beliefs and values and develop their skills and confidence. This study has shown that video-aided reflection and a supportive PLC led participants to consider their beliefs and orientations to a greater degree, with participants discussing their reflections and concerns about using some forms of student-centred learning. It shows that a video club protocol has some potential for helping teachers to examine their beliefs and think about their orientations and consider what may be best for their students.

It is possible that if teachers are willing to try different teaching methods and engage in reflection through participation in a program such as this, they may be more likely to adopt a range of pedagogical approaches to include more inquiry-oriented learning, with a critical awareness that one pedagogy is not necessarily better than another (Banilower et al., 2010).

Townsend (2015) suggests that a teacher should be able to select from a range of teaching approaches and Hattie (2008) presents the view that it is not a case of traditional teacher-centred learning being "bad" and constructivist, child-centred approaches being "good" but that effective teachers will use a range of appropriate strategies to suit the context and learning objectives.

It was clear that a positive approach to teaching and learning was an important characteristic of teachers and this was seen in the way the participants approached their own learning and development as well. This positive approach was enhanced by the supportive PLC video club (Borko et al., 2008). The participants were able to encourage and build each other's confidence in order to use the video technology and to observe their own positive behaviours. In doing so, each teacher developed a more positive attitude towards the PD initiative. The participants were also buoyed by the discussions which allowed them to see that their experiences and feelings were similar to others'. When the teachers were able to reflect more subjectively on their teaching they were also pleased to see many good behaviours and learning activities taking place as well as areas for improvement. All of this helped to build confidence which research shows is linked to self-efficacy and can help teachers' willingness to develop and adopt 'reform' teaching practices (Margot & Kettler, 2019; Rennie et al., 2001; Whitworth & Chiu, 2015). Many of the participants reported that the process renewed their enthusiasm and passion for Science teaching (Woolhouse & Cochrane, 2010).

Teacher effectiveness can be broken-down into PCK-based skills and knowledge as well as a teacher's individual approach to teaching and learning

> "I appreciate more the importance of science content knowledge but also personal attributes and knowledge of the students in front of you. There is no one correct methodology or orientation as this should change but that students need to be given more responsibility for their learning and teachers should be there to inspire, motivate and guide." – Sacha – Q9 – Post-study Questionnaire

The study allowed insight into experienced teachers' thoughts and discussions about effective teaching, leading to a proposition that teacher effectiveness is made up of teacher's skills and knowledge and contributed to by their approach to teaching and learning. This is based

on a rearrangement of PCK ideas and the framework presented at the beginning of the study. The preliminary findings of this study in this area provide a basis for further research.

The analysis of the data identified themes which correspond with teachers' skills and knowledge areas as suggested by various PCK research (Cochran et al., 1993; Kind, 2009; Lee & Luft, 2008; Magnusson et al., 1999; Park & Oliver, 2008; Park et al., 2011; Shulman, 1986; Townsend, 2015). The participants in this study identified GPK and SCK as being important areas required for effective teaching and these were seen as areas for further development and as having an impact on other skills and knowledge. Teachers' strategies and representations were also seen as very important and participants were pleased to see these in action, leading to positive feelings. Participants also discussed their goals with regard to knowledge and skills in assessment and their concerns about curriculum requirements.

A tentative representation of the teacher skills and knowledge themes identified in this study is presented in Figure 6.2. It shows how SCK is seen as central to effective teaching and needs to be well-developed and that GPK builds on this, also playing a fundamental role in effective teaching. The diagram represents the findings which suggest that both SCK and GPK influence the other skills and knowledge areas, specifically, knowledge of curriculum, assessment and strategies and representations. It symbolizes how if SCK or GPK are lacking, as when teachers teach out of their specialist area or have less experience in the classroom, then teachers will have less to draw on within these other knowledge areas. It is these areas of teacher skills and knowledge where a lot of PD and teacher training is directed (Cochran et al., 1993; Hattie, 2008) and while the development of these skills has impact and influence on teaching effectiveness the results also suggest other elements that contribute to effective teaching. Townsend (2015) suggests that effective teachers will have an integrated version of PCK and a PCK-based conceptual framework could serve as a PD guide. Upon final member checks with the participants, they were keen to see the effective teaching findings presented in a way which could be of use in the future.

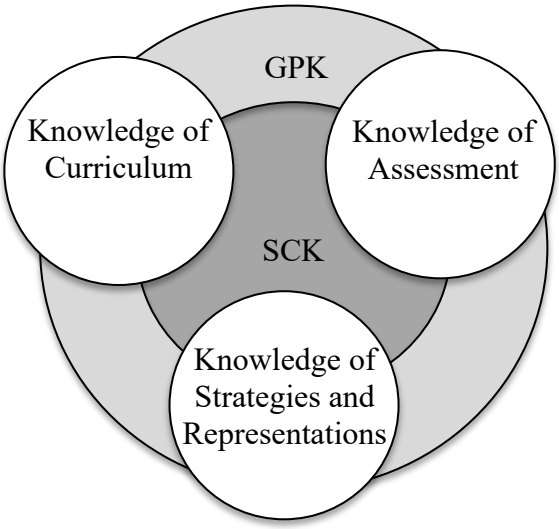

Figure 6.2. Representation of Teacher Skills and Knowledge themes and their relationships

The other findings which influence the way teachers enact their skills and knowledge are related to their approach to teaching and learning. Participants identified many elements of effective teaching as related to knowing their students, making learning engaging and relevant for them, differentiating and being interested in their lives. They also discussed their beliefs about student learning and orientations or goals for teaching and learning. In the original framework and background research (Kind, 2009; Lee & Luft, 2008; Magnusson et al., 1999; Park & Oliver, 2008; Shulman, 1987; Smith & Neale, 1989). these elements were presented as being similar to the skills and knowledge themes discussed above however the manner in which these themes were discussed implied that they consisted of more than learned knowledge and were actually based on personal teacher beliefs, outlook and attitudes. Another theme in this category was teachers' positive approach and confidence which came across as passion, interest, enthusiasm and positive relationships with students and colleagues. Others suggest that self-perception and confidence play an important role (Appleton, 2006; Pajares, 1992). Bybee et al. (2014) state that a teacher's "perceptions of self, students and the teaching task are critical to effective instruction" (p. 24). This follows suggestions by Kind (2009) and Townsend (2015) who suggest an element of PCK as well-adjusted emotional attributes; and Decker and Rimm-Kaufmann (2008) and Bybee et al. (2014) who state that effective teachers require positive perceptions and relationships with students and colleagues as well as enthusiasm and flexibility.

This positive approach to teaching and learning regarding the understanding of students, beliefs and orientations and personal attitude are seen to influence the way that skills and knowledge are enacted and while teachers can learn techniques and ideas associated with them

they are more influenced by a teacher's experience, personality and outlook and their self-efficacy. Self-efficacy was suggested by Bandura (1994), which has been related to higher student achievement (Whitworth & Chiu, 2015) and teachers' persistence in the face of difficulty (Lauermann & Konig, 2016; Sachs, 2004) and tends to be higher in more experienced teachers (Whitworth & Chiu, 2015). Tschannen-Moran and McMaster (2009) report that self-efficacy influences effort and persistence as well as thoughts and emotions influencing behaviour. Mintzes et al. (2013) state that lower self-efficacy is related to reduced goal setting and avoidance of difficult tasks. Tschannen-Moran and McMaster (2009) and Kopcha and Alger (2011) both stress the importance of investigating more about self-efficacy as it plays an important role in teachers' implementation of new and effective teaching strategies. Gröschner et al. (2018) report that there is little research about cycles of video reflection and its effects on self-efficacy. The results of this study suggest that such an initiative can serve to help develop a teacher's self-efficacy and seems to support the notion of a reciprocal relationship between self-efficacy, video-reflection, PD and development of effective teaching.

The background research showed PCK to be an enticing idea, however, many researchers point to the difficulty of precisely explaining what it is (Loughran et al., 2004). Cochran et al. (1993) state that PCK is "the manner in which teachers relate their pedagogical knowledge (what they know about teaching) to their subject matter knowledge (what they know about what they teach), in the school context, for the teaching of specific students" (p. 4). This study presents evidence that many teachers are unfamiliar with the concept of PCK (Bertram & Loughran, 2012), consequently observing or reflecting on the articulation of PCK in one's practice is difficult. Van Driel et al., (1998) state that PCK is a type of 'craft knowledge' that is an integrated knowledge form which guides teachers' actions in practice.

The findings of this study suggest that rather than focusing on PCK it may be useful to consider the skills and knowledge which teachers have and can develop, and the factors which influence the way they enact these skills or approach teaching and learning. It is also pertinent to consider how these skills, knowledge and approach to teaching and learning elements can be developed. In this study five essential skills and knowledge themes were identified. SCK and GPK were seen as essential to be able to interpret curriculum and use effective strategies, representations and assessment. Three other themes were identified as related to a teacher's approach to teaching and learning, these were understanding of students, beliefs, orientations and positive approach, confidence and self-efficacy.

The findings suggest a reciprocal and overlapping relationship between each of the themes pertaining to a teacher's approach to teaching and learning, which could be represented as shown in Figure 6.3. Participants' responses in this study suggest that a teacher's beliefs and orientations towards teaching and learning, their approach towards their students and their own personal attitude, confidence and self-efficacy, or positive feelings, are dependent on the individual teacher and their experience, personality, stage in life, environment and other personal factors potentially giving each one different weight, focus and expression.

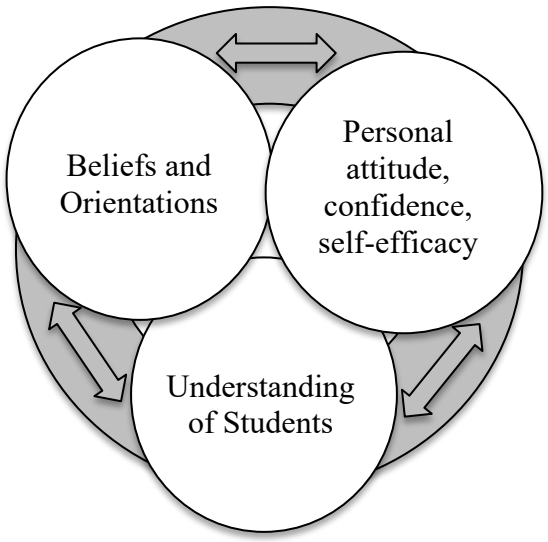

Figure 6.3. Representation of Teacher's Approach to Teaching and Learning themes and their relationships

The findings further suggest that these two categories of skills and knowledge and approach to teaching and learning have a reciprocal effect on each other. A teacher's approach will influence their enactment of their skills and knowledge but also as a teacher's skills and knowledge develop their beliefs, confidence and approach can change and develop. Other researchers (Appleton, 2006; Bybee, 2010; Pajares, 1992; Townsend et al., 2016) also suggest that teacher confidence and beliefs about their own abilities (i.e.., their self-efficacy), are not only essential for employing and transforming their skills and knowledge effectively but that development of their skills and knowledge has a positive influence on their self-efficacy and beliefs.

Kind (2009) suggested three key factors required for good PCK: possession of good subject matter knowledge (SMK); classroom experience; and, emotional attributes such as good levels of personal self-confidence, provision of supportive working atmospheres, and collaboration. The results of this study support this notion showing that the use of video-reflection and a video club PLC is capable of inducing a change in both a teacher's skills and knowledge and their understanding of students, their beliefs and orientations and their confidence and self-efficacy. Importantly the findings also suggest that this is a reciprocal relationship, whereby, as teachers improve their confidence and self-efficacy as they are made aware of their capabilities and improvements in their skills, knowledge and practices they are more likely to continue pursuing professional development opportunities. This supports a social, constructivist model of change as presented by Bandura (1994), Guskey (1988, 2003) and Korthagen (2004, 2017) and others (Kwasnicka et al., 2016; Whitworth & Chiu, 2015).

The initial background research led to the synthesis of PCK research to produce a PCK-based teaching framework. The effect of the use of this framework was not fully evaluated during this study, however, the elements contained in it emerged from the data as being important for effective teaching suggesting that it had some merit. However, the findings lead to a suggested rearrangement of the PCK-based teaching framework which includes teacher skills and knowledge, their approach to teaching and learning and teacher development processes. This suggested rearrangement is seen in Figure 6.4. It shows the likely reciprocal relationship between the three categories. As skills and knowledge become more proficient it is probable that personal attributes such as self-efficacy and confidence improve and understanding of students develops leading to possible changes in beliefs and orientations. These in turn have the effect of teachers being open to developing their skills and knowledge further and accessing PD opportunities to do so. It also represents how PD opportunities which encourage self-reflection and collaboration can help teachers to develop in both areas. Whitworth and Chiu (2015) also found that self-efficacy is positively correlated with teacher change and professional development lending further support to this model.

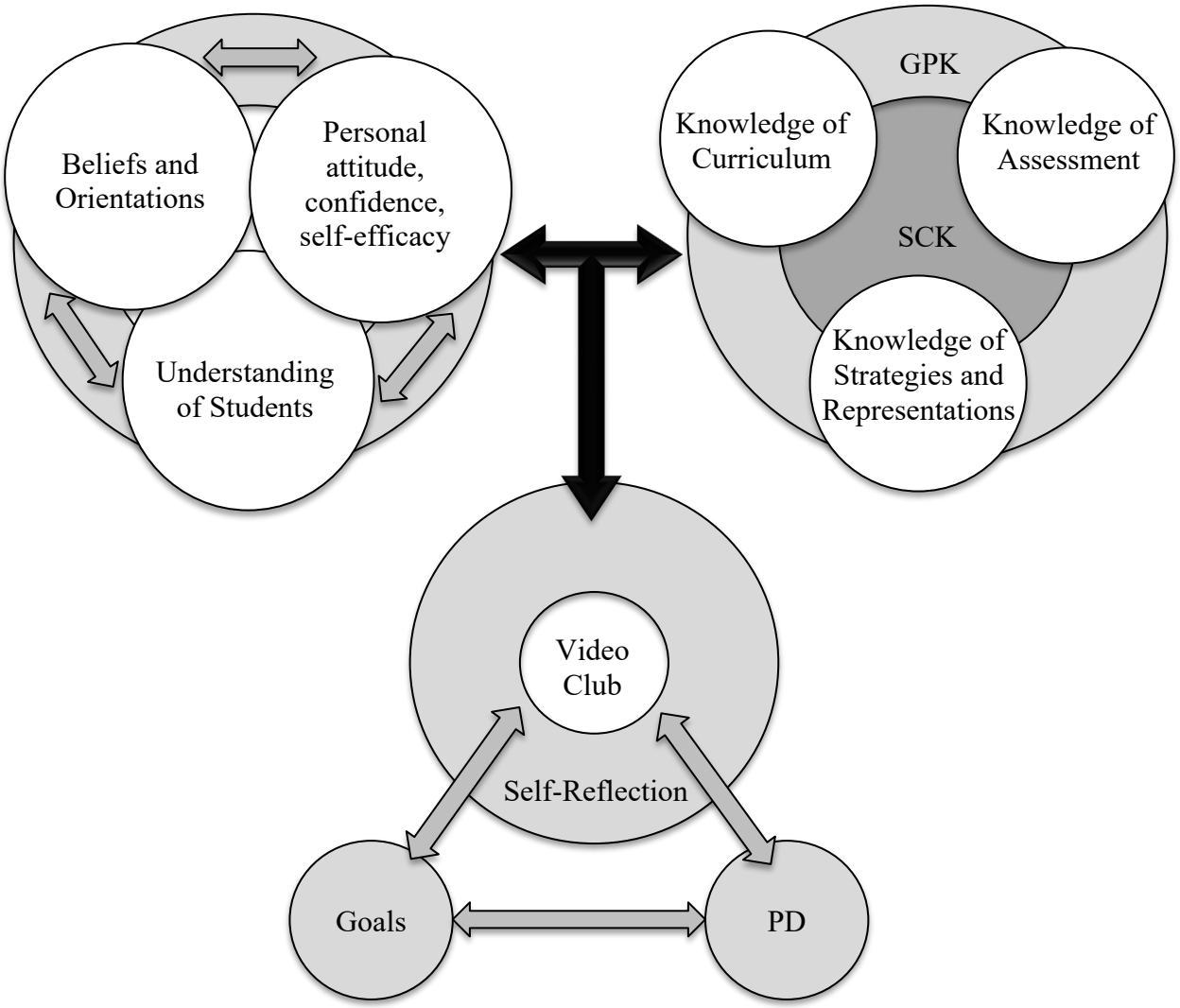

Figure 6.4. Representation of relationships between the three categories of themes influencing teacher effectiveness.

The development of a framework was recognised as being useful by the teachers participating in this study and other researchers also advocate for documenting what effective teachers do for the purpose of further research, teacher development and training and self-reflection (Abell, 2008; Gess-Newsome et al., 2019; Loughran et al., 2001; Townsend, 2015). The initial PCK-based teaching framework is aligned relatively closely with the Australian Institute for Teaching and School Leadership (AITSL) standards (AITSL, 2013). However, Townsend (2015) implies that the standards lacked a complete picture. Comparing the reorganised framework representative of the findings of this study, with the AITSL standards shows that the latter lacks attention to teacher's individual attributes, beliefs and circumstances

which shape their approach to teaching and learning and their own development. This study suggests that these concepts need to be recognised in order to get the best out of teachers in the classroom.

6.2 IMPLICATIONS AND CONTRIBUTIONS

The conclusions of this study suggest that the use of self-tracking video by the participants alongside a supportive PLC was a valuable development tool for teachers. While generalisation is not an aim of this type of study it does suggest that it could be implemented in a broader population alongside or in place of other professional development programs. This could have many potential positive implications with little risk. In many cases, this type of initiative could be used in schools at little cost and could actually save money and teacher time. It could be used to replace some professional development already occurring and would very likely add value to many formal professional development courses. This model is likely to be useful for a broad cross-section of teachers from different learning areas, teachers at primary school and perhaps tertiary level and particularly regional and remote teachers, however, this warrants further exploration.

This study offers suggestive evidence for the importance and inclusion of an affective or personal element to effective teaching frameworks. It seems that a teacher's approach towards and beliefs about teaching and learning is a very important element in being an effective teacher. This includes the relationships that they form with students and their colleagues and the way that they approach their own professional development. It seems that what is required is a positive, open approach which takes into account the individual needs of the students, class, teacher and the learning goals. Teachers' personal attitude, confidence and self-efficacy were also linked with the other teacher development themes and suggests that a positive attitude supports teachers to be able to embrace the use of self-tracking video technology. Conversely, the methods used such as video technology and collaborative discussion through a "video club" could have the capacity to also build a teacher's confidence and self-efficacy and thus have a huge impact on all other areas.

6.3 RECOMMENDATIONS

> "Everyone should SWIVL as a way to develop their teaching" – Chris – Q11 – Post-study Questionnaire

The small case-study design of this study limits the generalisability of the findings, as such there are areas where further research is warranted. However, the results also suggest a number of positive actions which could be undertaken and are likely to improve teaching within schools and outcomes for teachers.

6.3.1 Actions

The results suggest that teachers are likely to take an interest in their own professional development and implementation of effective teaching when they are in a supportive environment. This requires positive relationships with their immediate colleagues, a level of trust and logistical support from administration and safe, positive classrooms. PLCs are commonly used within schools, however, the results suggest that the makeup of these and the way that they are guided is important. Teachers need to feel safe and supported.

The research also provides evidence that the use of self-tracking video by teachers is beneficial for encouraging self-reflection and can promote positive feelings when implemented in a supportive, non-judgmental, teacher-directed way. Many schools have adopted PLCs as part of their professional development activities (OFSTED), this study showed that self-tracking video reflection can enhance discussions of PLCs as well as enhance teachers' individual reflection. This can support current PD initiatives in place in a school. Individual teachers can also use it to determine their PD needs. It is important to note that Finding 3 regarding the importance of support, mentoring, the school administration and school culture would suggest that use of video technology needs to be well-supported by learning area leaders, the school administration and the culture of the school. Implementation needs to be supported in such a way as to promote positive relationships and outcomes so that teachers feel that they have ownership of the process and the goal is personal teacher reflection rather than assessment and judgement (Grant & Kline, 2010; Sherin & Han, 2004; Woolhouse & Cochrane, 2010). It should also be noted that Sherin and Han (2004) found that group members matter when putting together effective PLCs and this study shows that they can be effective when members have a good working relationship.

6.3.2 Research

The use of the video-club and self-tracking video technology in this study had positive results for the participants. It would be useful to test this initiative with other groups of teachers to determine its benefits across a larger group, and in similar and different learning areas and school settings. Research could extend to secondary school teachers in other learning areas as well as at other schools in other sectors. It would also be useful to determine if there was a difference for experienced teachers versus pre-service and early years teachers and the effect of having mixed experience groups. Primary school teachers and tertiary-level educators may also benefit from being included in future research. In this study the close, supportive relationships of the participants were further strengthened and proved to be beneficial for the goals of the study, therefore the make-up of different groups and the effect of this would be interesting. The educational context and student socio-economic base likely also played a role.

This research would also benefit from trialling the model over a longer time period to gain greater insight into sustained changes in teachers' beliefs, thinking and behaviour; and practices. Blomberg et al. (2013) found that improvement using video reflection takes time. This would likely involve an evolving model of implementation as teachers begin to use it in different ways. It could be linked with whole school PD programs or trialling of particular pedagogical initiatives. There is also the potential for such a model to be of use for supporting regional and remote teachers' access to PD by creating networks who can support each other and discuss their reflections virtually as suggested by Townsend (2015). These virtual PLCs may allow such teachers to participate in effective professional development activities.

The themes identified and their tentative relationships have the potential to guide further research into the elements of effective teaching. Background research informed the production of the PCK-based teaching framework used throughout the study. This study supported many of the ideas about effective teaching put forward by PCK researchers as presented in the background research and some conclusions have been suggested about their reorganisation and other inclusions. Abell (2008) identified investigations of master teachers' ideas about PCK as a gap in the knowledge, this study offers a contribution in this area which could stimulate further research. The participants considered that a framework representing effective teaching skills and knowledge, and other influences was of use and so further research may go some way towards this. A number of previous researchers also recommended a guide, rubric or PCK-based continuum of effective teaching.

Another finding in this study is the importance of a teacher's personal attitude and their approach to teaching and learning. This seems to be related to teacher confidence, self-efficacy, passion and drive to improve, all of which depend on a positive affect. It also seems to influence a teacher's willingness to adopt innovative teaching practices and form positive and supportive relationships with other teachers. There are many elements at play within this finding and as such requires a lot of unpacking. This is unlikely to be surprising to many teachers, however, policy, teacher standards and school expectations often do not seem to recognise the importance of teacher self-efficacy and what contributes to it.

6.4 AUTOBIOGRAPHICAL REFLECTIONS

The rationale for this study was based on the researcher's own desire to look at what makes Science teachers effective in an effort to improve her own teaching and support her team members to develop their teaching. This came out of the current emphasis globally on the importance of STEM education, 21st Century skills, and student-centred, inquiry-based learning as well as the need for scientific literacy. In the current educational system it is very difficult for Science teachers to deliver all of the perceived outcomes expected of them. It was, and remains, the view of the researcher that balance is required in terms of the educational approaches used and that the greatest outcomes will be achieved if teachers can instil in students a love of Science and interest in science learning such that they will develop the skills required, whether they go on to become scientists or merely retain an interest in global developments. The findings of this study only served to make this more apparent and that what teachers need in order to be effective is the space and time to think about their own teaching and discuss teaching and learning with like-minded colleagues. In a supportive, reflective, positive environment, teachers can improve their confidence and realise or reignite their passion and interest in topics and their students. Through this, it is the researcher's belief that they are more likely to teach in such a way that benefits students, embrace new ideas and maintain a positive attitude towards the changing nature and pressures of teaching. The implementation of such initiatives as that used in this study requires a leap of faith by school administration to trust their staff and the development of a positive teacher development culture. All teachers want to do the best job that they can and just like the students in any classroom the needs and willingness to change of each teacher is different requiring an individual approach utilising various methods with appropriate guidance and support.

6.5 SUMMARY

> "Re-energised my enthusiasm for Science teaching to a higher standard" – Kelly – Q10 – Post-study Questionnaire

> "I think this is very rewarding and productive" – Aidan – Q5 – Post-study Questionnaire

The background research presented showed how the purposes, goals and requirements of an effective Science education today places Science teachers in a position which requires them to expand and change their teaching beliefs, develop their skills and approach planning and assessment in new ways. Studies suggest that teachers need to be 'confident', 'inspiring', 'positive' and 'dynamic' (Margot & Kettler, 2019; Office of the Chief Scientist, 2014). However, Margot and Kettler found that the beliefs that teachers have about their own skills determine their confidence and thus their effectiveness in implementing innovative pedagogy and curriculum.

This study presented a way that experienced Science teachers could reflect on their teaching using video technology and then through the support of a video club PLC were able to notice positive behaviours and practices in the classroom and set goals for improvement. The results indicated that the combination of these activities was seen as a growth experience and made teachers feel more confident and positive and enhanced their collegiality. This led to further willingness to develop their skills. The process also led to the participants discussing their beliefs and concerns about innovative pedagogy and demonstrates the potential of a constructivist or conceptual change view of teacher development.

Although the sample was small, it did allow insight into experienced teacher's thoughts about effective teaching. The results suggest that teachers require a set of skills and knowledge which enable them to employ a range of pedagogical practices, these can be learned and developed in in-service teacher training and professional development activities. The way a teacher enacts and develops their skills and knowledge is influenced by their personal approach to teaching and learning. This is made up of their beliefs and orientations towards teaching and learning and what works, their understanding and relationship with students and their personal attitude, confidence and self-efficacy. The way a teacher approaches teaching and learning, including their own development, can be supported through PD but is likely influenced more through experience, positive relationships and school culture, positive self-reflection activities and general well-being. These ideas are largely ignored in effective teaching frameworks, however this study indicates that it warrants further attention. As Kamener (2012) points out,

quality teaching is essential to student outcomes but it is a complex issue comprising individual teacher qualities and effective on the job performance and development.

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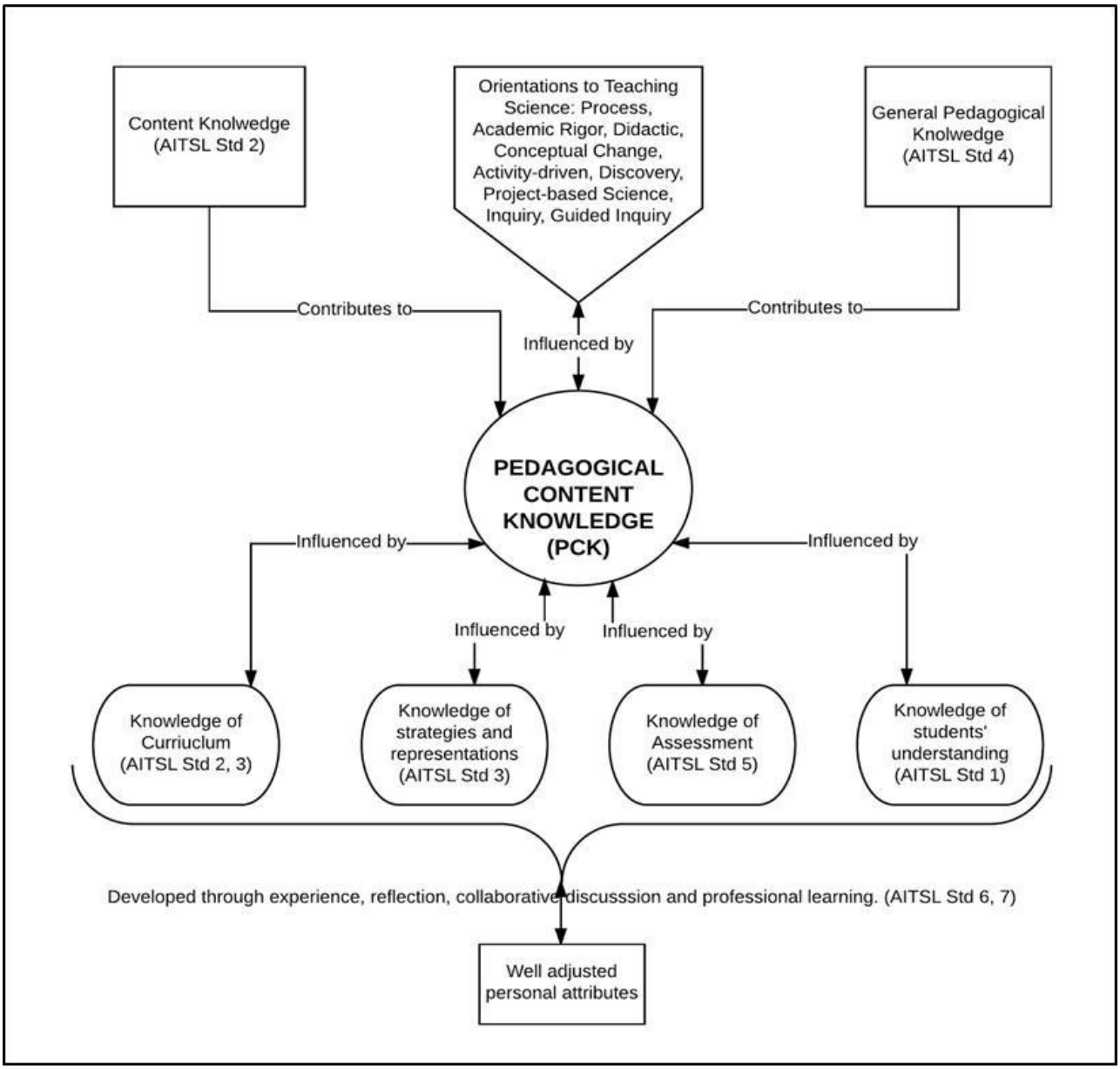
Appendices

Appendix A

PCK-Based Teaching Framework



A conceptual framework used to represent the elements and contributing knowledge types to PCK mapped to the AITSL standards (see Appendix A and B). Based on Shulman (1986), Kind (2009), Magnusson et al. (1999), Park & Oliver (2008) and Townsend (2015).

Appendix B

Teacher Participant Information Letter and Consent Form

Edith Cowan University
School of Education
2 Bradford Street
MT LAWLEY WA 6050
Phone: 134 328
Researcher: Ms Dallas Bruce [redacted]
Supervisor: Dr Jenny Lane [redacted]

INFORMATION LETTER FOR TEACHER PARTICIPANTS

Dear Teacher,

Improving science teaching through the use of video reflection and a pedagogical content knowledge framework.

As part of my Masters by Research (Education) through Edith Cowan University I am seeking participants for a research project. The title of the research is "Improving Science Teaching Through the Use of Video Reflection and a Pedagogical Content Knowledge Framework".

The purpose of this research is to explore the use of video technology and reflection by experienced, practising science teachers. Through this research, I aim to provide a safe and supportive environment where like-minded teachers can reflect on their own teaching after watching a video of themselves teaching and participate in collaborative discussion and exchange of ideas, this is called a video-club model. The process is not one of judgement but instead aims to provide a means of professional development and learning for teachers.

Expectations will be to participate in meetings approximately twice per term with the view to recording and reflecting on at least one lesson of your choosing to discuss with the group over the course of the study. A guideline for reflection and discussion will be provided, and teachers will be supported through the process. These "video-club" meetings will take place during school time, with relief provided. This kind of reflection has been shown to be very beneficial to teachers.

Data collected will include short questionnaires, recorded and transcribed interviews as well as transcribed audio recordings of collaborative discussions and meetings. This data will be collected with the aim to gain an understanding of the thought processes, feelings and ideas of the teachers involved. A framework based on Pedagogical Content Knowledge (PCK) will be used as a lens for discussion and analysis. The data collected will be combined, coded and analysed to determine whether this type of activity is valuable to teachers and be used to present a research thesis for the purpose of gaining my Masters by Research. All video data recorded will remain your own private property and can only be viewed by yourself and those you wish to share it with.

Participation is completely voluntary and participants' anonymity will be protected. You will have the right to withdraw from the study at any time without penalty or recourse. This study has been approved by the Human Research and Ethics Committee of Edith Cowan University

and the appropriate risk analysis has been completed. It can also be counted towards professional learning hours.

If you would like further information, I am happy to discuss this research or provide you with greater detail. If you would like to take part please read and sign the attached Consent Form.

If you have any concerns or complaints about the research project and wish to talk to an independent person, you may contact:

Research Ethics Officer
Edith Cowan University
270 Joondalup Drive
JOONDALUP WA 6027
Phone: (08) 6304 2170
Email: research.ethics@ecu.edu.au

Sincerely,

[redacted]

Ms Dallas Bruce
[redacted]

31 July 2017

Edith Cowan University
School of Education
2 Bradford Street
MT LAWLEY WA 6050
Phone: 134 328
Researcher: Ms Dallas Bruce [redacted]
Supervisor: Dr Jenny Lane [redacted]

TEACHER PARTICIPANT CONSENT FORM

Improving science teaching through the use of video reflection and a pedagogical content knowledge framework.

I, ... [PRINT NAME], agree to take part in this research study for the purpose of Masters by Research (Education).

In giving my consent I state that:

I understand the purpose of the study, what I will be asked to do, and any risks/benefits involved.

☑ I have read the Participant Information Statement and have been able to discuss my involvement in the study with the researcher if I wished to do so.

☑ The researcher has answered any questions that I had about the study and I am happy with the answers.

☑ I understand that being in this study is completely voluntary and I do not have to take part. My participation in the study, or decision not to, will not affect my relationship with the school or the department now or in the future.

☑ I understand that I can withdraw from the study at any time without penalty.

☑ I understand that personal information about me that is collected over the course of this project will be stored securely and will only be used for purposes that I have agreed to. I understand that information about me will only be told to others with my permission, except as required by law.

☑ I understand that the video data collected of me will be viewed only by me and those that I give consent to.

☑ I understand that the results of this study may be published, and that publications will not contain my name or any identifiable information about me.

....

Signature **Date**

Appendix C

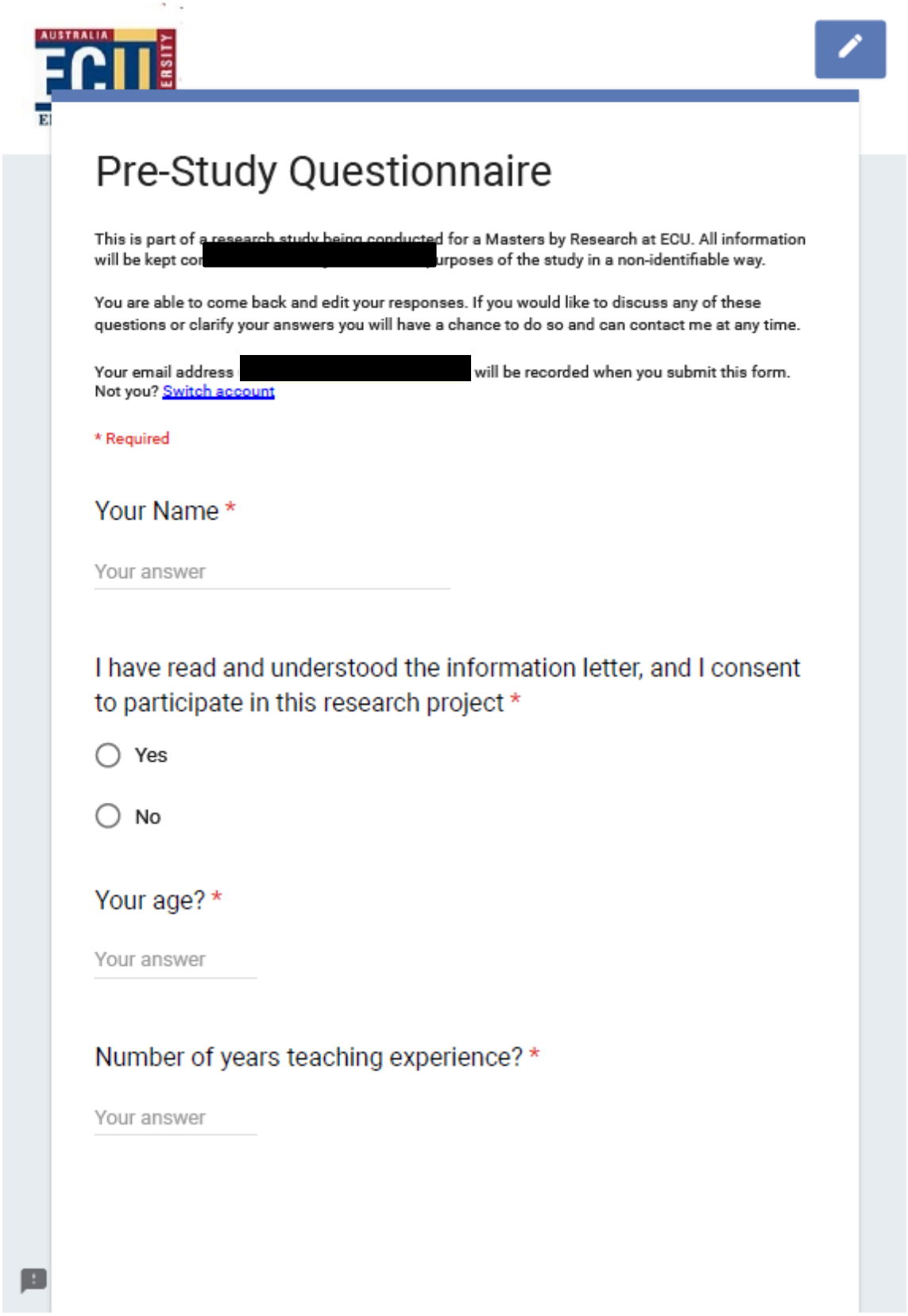
Physical Resources Used

SWIVL device	The participants and researcher had access to a C5 SWIVL robot with marker and built-in microphone and flor stand. The SWIVL holds an iPad (or other similar device) and is able to pan around to track the movements of the person with the marker while the iPad records.
iPad with SWIVL app	The researcher and participants had their own iPads with the SWIVL app downloaded. The SWIVL, iPad with the app and the marker allows for visual and audio recording as the teacher moves around the room. The recording then gets saved in the SWIVL cloud in an individual, password protected account. From there the video could be shared or downloaded. The researcher facilitated the collection of video on her own iPad and then shared the video with the participant before deleting it from her iPad and cloud account.
Audio recording equipment	The researcher used and audio recording app on her phone to record video club meetings.
Portal for dissemination of questionnaires	Google forms was used to create and share the pre-study and post-study questionnaires. The responses were collated automatically in Google Sheets.

All data was stored electronically on a secure password protected computer.

Appendix D

Pre-Study Questionnaire



Pre-Study Questionnaire

This is part of a research study being conducted for a Masters by Research at ECU. All information will be kept con [redacted] urposes of the study in a non-identifiable way.

You are able to come back and edit your responses. If you would like to discuss any of these questions or clarify your answers you will have a chance to do so and can contact me at any time.

Your email address [redacted] will be recorded when you submit this form.
Not you? Switch account

* Required

Your Name *

Your answer

I have read and understood the information letter, and I consent to participate in this research project *

- Yes
- No

Your age? *

Your answer

Number of years teaching experience? *

Your answer

Qualification(s)? *

Your answer

Science year levels taught? *

Your answer

What do you consider to be your specialist areas? *

Your answer

Q1. In what areas of your teaching do you feel most confident? Explain. *

Your answer

Q2. What do you think good science teachers do? *

Your answer

Q3. What skills and knowledge do good science teachers need/possess? *

Your answer

Q4. What strategies do good science teachers use? *

Your answer

Q5. What do you think sets expert or very accomplished science teachers apart from others? *

Your answer

Q6. What areas of your science teaching would you most like to improve? *

Your answer

Q7. Have you been exposed to the concept of Pedagogical Content Knowledge (PCK)? If yes, what do you know about it and its use? *

Your answer

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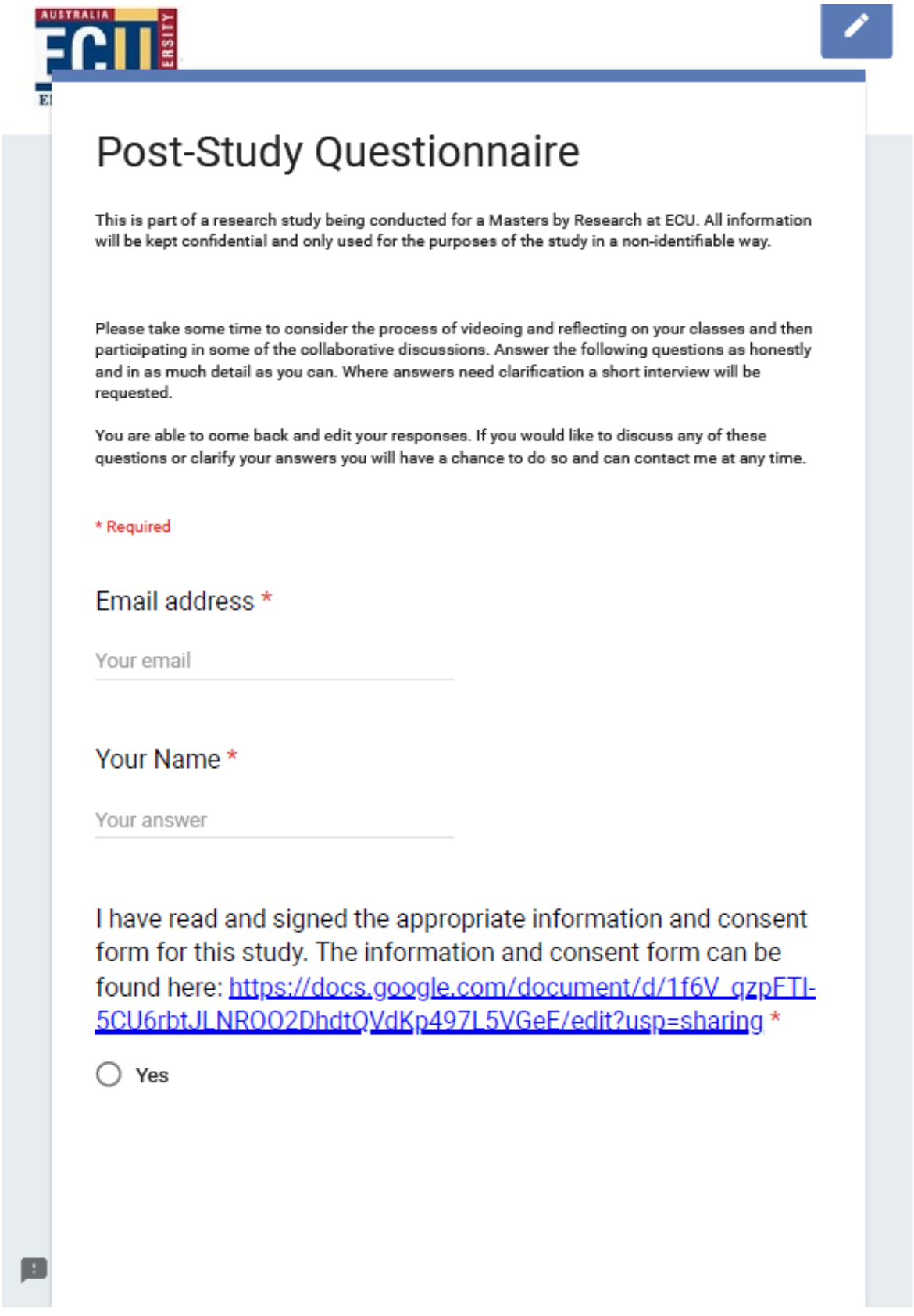
Appendix E

Post-Study Questionnaire



Post-Study Questionnaire

This is part of a research study being conducted for a Masters by Research at ECU. All information will be kept confidential and only used for the purposes of the study in a non-identifiable way.

Please take some time to consider the process of videoing and reflecting on your classes and then participating in some of the collaborative discussions. Answer the following questions as honestly and in as much detail as you can. Where answers need clarification a short interview will be requested.

You are able to come back and edit your responses. If you would like to discuss any of these questions or clarify your answers you will have a chance to do so and can contact me at any time.

* Required

Email address *

Your email

Your Name *

Your answer

I have read and signed the appropriate information and consent form for this study. The information and consent form can be found here: https://docs.google.com/document/d/1f6V_qzpFTI-5CU6rbtJLNROO2DhdtQVdKp497L5VGeE/edit?usp=sharing *

Yes

1. After watching and reflecting on yourself teaching a number of times, how did it make you feel? What thoughts did you have? What did you learn or notice from watching yourself teach? *

Your answer

2. How was the experience of watching yourself teach? As an overall experience, was it positive or negative? *

Your answer

3. After taking part in the series of collaborative discussions about the use of video reflection, how did it make you feel and what thoughts did you have? What did you learn? *

Your answer

4. Was participating in the collaborative discussion sessions an overall positive or negative experience? *

Your answer

5. What are your thoughts about the use of a video club model as a form of professional or performance development? *

Your answer

6. Did any of the discussions, observations or reflections surprise you? Explain. *

Your answer

7. Can you suggest any changes or improvements to the use of the video club model and PCK as a form of PD to make it more useful? *

Your answer

8. The Pedagogical Content Knowledge (PCK) framework helps to outline what teachers do and know, how did this framework impact on your reflections on your teaching and what effective science teachers do? *

Your answer

9. Have your thoughts about effective science teaching changed? If so how? *

Your answer

10. How do you think these experiences of videoing, reflecting on and discussing your teaching have changed your teaching and personal goals? *

Your answer

11. Any other thoughts?

Your answer

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Appendix F

Optional Reflection Proforma

Teacher Name		**Date**	
Class Details Year level, topic, period, background, lesson aims & type			
What are your thoughts as you watch the video?			
What are students doing?			
What are you doing?			
Considering PCK and the AITSL standards reflect on the following. Consider capturing segments to show for discussion.			
What are some of the successful elements of the lesson? How do you know?			
What could be improved in this lesson? Explain.			
What surprises you in this lesson? What captures your attention?			
Is there anything that comes to mind that you would do differently or try?			
Can you identify any goals for yourself?			
How useful did you find this activity?			

Please feel free to make further reflections in your own format. You may wish to select clips or sections to show the group for discussion/feedback.

Appendix G

Student and Parent Information Letter and Consent Form

Edith Cowan University
School of Education
2 Bradford Street
MT LAWLEY WA 6050
Phone: 134 328
Researcher: Ms Dallas Bruce [redacted]
Supervisor: Dr Jenny Lane [redacted]

INFORMATION LETTER FOR STUDENTS AND PARENTS
RE: Science Teaching Research Project

Dear Students and Parents/Guardians,

Improving science teaching through the use of video reflection and a pedagogical content knowledge framework.

As part of my university studies I am conducting a research project that aims to enhance science teaching. This project is being done as part of a Masters by Research (Education) through Edith Cowan University. The title of the research project is "Improving Science Teaching Through the Use of Video Reflection and a Pedagogical Content Knowledge Framework".

The purpose of this research is to explore the use of video technology and teacher's reflections of their teaching. Teachers will be asked to video-record and reflect on their own teaching and then discuss their thoughts with other teachers. This type of video-club model and video reflection of their teaching has been shown to be very beneficial to teachers and have positive impacts on their teaching.

What will you be asked to do?
Your consent is being sought to help with this project as your science teacher may wish to record one of your science lessons this year. You will not be asked to do anything other than participate in the lesson as normal.

How will the video be used?
The video recording will only be used by the individual teacher. They will watch their lesson and make reflections which they will then share verbally with other teachers within the department. They may choose to share short sections of their video with the other teachers but the purpose is to look at the teaching not student behaviour. Participating teachers will be made aware of the constraints of the use of the video data. Students will not be penalised for agreeing to take part in any way and the video will not be used for any other purpose than those intended by the study. Student information, identity and input will remain private and confidential. The video data will be stored securely by me for access by the individual teacher alone.

Do you have to participate?
If you do not wish to be recorded, you have the right to withdraw your consent and there will be no penalty. Participation (or declining to participate) will not affect your grades, your relationship with your teacher(s) or with your school. If you choose not to give consent you

will not be removed from the lesson but will be placed in the classroom where you will not be recorded.

What data will be collected and used?
The data collected for analysis will be the discussions among teachers based on their reflections as well as teacher questionnaires and interviews, it will not include the video data itself or input from students. This data will be analysed and coded to determine whether this model of teacher professional development is useful and effective. This will then be presented as a research thesis for the degree of Masters by Research. This research has been approved by the Human Research Ethics Committee (HREC) and risk assessment bodies of Edith Cowan University.

Students have had the research explained to them and are asked to discuss it with their parents/guardians. If you would like to find out more about this research project I am happy to answer any questions or provide more detailed information. If you and your parents are satisfied with this information and you give your consent to be recorded as part of this project please complete the following Consent Form. Should you not wish to give your consent please tick the appropriate box.

If you have any concerns or complaints about the research project and wish to talk to an independent person, you may contact:

Research Ethics Officer
Edith Cowan University
270 Joondalup Drive
JOONDALUP WA 6027
Phone: (08) 6304 2170
Email: research.ethics@ecu.edu.au

Sincerely,

Ms Dallas Bruce
[redacted]

24 January 2018

Edith Cowan University
School of Education
2 Bradford Street
MT LAWLEY WA 6050
Phone: 134 328
Researcher: Ms Dallas Bruce [redacted]
Supervisor: Dr Jenny Lane [redacted]

STUDENT AND PARENT/GUARDIAN PARTICIPANT CONSENT FORM

Improving science teaching through the use of video reflection and a pedagogical content knowledge framework.

In giving my consent I state that I /my student:

- ☑ have read the Information Statement and have been able to discuss involvement with the researcher if required
- ☑ understands the purpose of the study
- ☑ understands that involvement in this project is not compulsory, but I give my consent.
- ☑ understand that I am free to withdraw my consent at any time
- ☑ understand that participating in this project will not affect my/my student's grades, relationship with teacher(s) or with the school.
- ☑ understands that video data collected will not be used for any purpose other than the purposes of this study and can only be viewed by the teacher involved or who they give their consent to. It cannot be used against students involved in any way.
- ☑ understands that the results of this study may be published, and that publications will not contain my child's name or any identifiable information about my child.

☐ I do not give my consent for my student to be recorded for the purposes of this study.

Student Name:_____ **Class**_____

....
Student Signature **Date**

....
Parent/Guardian Signature **Date**

Appendix H

Principal Information Letter and Consent Form

Edith Cowan University
School of Education
2 Bradford Street
MT LAWLEY WA 6050
Phone: 134 328
Researcher: Ms Dallas Bru[redacted])
Supervisor: Dr Jenny La[redacted])

INFORMATION LETTER FOR PRINCIPAL

Dear Principal

Improving science teaching through the use of video reflection and a pedagogical content knowledge framework.

As part of my Masters by Research (Education) through Edith Cowan University I am seeking permission to complete a research project within the school setting. The title of the research is "Improving Science Teaching Through the Use of Video Reflection and a Pedagogical Content Knowledge Framework".

The purpose of this research is to explore the use of video technology and reflection by experienced, practising science teachers as a means of professional development and capacity building. Through this research, I aim to provide a safe and supportive environment where like-minded teachers can reflect on their own teaching after watching a video of themselves teaching and participate in collaborative discussion and exchange of ideas, this is called a video-club model. The process is not one of judgement but instead aims to provide a means of professional development and learning for teachers.

Expectations of teachers will be to participate in meetings approximately twice per term with the view to recording and reflecting on at least one lesson of their choosing to discuss with the group over the course of the study. A guideline for reflection and discussion will be provided, and teachers will be supported through the process. It is hoped that these "video-club" meetings will take place during school time, with relief provided as part of the professional learning opportunities provided to staff. This kind of reflection has been shown to be very beneficial to teachers.

Data collected will include short questionnaires, recorded and transcribed interviews as well as transcribed audio recordings of collaborative discussions and meetings. These sources will aim to gain an understanding of the thought processes, feelings and ideas of the teachers involved. A framework based on Pedagogical Content Knowledge will be used as a lens for discussion and analysis. The data collected will be combined, coded and analysed to determine whether this style of activity is valuable to teachers and be used to present a research thesis for the purpose of gaining my Masters by Research.

Participation is completely voluntary and participants' anonymity will be protected. They will have the right to withdraw from the study at any time without penalty or recourse. Permission will also be sought from students and parents of the classes which will be recorded. Where students do not have consent they will be placed in the classroom where they will not be

recorded. This study has gained approval from the ECU Human Research Ethics Committee (HREC) and risk analysis approval. It can also be counted towards professional learning hours. All video data recorded will remain the private property of the individual teacher, to be used only for the purpose outlined by the study.

If you would like further information, I am happy to discuss this research or provide you with greater detail. If you agree to allow this research to take place please sign the attached Consent Form.

If you have any concerns or complaints about the research project and wish to talk to an independent person, you may contact:

Research Ethics Officer
Edith Cowan University
270 Joondalup Drive
JOONDALUP WA 6027
Phone: (08) 6304 2170
Email: research.ethics@ecu.edu.au

Sincerely,

Ms Dallas Bruce
[redacted]

24 January 2018

Edith Cowan University
School of Education
2 Bradford Street
MT LAWLEY WA 6050
Phone: 134 328
Researcher: Ms Dallas Bruce [redacted]
Supervisor: Dr Jenny Lane [redacted]

SCHOOL PRINCIPAL PARTICIPATION CONSENT FORM

Improving science teaching through the use of video reflection and a pedagogical content knowledge framework.

I, ... [PRINT NAME], agree for Geraldton Grammar School to take part in this research study for the purpose of Masters by Research (Education) through Edith Cowan University.

In giving my consent I state that:

☑ I understand the purpose of the study, and any risks/benefits involved.

☑ I have been able to discuss the participants' involvement in the study with the researcher if I wished to do so.

☑ The researcher has answered any questions that I had about the study and I am happy with the answers.

☑ I understand that being in this study is completely voluntary. Participation by teachers and students/parents in the study, or decision not to, will not affect their relationship with the school or the department now or in the future.

☑ I understand that participants can withdraw from the study at any time without penalty.

☑ I understand that personal information about participants that is collected over the course of this project will be stored securely and will only be used for the purposes agreed to.

☑ I understand that the video data collected will be viewed only by the teacher involved and those that they give consent to. It will only be used for the purposes of the study.

☑ I understand that the results of this study may be published, and that publications will not contain names or any identifiable information.

....

Signature **Date**