The Impact of Professional Learning on Science Teaching Efficacy: A Case Study of One New Zealand Primary Teacher.

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Abstract

Despite the introduction of a new science curriculum in 2007, focused on developing scientific literacy, New Zealand primary school students have continued to lose interest in science, and perform poorly compared to other countries (Bolstad & Hipkins, 2008; Mullis et al, 2016). A lack of confidence in teaching science has been identified as a contributing factor to primary schools failing to deliver high quality science teaching and learning which may explain students' lack of interest and performance in science. This study focusses on exploring the impact of three concurrent, professional development programmes, on one primary teacher's nature of science teaching efficacy. This professional development includes a combination of a scientist-teacher partnership, enactive mastery experiences, in-class mentoring, and a professional learning community.

A qualitative case study design was employed, with data collected using adapted forms of both the Nature of Science as Argument Questionnaire, and the Science Teaching Belief Instrument, semi-structured interviews and classroom observations. The thematic analysis revealed changes in the teacher's nature of science beliefs, classroom practice, and identity, as well as his leadership efficacy. Overall, the study found that the professional learning opportunities had promoted the teacher's developed personal efficacy and outcome expectancy for teaching the nature of science, with the support of instructional leadership within his school. The opportunity for critical reflection was found to be beneficial for developing the teacher's informed view of the nature of science. The study recommends that productive professional development needs to enable primary teachers to make connections to their personal and professional identities, what they know, and what they are interested in, in order to develop their nature of science pedagogical content knowledge.

Keywords: Primary teacher, nature of science, professional development, teaching efficacy, pedagogical content knowledge, scientist-teacher partnerships, mastery experiences, mentoring, professional learning community.

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Chapter One - Introduction

1.1 Overview

Currently the world faces many challenges that are difficult or seemingly impossible to solve, commonly referred to as 'wicked problems', such as climate change, an aging population, environmental degradation, and more recently COVID-19. These challenges can be solved with the help of science and technology and require expert teachers in these fields alongside citizens who are scientifically literate (Gluckman, 2011). Schooling, therefore, has a large part to play in addressing these challenges and should "aspire to engage students in understanding of how the scientific process operates and engage them in thinking about socio-scientific challenges facing society" (Gluckman, 2011, p. 4).

In spite of the need for schools to address these challenges, international trends continue to highlight a growing decline in student interest in science, with large numbers of students becoming disengaged in science by the time they reach secondary school (Potvin & Hasni, 2014; The Royal Society, 2010). These trends have also been seen in New Zealand (NZ) with Bolstad and Hipkins (2008) reporting that approximately 70% of Year 4, and less than 30% of Year 8 students enjoy science. However, while many countries now show an upward trend in student achievement over the last twenty years, NZ has stayed the same (see Table 1), with NZ primary school science achievement ranked very low compared to other countries (Caygill et al., 2016).

Table 1:

Trends in 4th and 8th Grade Student Science Achievement from 1995-2015. (Mullis et al., 2016, p. 11)

Fourth Grade Science			Eighth Grade Science		
Countries Improving	Countries Unchanged	Countries Declining	Countries Improving	Countries Unchanged	Countries Declining
Cyprus	Australia	Netherlands	Hong Kong	Australia	
England	Czech Republic	Norway	Ireland	England	
Hong Kong	New Zealand		Japan	Iran	
Hungary	United States		Rep. of Korea	New Zealand	Hungary
Iran			Lithuania		Norway
Ireland			Russian		Sweden
Japan			Singapore		
Rep. of Korea			Slovenia		
Portugal			United States		
Singapore					
Slovenia					

Research has investigated the reasons behind these trends. International reports have highlighted the fact that many primary students continue to experience a transmission approach to the teaching of science, focussed on the content knowledge of science, with little consideration of the true nature of science (Fitzgerald et al., 2012; The Royal Society, 2010). Other research points to a lack of adequate science content knowledge, pedagogical content knowledge (PCK), and low levels of confidence in primary teachers, as contributing to the problem (Hume, 2016).

Despite the introduction of a new curriculum in 2007, with a strong emphasis on developing scientific literacy by making the nature of science (NoS) strand the only compulsory one, NZ policy makers and science educators share many of the concerns identified above. In 2012, the Education Review Office (ERO) released a report on Year 5-8 science in the NZ curriculum, in which they stated that only 27% of the schools in the sample were judged to be providing effective or generally effective science programmes, with many not grasping the requirement of the NoS in the current science curriculum. For the third successive report, ERO (2012) identified a lack of primary teachers' confidence to deliver high quality science teaching and learning. ERO went on to recommend that steps be taken to build teacher confidence, through developing their knowledge of effective science pedagogy. At the same time that this report was published, Hipkins and Hodgen (2012) reported that more than half of NZ primary teachers did not understand how to shift their science teaching to incorporate the NoS.

As well as lacking confidence, most NZ primary teachers are generalists, with little to no background understanding in science (Bull et al, 2010), meaning they have little understanding of how to support their students to become scientifically literate. Primary teachers often view science as facts and figures that need to be transmitted to students, which is reflected in the pedagogical approaches they use in their classroom (Appleton, 2006). It is what teachers think, believe, and do at the level of the classroom that ultimately shapes the kind of learning their students experience (Fitzgerald & Smith, 2016).

In order to develop primary teacher confidence, skills and capabilities in science, teachers must engage in professional development (PD) that focuses on developing their content knowledge, PCK, classroom practice and teaching efficacy (Hume, 2016). However, the 2018 National Monitoring Study of Student Achievement revealed that 40% of NZ primary teachers surveyed had not participated in science PD over the last five years, with 20% stating they had never received any science PD (NZCER, 2018). If NZ is to address the issues of declining interest in science as students' progress through the education system, and poor science achievement levels, investment must be made to help primary teachers to upskill, so that they can gain the necessary confidence levels, and have the level of understanding required to develop scientific literacy in their students.

1.2 Definition of Terms

In education, and educational research, certain terms are used with the assumption that readers understand their meaning. In order to avoid any misunderstandings, it is important to clearly define what is meant by key terms referred to in this research study.

Teacher efficacy, refers to the beliefs' teachers hold about their individual and collective capability to affect their students' engagement and learning (Klassen et al., 2011). Teacher efficacy varies from context to context, and changes with experience. Teacher efficacy is considered a key motivating belief, and influences the effort a teacher invests in their teaching, the goals they set, what they aspire to, and their persistence when faced with a challenge (Tschannen-Moran & Woolfolk Hoy, 2001). Science teaching efficacy refers specifically to the beliefs a teacher holds about the level of confidence they have in their own ability to influence their students' learning and achievement in science (Yangin & Sidekli, 2016).

The nature of science (NoS) is commonly defined as the epistemology of science, and is a critical component of scientific literacy (Lederman, 2007). It refers to the values and beliefs inherent to scientific knowledge and how this knowledge was developed. There are many beliefs associated with the NoS, such as scientific knowledge is:

- tentative (subject to change),
- empirical (based off observations of the natural world),
- subjective (involves personal background, biases and/or theory),
- creative (involves the development of explanations), and
- socially and culturally embedded (Lederman, 2007).

In *The New Zealand Curriculum* (Ministry of Education, 2007) the NoS is the overarching, and unifying strand through which students learn about what science is and how scientists work. According to Hipkins (2012), the NoS allows students to consider how science actually works in the world; how to assess the trustworthiness of scientific claims; and how to make informed personal decisions.

According to Timperley et al. (2007) teachers' professional development (PD) involves the communication of information to teachers in order to change their classroom practice and thinking about their practice, and ideally involves professional learning. Professional learning positions the teacher as the learner, empowering them to take ownership of their own learning in terms of what is learned, when and how (Poskitt, 2014). In this research study, PD is defined as opportunities, such as workshops, mentoring, scientist-teacher partnerships, and professional learning communities, that develop a teacher's knowledge and skills, in order to change their classroom practice.

1.3 Rationale

Despite the introduction in 2007 of a new science curriculum, with a strong focus on scientific literacy, NZ primary students continue to lose interest in science, and perform poorly in comparison to other countries. In 2008, Hipkins and Bolstad suggested that a lack of science content knowledge, PCK, and low teaching efficacy were inhibiting NZ primary teachers from effectively using the pedagogy aligned with changes to the science curriculum. Findings from the 2012 ERO report supported this view, identifying a lack of confidence as a continuing challenge to effective science teaching and learning, recommending that steps be taken to build teacher confidence.

Primary teachers who express low levels of confidence in teaching science, doubt their own ability to teach science, and also to affect their students' outcomes; these teachers have low teaching efficacy. Given that teacher efficacy is positively associated with a teachers' willingness to try new things, and to adopt new innovations (Wheatley, 2002), a lack of teacher efficacy may well explain why half of all NZ primary teachers lacked an understanding of the changes made to the science curriculum, two years after its implementation (Hipkins & Hodgen, 2012). Teacher efficacy is also believed to influence student motivation and achievement (Bandura, 1997). It can, therefore, be postulated that by increasing NZ primary teachers' teaching efficacy for science, student interest and achievement in science may also increase.

A lack of understanding about the NoS is also frequently regarded as a barrier to primary teachers implementing reform-based changes to science curricula (Hipkins, 2012). Most NZ primary teachers have a background in the humanities, and their own school science education did not include the NoS. It is, therefore, not surprising that 28% of Year 4 teachers, and 39% of Year 8 teachers reported either low, or no confidence in teaching the NoS (NMSSA, 2018). If teachers are to incorporate the NoS into their science teaching and learning, they not only require an understanding of the NoS, but also a knowledge of effective pedagogy, so they can develop the PCK needed to improve their classroom practice (Deniz & Adibelli, 2015), and in turn their efficacy.

In 2013, 53% of primary principals surveyed in the National Survey of Primary and Intermediate Schools, reported not being able to readily access external expertise or knowledge in science (Wylie & Bonne, 2014). While in 2018, the NMSSA reported that 20% of NZ primary teachers surveyed had never received science PD, and 59% of Year 4, and 43% of Year 8 teachers, had never observed a colleague teaching science (NZCER, 2018). In terms of the science PD support offered, research completed in 2016 indicated that many providers focussed on one-off workshops and short-term support, with only 12% providing PD that extended up to 6 months (Bull, 2016). If primary teachers are to engage with new ideas and practices, PD must be more than a brief encounter, and sustainability must be considered (Timperley et al., 2007).

The challenge, therefore, is how to provide New Zealand primary teachers with the skills and knowledge needed to deliver the science curriculum as it was intended, so students become interested and engaged in science, and achieve at a higher level than currently. Teacher efficacy lies at the heart of this problem; therefore, science PD needs to focus on developing the skills and capabilities to enable teachers to become more efficacious to deliver the curriculum as it was intended.

In 2011, Gluckman stated that every primary school should have a science champion; namely a science expert who could help other less confident teachers develop their science teaching and learning. This idea utilises the cascade model of teacher PD; a top-down model where information flows from an ‘expert’ teacher down to other teachers (Ngeze et al., 2018). By using this type of model, a whole school can receive the benefits of one teacher’s participation in PD.

In 2016, the secondary school where I was teaching science became part of a new initiative launched by the Ministry of Education, called a Kāhui Ako; a group of 10 collaborating schools, made up of one secondary, one intermediate, and eight primary schools, all working together to improve student outcomes. An initial target for this group was to improve the engagement and achievement of students as active and self-directed learners using science. Very quickly it became apparent that most of the primary teachers either lacked confidence in teaching science, or lacked any science PD since beginning teaching. As a result, the Kāhui Ako began sending teachers on the Science Teacher Leadership Programme, run by The Royal Society of New Zealand, in an attempt to develop science champions within each school. In addition, they sought Ministry funded PD to support them within their schools, and developed a professional learning community for the participants. In an attempt to see how successful this combined PD approach would be, in improving primary teacher NoS efficacy, I decided to carry out this research.

1.4 Purpose and Significance of the Study

The purpose of this research is to carry out an in-depth examination of the impact of three, concurrent, NoS PD programmes, on the NoS teaching efficacy of one New Zealand primary teacher. A primary objective of this study is to explore a practical solution to address the challenge of developing NoS primary teacher teaching efficacy, so that they may make use of NoS pedagogies, leading to better student engagement and achievement in science. As Hipkin's (2012) argues "unless and until teachers are both challenged and supported to change the ways they understand and enact science education in and for the 21st century, very little change is likely to occur" (p. 15).

By exploring in-depth the development of a practising primary teacher's NoS teaching efficacy, this study will help to bridge the existing gap in research, both internationally and nationally about science teaching efficacy. This study will contribute in this area of science teaching efficacy, by exploring the development of one primary teacher's NoS teaching efficacy. The study also aims to add to the existing research into effective NoS PD programmes, by exploring a unique approach involving three concurrent, targeted PD programmes.

To explore the teacher's perspectives and changes in understanding and efficacy, an instrumental case study will be conducted. The teacher will have been involved in PD prior to the start of the case study, with the research being completed over an 11-month period. Data will be collected using questionnaires, semi-structured interviews and classroom observations to ascertain changes from participation in the PD, in the teacher's

NoS understanding, personal NoS efficacy and NoS outcome expectancy, as well as PCK and classroom practice.

1.5 Thesis Outline

This thesis is presented in six chapters. Chapter One provides the background to this study, and justifies the need for the research. The second chapter provides an overview of the literature related to the study. This chapter is divided into three main sections. The first section discusses literature related to science teaching efficacy. The second section explores the NoS, including primary teacher's views and understandings, and NoS PCK. While the last section considers the literature on science PD, with regard to primary teachers. Chapter Two also explores the factors that influence the success of PD, specific NoS PD strategies, and the use of scientist-teacher partnerships.

The research methodology used in this study is discussed in Chapter Three. This chapter includes an explanation of the qualitative research design and the case study methodology. Data collection and analysis tools and methods are outlined, along with issues relating to their validity, and dependability. The ethical protocols for this case study are also considered. Finally, background information about the PD programmes is provided.

Chapter Four presents the findings in response to each of the research questions. Divided into three sections, it first presents the data collected from the two questionnaires completed, at the start and finish of the study. Section two, presents the findings from the three semi-structured interviews completed, and the third section presents the findings from the two classroom observations.

The final two chapters present the analysis and discussion of the findings, and the conclusions. Chapter Five discusses the four key themes, examining them in relation to contemporary literature, looking for areas of convergence and divergence, as well as providing emerging insights. Finally, Chapter Six presents the key conclusion of the study, its limitations, implications for practice, and recommendations for future research.

Chapter Two - Literature Review

2.1 Introduction

Recent science education reforms worldwide have focused on developing scientific literacy, where the nature of science (NoS) is a critical component (Lederman, 2007). Successful enactment of these changes requires teachers to understand the NoS as well as to develop a strong sense of efficacy to teach it. However, national reports identify low science teaching efficacy as a challenge to providing quality teaching and learning in New Zealand (NZ). The National Monitoring Study of Student Achievement (New Zealand Council for Educational Research, 2018) found that approximately 28% of Year 4 teachers, and 39% of Year 8 teachers reported either low or no confidence in teaching the NoS. Furthermore, 20% of them had received no science professional development over the last five years.

This chapter provides a review of the literature related to the impact of professional development on primary school teacher's teaching efficacy of the NoS. It is divided into three sections. The first section provides a theoretical background of self-efficacy and teaching efficacy, a discussion of instruments used to measure science teaching efficacy beliefs, and reviews the current literature related to primary teachers' science teaching efficacy. The second section identifies the theoretical underpinnings of the NoS, and primary teacher's views and understandings of it. Instruments that can be used to assess teachers' understanding of the NoS are also reviewed, as this is a focus in this study. Literature related to pedagogical content knowledge of the NoS is provided, as development of this aspect has effects on teaching efficacy. The third section evaluates the effectiveness of various science professional development programmes designed to improve primary teachers' science knowledge and efficacy. Professional development strategies used to improve teachers' NoS understanding and teaching practice, including scientist-teacher partnerships are examined.

2.2 Science Teaching Efficacy

According to Klassen et al. (2011), teacher efficacy relates to the confidence teachers hold with regard to their individual and collective capability to shape their students learning and is considered a key motivating belief influencing a teachers' professional behaviour. "Efficacy affects the effort they invest in teaching, the goals they set, and their level of aspiration" (Tschannen-Moran & Woolfolk Hoy, 2001, p. 783). It therefore follows, that primary school teachers with a high sense of self-efficacy in teaching science are more likely to teach science, be enthusiastic about the subject, and persist when things do not go to plan, whereas those with a low sense of efficacy will tend to avoid teaching science.

Given that teachers are tasked with preparing students to be scientifically literate and competent in a technologically changing world, science teacher efficacy is a concern (Bandura, 1997). According to Yangin and Sidekli (2016), the preparation of primary school teachers to successfully teach science is a central issue in science education.

2.2.1 Theoretical background

In 1977, Albert Bandura introduced the construct of self-efficacy as the key element of his social cognitive theory. Bandura (1997) stated "unless people believe they can produce desired effects by their actions, they have little incentive to act" (pp. 2-3). A person's self-efficacy beliefs therefore act as a guide to their lives. Bandura (1997) went on to state that "perceived self-efficacy refers to beliefs in one's capabilities to organise and execute the courses of action required to produce given attainments" (p. 3). In terms of teaching, a teacher's personal self-efficacy will determine what and how they teach.

Self-efficacy is not a fixed attribute; it varies from context to context and can change with experience. Bandura (1997) described four sources of information that contributed to efficacy beliefs, and could be utilized to enhance an individual's self-efficacy: mastery experiences, vicarious experiences, verbal persuasion, and physiological responses.

Mastery experiences are viewed as the most influential source of efficacy information by Bandura (1997), including both positive and negative experiences. For example, a positive experience in performing a particular task, such as teaching of science, raises efficacy beliefs, whereas repeated failures at the same task reduces it. Vicarious experiences are those observed by an individual of another's performance of a task, such as observing another teacher teaching a science lesson. The more closely the observer relates to the person being observed, the greater the impact on efficacy. Verbal persuasion occurs when an individual receives feedback and/or encouragement from another person, about their capability to perform a task, for example feedback provided by an observing teacher. The last type of experience, physiological responses, refers to an individual's state of physiological or emotional arousal while performing a task, for example, high levels of stress or fear may lead to low self-efficacy belief, while high levels of joy may increase it. According to Bandura (1997) physiological responses are the least effective source of information for development of self-efficacy.

Although there are four sources of information, individuals may not always have access to them. An individual's culture may affect the type of information provided and selected from sources, as well as how they are valued and integrated into their own personal efficacy beliefs (Oettingen, 1995). For example, efficacy beliefs typically consist of 'I' statements, indicating a cultural dimension of individualism. Individualistic cultures value uniqueness, independence and self-reliance, stressing the needs of the individual over the needs of the group, and are typically found within Western cultures. In contrast, collectivist culture refers to beliefs about 'we', and relates to the connectedness of the group. A review of 20 studies completed by Klassen (2004) found that self-efficacy levels depended on cultural contexts, and therefore concluded that professional development aligned with an individual's cultural background, level of connectedness, and current setting enhanced efficacy beliefs and performance.

2.2.2 Primary Teacher Science Teaching Efficacy

A report by the Education Review Office (ERO) of NZ identified a lack of confidence in primary teachers as a significant challenge in providing high quality science teaching and learning (ERO, 2012). In a review of the literature over the last ten years most research has focused around the development of science teaching efficacy in pre-service teachers, rather than practicing teachers, and all have been completed outside of NZ. The lack of literature on practicing teachers' science teaching efficacy is significant, as the current case study investigates changes in a NZ practicing teacher's NoS teaching efficacy, meaning it may be able to contribute to existing research.

Most NZ primary teachers are generalists, having little to no background knowledge of science (Bull et al., 2010), and as a result tend to focus on areas in which they feel more comfortable. German research has shown a positive correlation between primary teachers' science teaching efficacy and the amount of science taught by teachers (Oppermann et al., 2019). The quantitative study examined the relationship between preschool teachers' science teaching efficacy, their teaching practice, and children's science-related motivation. As well as finding that teachers were more likely to teach science, the study also revealed a positive relationship between teachers' science self-efficacy beliefs and their children's science self-efficacy. This finding is highly significant for the current study because in order to engage in quality primary science teaching and learning, science teaching efficacy must be developed first.

Research into Bandura's four sources of efficacy have shown that mastery experiences, vicarious experiences, and verbal persuasion serve to increase science teaching efficacy (Palmer, 2010). This Australian study investigated the effectiveness of sources of information on science for enhancing science teaching efficacy in twelve primary teachers. Their study concluded that the provision of cognitive and enactive mastery, in situ modelling, and in situ feedback led to substantial increases in science teaching efficacy of experienced primary teachers. They went on to state that "by focusing on a useful set of subskills it can be possible to increase teachers' self-efficacy to the point where they are willing to do more science teaching" (p. 596). Palmer's findings are relevant to the current study in that changes in science teaching self-efficacy, having engaged in professional development, are being investigated.

Research has found that prior experiences strongly influence teachers' attitudes towards science and their resultant interest in science and science teaching (Ramey-Gassert et al., 1996; Wang et al., 2015). Ramey-Gassert et al. (1996) looked at personal science teaching efficacy (PSTE) and science teaching outcome expectancy (STOE) separately, finding that internal factors, such as interest, related to a teacher's PSTE, whereas STOE was related to external factors or those perceived as outside of their control. They also found that collegial and school administration support was important to enhance teacher science self-efficacy. A Taiwanese study also found that primary teachers who held constructivist conceptions of teaching and learning had higher levels of teaching efficacy in science, most likely due to the investigative nature of the subject (Wang et al., 2015). These findings will be considered when interviewing the participant teacher in the current case study.

Research into professional development opportunities aimed at developing science teaching efficacy in primary teachers has revealed a number of strategies which are effective. Research in North America found that using a combination of both content knowledge courses and a professional learning community (PLC) over a prolonged period had a positive impact on teacher self-efficacy and teacher implementation of reformed science teaching in the classroom (Lakshmanan et al., 2010). This longitudinal study completed over three years used the STEBI questionnaire, and the reformed teacher observation protocol on classroom observations to assess the effectiveness of a professional development program on science teaching efficacy. Lakshmanan et al. (2010) found that the content knowledge courses only led to a deeper understanding of the science subject matter, whereas the PLC led to increases in the participants' science teaching efficacy. This finding is significant to the current case study as it indicates the value of adding a PLC to professional development to increase teaching efficacy, as one of the professional development programs involved utilises a PLC.

2.2.3 Measures of Science Teaching Efficacy Beliefs

Over the last 40 years researchers have worked to develop instruments to measure self-efficacy in all its forms. In 1989, Riggs and Enochs developed their "Science Teaching Efficacy Beliefs Instrument" (STEBI) as a specific measure of science teaching efficacy. The instrument used a very different construct of science teaching efficacy beliefs, referring specifically to beliefs about the level of confidence individuals have in their ability to influence student learning in science (Yangin & Sidekli, 2016). STEBI is a combination of two scales which measures two discrete and homogeneous constructs - the "Personal Science Teaching Efficacy Belief" scale (PSTE) and the "Science Teaching Outcomes Expectancy" scale (STOE). Two forms of the instrument were developed, one for preservice teachers and one for practicing.

STEBI has been widely used over the last 25 years and has been modified by various researchers, and used in a variety of languages, proving itself to be a valid and reliable measure of both personal and general science teaching efficacy beliefs (Deehan, 2017). A psychometric re-examination of the STEBI was completed by Moslemi and Mousavi (2019) that involved 1630 Canadian secondary science teachers. The examination found that the STOE subscale showed a lower reliability and validity than the original, indicating a susceptibility to errors of measurement (Moslemi & Mousavi, 2019). As the STOE focuses on the teachers' potential effect on students' learning outcomes, Moslemi and Mousavi (2019) believed the futuristic nature of the sub-scale contributed to its subjectivity.

In 2016, Yangin and Sidekli, published their research into developing a new self-efficacy for science teaching scale which was more context-specific and aligned with Bandura's social cognitive theory and the idea that teachers' beliefs around science are complex. The "Self-Efficacy for Science Teaching Scale" (SSTS) (Yangin & Sidekli, 2016) is composed of three parts; science teaching self-efficacy, efficacy for understanding elementary science content, and efficacy for teaching science content. Results showed that the SSTS is a valid and reliable measure for only two of these aspects – science teaching self-efficacy and efficacy for teaching science content. Yangin and Sidekli (2016) identified that the SSTS did not measure any interaction with pedagogical content knowledge, and that this along with other factors may contribute to self-efficacy.

2.3 The Nature of Science

Typically referred to as the epistemology of science, the NoS describes "the values and beliefs inherent to scientific knowledge and its development" (Lederman, 2007, p. 833). The NoS affects science teaching and learning, dealing with issues such as the philosophy of science, history, sociology and psychology (Mihladiz & Doğan, 2014). The NoS includes a variety of aspects such as: science knowledge is tentative, empirically based, subjective, involves human inference, imagination, and creativity, and is socially and culturally embedded. Both Lederman (2007) and Mihladiz and Doğan (2014), state that understanding of the NoS is a key component to achieving scientific literacy in any science education reform.

The NoS strand of *The New Zealand Curriculum* (NZC) (Ministry of Education, 2007) is the only compulsory strand: the reason being that to achieve the NZC goal of producing scientifically literate citizens requires knowledge about how science works (Bull et al., 2014). The NoS strand enables students to "learn what science is, what is valued and how knowledge is developed in science" (Bull et al., 2010b, p. 1). However, a report by Bull et al. (2010a) clearly showed that NZ teachers had poor levels of understanding and confidence in teaching the NoS.

2.3.1 Primary Teachers' Views and Understanding of the NoS

International research found that primary teachers lacked understanding of most of the NoS aspects (Koksal & Cakiroglu, 2010). Using the NoS knowledge test and open-ended questions on 47 Turkish primary teachers, these researchers assessed the understanding of different NoS aspects. Their study revealed that the teachers had naïve views regarding their understanding of the relationship between theories and laws, and only half had an informed view of the role of creativity and imagination in generating scientific knowledge. For all other aspects of the NoS, teachers were transitioning towards an informed view to varying degrees.

In 2019, Cofré et al. completed a critical review of students' and teachers' understandings of the NoS, reviewing 52 studies. They found that teachers generally held an informed view of the creativity of science, while the most commonly held naïve views were observation and inference, theory and law, and the socio-cultural embeddedness of science. Their research also revealed that when interventions were put in place, views about observation and inference, and the socio-cultural embeddedness of science improved the most, while understanding of the empirical nature of science improved the least (Cofré et al., 2019). These interventions tended to last between one and three years, included both integrated and non-integrated activities, using strategies such as hands-on activities followed by reflection, readings, and inquiry. These findings are of particular significance to this study, as the impact of professional development on a primary teacher's understanding of the NoS is being investigated.

Research in the United Kingdom suggests that primary teachers' views and understanding of the NoS colour their interpretations of their science teaching. A case study of five primary teachers by Lunn (2002) found wide variation between the teachers in the way they taught science and the way they conceptualised it. Lunn (2002) went on to state that very few primary teachers in the UK have been educated in the NoS, and therefore the views they express in their teaching have been developed through practice, drawing on their life experiences, engagement with science outside of school, collegial discourse, as well as the science content in their curriculum. As the participant primary teacher in this study has no background knowledge of the NoS prior to his professional development involvement, despite having completed a science module as part of his Graduate Diploma of Teaching, this finding is pertinent.

When asked to describe NoS teaching, primary teachers describe it as being linked to different competencies, and that it is different to the traditional recall of facts and experiments commonly used in science teaching (Leden et al., 2015). Using the VNOS-C questionnaire and follow-up interviews on twelve practicing teachers, their study investigated how Swedish teachers talk about the NoS and its specific aspects in relation to their teaching. The study revealed that teachers considered the NoS to be important, but they did not address it in class, regarding it to be time-consuming and distracting to the main purpose of their teaching, namely the recall of facts in combination with lab work. Teachers also reported needing strategies to find ways to explicitly connect different aspects of the NoS, and concrete examples to which they could relate their understanding of the NoS aspects. This finding will be considered when discussing changes in the participant teacher's science teaching practice as a result of his involvement in professional development.

2.3.2 Measuring Understanding of the NoS

Teachers' and students' views about science have been measured for more than half a century. Over the last thirty years a number of instruments have been developed to assess the level of understanding of different aspects of the NoS. Instruments such as Views on Science-Technology-Society (Aikenhead & Ryan, 1992), Scientific Attitudes Inventory II (Moore & Foy's, 1997) and Views about Science Survey (Halloun & Hestenes, 1998) were specifically designed to measure students' views about the NoS.

In 2002, Lederman et al. developed a new instrument called the Views of Nature of Science Questionnaire (VNOS). The VNOS was designed to be used in conjunction with individual interviews to provide a more meaningful assessment of a learners' NoS views (Lederman et al., 2002). Unlike the previous instruments, various forms of the questionnaire were produced, so that students as well as pre-service and practising teachers could be surveyed.

All of the above instruments have been shown to be successful to measure the epistemological beliefs of learners, but according to Sampson and Clark (2006) "they are either too domain specific, too general or they incorporate an assessment of an individual's views on learning and attitudes towards science" (p. 4). Sampson and Clark developed their Nature of Science as Argument Questionnaire (NSAAQ) in 2002 in response to the goal of the USA K-12 science curriculum, that argumentation should be central in the teaching and learning of science. The NSAAQ assesses specific NoS aspects that influence a learners' ability to engage in argument, in order to develop scientific knowledge (Sampson & Clark, 2006).

The NSAAQ assesses four specific aspects of the NoS, namely the nature of scientific knowledge, science knowledge generation, the reliability and validity of scientific knowledge and the role scientists play in the generation of knowledge. These four aspects closely align with three of the NoS strands identified in the NZC, namely, understanding about science, investigating in science, and participating and contributing to science. The NSAAQ instrument has been successfully used in a NZ context to successfully measure teacher's NoS understanding (Rice, 2012), making it suitable for the current case study.

2.3.3 NoS Pedagogical Content Knowledge

A range of different definitions are shown in the research literature for science pedagogical content knowledge (PCK). For instance, Shulman (cited in Appleton, 2006) saw PCK as content knowledge transformed by a teacher into a form that is understandable to students. Conversely, Cochran (cited in Appleton, 2006) defined it as an integration of teachers' pedagogical and content knowledges. In terms of the NoS, Lederman et al. (2007) defines a teachers' PCK for the NoS as an interaction between a teachers' NoS content knowledge, their science content knowledge, and their ability to make relevant NoS connections between them during their teaching using appropriate pedagogical approaches (refer to Figure 2).

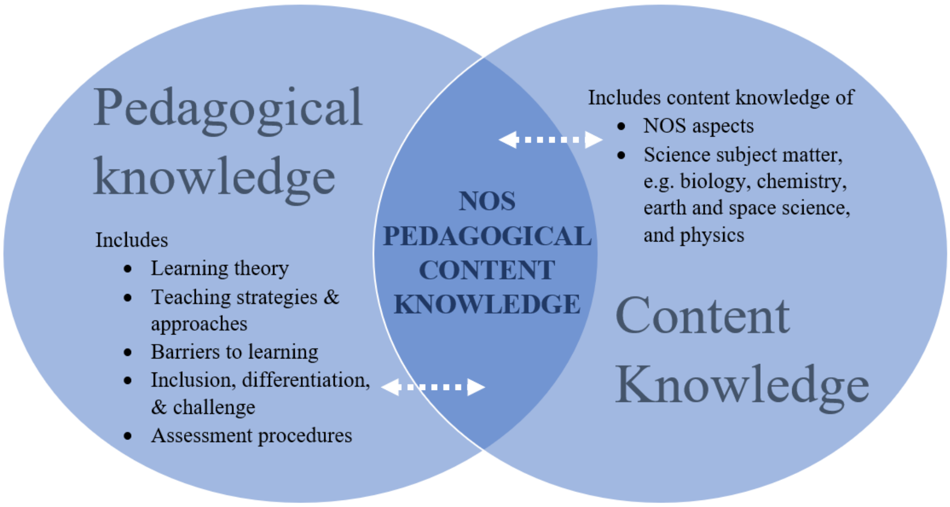


Figure 2. Diagram explaining the NoS pedagogical content knowledge. (Adapted from McCrory, 2018, p. 30)

As the NoS strand of the NZC is the only compulsory science strand, primary teachers require not only an adequate understanding of the NoS aspects, but they also need a NoS PCK (Hipkins et al., 2005). A review of the literature produced limited studies that have investigated PCK of the NoS in primary school teachers. As the current study investigates changes in a teacher's NoS PCK having engaged in professional development, it will be well placed to contribute to existing research.

Teachers require a robust understanding of the NoS content knowledge, as well as knowledge of effective pedagogy, if they are to develop their NoS PCK (Deniz & Adibelli, 2015). How these two factors combine to develop teachers' NoS PCK were investigated in two North American studies (Hanuscin et al., 2011; Hanuscin, 2013).

Using PCK as a theoretical lens, Hanuscin et al. (2011) examined the development of three North American primary teachers NoS PCK using interviews, questionnaires, classroom observations, and classroom artefacts collected over a three-year period. Their findings indicated that even when teachers had an adequate knowledge of NoS instructional strategies, they lacked sufficient knowledge of how to assess learners' NoS understanding in order to support their development, and that this had consequences on the enactment of their PCK. This finding was supported by an instrumental case study of a single primary teacher, investigating critical incidents in the development of their NoS PCK (Hanuscin, 2013), which revealed a dynamic interaction between the components of PCK and knowledge transformation. Findings revealed that changes in one area, such as content or pedagogy, were not necessarily accompanied by changes in the other. Both studies recommended that professional development efforts focus on helping teachers to develop other aspects of their PCK, such as assessing students' NoS understanding, rather than focusing on developing particular instructional skills. In light of this finding, professional development strategies used in this case study, will be investigated to see how they change the teacher's NoS PCK.

Hanuscin's research (2013) also identified a number of potential sources of PCK for primary teachers. Findings revealed that positive feedback while teaching the NoS, co-facilitating lessons, analysis of student work, providing opportunities for reflective practice, and making discourse about the NoS explicit in the classroom combined to develop the teacher's NoS PCK. An additional source of PCK was provided by the ongoing mentor-mentee relationship, that provided the teacher with multiple opportunities for reflection. The mentor in this particular study acted as a critical friend helping the teacher identify gaps in their understanding as well as challenging their thinking.

Research completed in Australia investigated the role of mentors further, investigating the influence of them on the development of science PCK in experienced primary teachers, concluding they contributed to lasting changes in teacher practice (Appleton, 2008). This study involved two case studies of a professional development programme involving mentoring by the researcher. Data were collected using interviews, field notes, planning documents and video-taped lessons. Findings indicated that mentors assumed different roles at different times, including being an expert, supporter, classroom helper as well as providing teachers with alternative views and challenging their practice and thinking. Mutual respect and trust were identified as crucial to the success of the mentor-mentee relationship, and required time to be established. This finding is significant to my study, as one of the professional development programmes involves a PD provider working alongside the teacher in his classroom.

Research has revealed a number of potential barriers to teachers developing their NoS PCK (Hanuscin, 2013; Deniz & Adibelli, 2015). In addition to NoS understanding, personal and contextual factors influence teachers' enactment of the NoS aspects. These include contextual factors such as pressure to cover content, institutional and time constraints. Personal factors such as classroom management, concerns about students' abilities and motivation, teaching experience, lack of experience in assessment, and teaching efficacy have also been identified. In addition to these, Deniz and Adibelli (2015) identified three other factors in their action research study of four North American primary teachers: developmental appropriateness of activities, the teachers' selection of NoS aspects to teach, and the value placed on each NoS aspect. These findings will be considered during my study, to see if they impact the teacher's development of his PCK of the NoS.

2.4 Primary Teacher Professional Development

On reviewing literature related to professional development, numerous areas have been reviewed which link to the current study. Each study was considered with regards to the findings of the best evidence iteration (BES) of teacher professional learning and development completed by Timperley et al. (2007). Timperley et al. (2007) concluded that there were several contextual conditions necessary, but not sufficient, that promote the learning of content to the necessary level of depth required by teachers including:

- consistency of the professional development with wider policy trends and research
- extensive time for teachers to engage with new ideas and their implication for their practice
- external experts who can present ideas in ways that promote teacher engagement
- participation in a professional learning community that supports new ideas and practice, while at the same time challenging existing ideas and focussing on teaching and learning.

Timperley et al. (2007) went on to state that professional development that focussed on developing PCK, led to a sustained improvement in teacher practice, especially when coupled with evidence-based skills of inquiry and organisational support from the teachers' schools.

2.4.1 Factors Influencing the Success of Science Professional Development

Research completed in North America and England concluded that one year of science professional development for primary teachers, was insufficient in enhancing comprehensive changes in teacher practice and beliefs (Jarvis & Pell, 2004; Drits-Esser et al., 2017). Jarvis and Pell (2004) investigated the changes in attitudes and cognition of seventy primary teachers who had completed a two-year long in-service professional development programme. Findings indicated a significant improvement in teachers' confidence levels to teach science, but these researchers concluded that teachers with low initial attainment and confidence levels required more than one year of professional development if they were to improve their efficacy.

Sustained changes in primary teachers' science teaching efficacy requires participation in professional development over a prolonged period of time. Using a mixed-model approach, Drits-Esser et al. (2017) examined the sustainability of teacher learning of fifteen primary teachers who had completed a one-year science professional development programme. Findings revealed that only some parts of strategies modelled in the professional development, that required changes in the teacher's beliefs, were integrated one year after the completion of the programme. These researchers found that one year of professional development was insufficient to produce comprehensive changes in science teaching efficacy, and that fundamental change is a gradual and challenging process. These findings support the condition stated by Timperley et al. (2007), that teachers need an extended period of time to engage with and reflect on new ideas so they can become part of their teaching repertoire. The current case study involves professional development that spans a total of fifteen months.

Support from school leaders has been shown to support the sustainability of changes to primary science teaching efficacy (Drits-Esser et al., 2017; Sandholtz et al., 2016; Sandholtz et al., 2019; Sandholtz & Ringstaff, 2016; Shaharabani & Tal, 2017). A longitudinal mixed methods study in North America, investigated the sustainability of a three-year long state-funded professional development programme designed to improve K-2 science education three years after its completion (Sandholtz et al., 2016; Sandholtz & Ringstaff, 2016), and then again seven years after (Sandholtz et al., 2019). These researchers found that support from principals varied, and generally decreased after the professional development ended. An interesting finding was that without formal or informal expectations to teach science from the principal, the teachers found it increasingly hard to incorporate it into their daily teaching programme. This finding was further supported by the longitudinal, case study completed by Shaharabani and Tal (2017) investigating the sustainability of professional development, on four Israeli primary teachers a decade after their completion of a three-year science professional development programme. Their study found that there was varied use of the strategies learnt amongst the teachers after ten years and concluded that preservation of strategies was more likely to occur when teachers received support from a team or leader. This finding is supported by Timperley et al. (2007), who concluded that school leaders play a substantive positive role in the success of professional development. Teacher support by senior school leadership will be considered in this case study, as it is a requirement of one of the professional development programmes involved.

As well as support from principals, other contextual factors within schools can either support or impede long term changes in teachers' science practice after professional development (Sandholtz et al., 2016; Sandholtz et al., 2019; Sanholtz & Ringstaff, 2016). These researchers found that the most challenging contextual constraints for teachers on their return to school after professional development, was a lack of instructional time and administrative support, due to rigid daily schedules and lack of flexibility in the curriculum. Teachers also reported missing the support and opportunities to collaborate with their colleagues once the program ended, indicating the importance of ongoing collegial support for sustainable change. Sandholtz et al. (2019) also concluded that a teachers' personal motivation to teach science was not enough on its own to overcome ongoing contextual constraints, and without contextual support professional development outcomes are unlikely to persist. These factors are relevant to the current study, as it investigates change over ten months.

2.4.2 NoS Professional Development

The current case study investigates the impact of professional development (PD) on changes in one primary teacher's NoS content knowledge, pedagogical content knowledge, and teaching efficacy. A review of the literature is therefore required to establish what strategies have been used in PD to elicit successful change in participants, so that these can be compared with those used in the current study.

A North American study on a PD programme aimed at developing primary teachers' understanding of NoS through explicit-reflective instruction identified two strengths to the programme (Akerson & Hanuscin, 2007). Using the VNOS-B questionnaire, interviews, and teacher lesson plans, Akerson and Hanuscin (2007) assessed the influence of a three-year long professional development programme on three primary teachers. Each of the teachers received a total of 84 hours of workshops over a three-year period, with a further 42 hours of individual classroom support in their final year. The study found that a key strength of this programme was its extended period of time, which provided teachers time to "articulate, challenge, and revise their NoS conceptions" leading to an improvement in their NoS understanding (p. 675). Individual support for teachers, provided by mentors in the classroom, was also identified as a critical element to the success of this programme. By providing modelling, just-in-time teaching, and motivation, mentors helped the teacher put their learning into practice. These findings are relevant, as one of the PD programmes in the current case study, involves a single PD provider working alongside the teacher in their classroom.

Another PD programme involved in this Thesis case study, utilises a professional learning community. A professional learning community (PLC) or community of practice (CoP) is a group of teachers who meet regularly and share common learning or professional interests (Goodyear et al., 2019). The group works collaboratively, through discussion, analysis, and problem solving, to improve their own practice and student achievement.

A study of 16 North American primary teachers concluded that a CoP helped them to improve their understanding of the NoS, and for many their teaching practice in this learning area (Akerson et al., 2009). These researchers explored improvements in the NoS views and teaching practice of the teachers, as a result of the development of a CoP as part of a professional development programme. Their study used the VNOS-D2 questionnaire and interviews to assess teacher conceptions of the NoS three times over the study period, as well as notes and video recordings from classroom observations and workshops to track the impact of the CoP. Interactions between the teachers and their PD providers, as well as between the teachers themselves, were found to have had the biggest influence in changing their NoS views and teaching practice. The camaraderie developed over the school year, through regular meetings, meant teachers were "open in sharing" (p. 1111) their successes and challenges in teaching the NoS. Findings also showed that teachers did not always recognise their own naïve views of the NoS, until after they had tried them in the classroom, and then discussed them in their CoP. Akerson et al. concluded that the CoP provided a "safety net" for teachers, allowing them to "verbalise their learning process and internal struggle with new conceptions" (p. 1110) leading to changes in their NoS views. This aspect is of relevance and will be investigated in the current study with regard to the PLC involved.

A more recent Australian study explored a different type of CoP involving primary teachers, and scientists working together, and found participating teachers transformed their views about their own and their students' abilities to engage with science ideas (Forbes et al., 2017). Their research presented findings on two related experimental studies, one qualitative and one quantitative, investigating the impact of primary teachers' participation in a PD initiative called MyScience. MyScience was developed as a capacity-building initiative, aimed at developing both teachers' and students' understanding of the NoS, through sustained professional learning situated in the classroom, using scientists, engineers, and local secondary science teachers as mentors (Forbes et al., 2017). Findings showed that participation in the CoP had benefited the teachers' learning, firstly by legitimising the place of science in the primary curriculum, and secondly through the use of activities, which changed the teachers' pedagogical decisions and actions. The success of the CoP was attributed to five factors; involvement of a PD provider, focusing on one area, having members of the CoP with different expertise, willingness of the participants to actively engage and share ideas, as well as a mutual appreciation of all members of the CoP (Forbes et al., 2017). Consideration of these factors will be given to the PLC involved in the current study.

The potential of a targeted participatory PD programme on the development of NoS teaching efficacy and PCK has been noted (Murphy et al., 2015). Their study investigated the impact of a two-year continuing PD programme on Irish primary teachers' NoS confidence and teaching practice. Participants were involved in 18 workshops, as well as ongoing support through school visits, a virtual learning network, and emails. At the end of the programme, confidence to teach the NoS had improved, with teachers using student-centred approaches rather than the traditional teacher-centred approach (Murphy et al., 2015). Four aspects of the programme were identified by teachers as supporting the changes in their teaching practice. Firstly, the use of hands-on, reflective, inquiry-based activities helped them develop a better understanding of science pedagogy. Secondly, the strong emphasis placed on collaboration between the teachers, helped inform their teaching approaches. Thirdly, the use of reflective practice during workshops provided teachers with the opportunity to critically reflect on their teaching practice; this aspect was seen as most valuable towards the end of the programme when a safe learning environment had been established. Lastly, the duration of the programme was seen as critical as it allowed teachers time to develop their ideas, try them out, and then reflect on their experiences with other teachers. These aspects will be considered during the current case study, to see if they are pertinent to changes in the teachers NoS teaching efficacy and PCK.

Primary teachers' views of the NOS significantly improved during participation in a discourse-focussed PD program (Piliouras et al., 2017). These authors investigated the impact of a yearlong PD programme aimed at improving content and PCK of the NoS on four Greek primary teachers. The programme consisted of four activities designed to acquaint participants with the PCK of the NOS, with data being collected and analysed using the VNOS-B questionnaire, classroom observations, and discourse analysis of teacher-researcher's classroom discussions. They found that it was important to support the teachers to analyse their talk, and that reflective practice of their discourse was the most important factor leading to a transformation in the teachers' views about the NoS. These researchers also concluded that having a good understanding of the content knowledge of the NoS, was not enough on its own to lead to effective teaching of the NoS (Piliouras et al., 2017), and that teachers needed to be familiar with the pedagogical knowledge of the NoS. This is a highly pertinent finding for the current study.

In New Zealand, few primary school teachers have a tertiary science education. Primary teachers in North America were more likely to teach science when it was connected to a familiar subject area (Deniz & Akerson, 2013). Their study examined changes in fifteen primary teachers' NoS views and teaching efficacy, after completing a five-day professional development program. The program utilized a language arts integration to provide an additional layer of support to the teachers to improve their NoS understanding, as many primary teachers felt more comfortable with this subject area (Deniz & Akerson, 2013). Data were collected using the VNOS-B questionnaire and follow-up interviews, and the VOSI questionnaire, to assess the teachers NoS and nature of scientific inquiry

(NOSI) views, while the STEBI-B questionnaire was used to ascertain their science teaching efficacy. All participants improved their NoS content knowledge, and their NOSI views. In terms of their NoS teaching efficacy, teachers only improved their science teaching outcome expectancy scores, while their personal science teaching efficacy beliefs did not significantly improve. Deniz and Akerson (2013) concluded that by integrating NoS teaching with an area a teacher feels comfortable in, PD programs can improve both a teacher's NoS content knowledge and their teaching efficacy. It will be interesting to see whether the participant in the current study utilises his social science background to aid the development of his NoS understanding.

2.4.3 Scientist-Teacher Partnerships

One of the PD programmes involved in this case study involves the participant teacher working alongside scientists over a six-month period, to build connections with the science community and to develop his content knowledge of the NoS. A variety of approaches used to connect teachers and scientists together to improve their understanding of science is reported in the literature. Many of these are short term initiatives, and very few involve primary school teachers.

Authentic experiences, through scientist-teacher partnerships, provide teachers with the opportunity to conceptualise science as a creative process, rather than simply see it as a body of knowledge. The professional learning of five North American high school teachers' short-term participation in palaeontology fieldwork with scientists in the Panama Canal was studied by McLaughlin and MacFadden (2014). Using semi-structured interviews, teacher journal entries and artefacts, they explored the ways in which authentic inquiry experiences shaped teachers' conceptions and reported enactments of inquiry-based instruction. Their findings indicate that teachers' understanding of the NoS can change as a result of participation in fieldwork. By the end of their time with the scientists, the teachers came to realise that science was a process that is inherently unpredictable, and that knowledge generated as a result is tentative in nature, and reliant on evidence and theories. These teachers also changed their conceptions of inquiry-based instruction as a result of their changed NoS understanding.

McLaughlin and MacFadden's (2014) study is supported by a quantitative study of teachers participating in one of three summer research programs funded by the National Aeronautics and Space Administration (Buxner, 2014). She found that participants who entered the program with naïve views of the NoS made small shifts in their overall understandings of scientific inquiry and the NoS. Aspects of the NoS that changed as a result of participation included the realisation that there are multiple ways to do scientific investigations, and understanding of the social-cultural embeddedness of science. She concluded that research experiences for teachers were most valuable in helping them understand how science is done in a specific context, rather than for making radical changes in their NoS understanding. These findings will be considered in the current case study, when looking at changes in the teacher's content knowledge of the NoS, as a result of working alongside scientists for 15 weeks.

Buxner's conclusion is further supported and developed by an action research study of a three-year partnership program between teachers and scientists in North America (Willcuts, 2009). The study explored the impact of the experiences of ten middle school teachers involved in a summer academy partnership program with the Department of Energy, over three years. She found that the scientist-teacher partnerships were beneficial to both parties, with the teachers gaining a conceptual understanding of science through observing real-world applications of what a scientist does, and the scientist gaining appreciation of the realities of a school system. However, findings also indicated it was difficult for teachers to identify NoS aspects in the activities completed. As a result, she concluded that for teachers to learn from the partnership, learning must be constructivist in nature, and the principles of the NoS made explicit if they are to be seen and understood.

Short-term initiatives, such as those described above, have been found to have long-term value for teachers' professional learning. A similar North American study investigated the impacts of a six-week summer institute programme, that provided teachers with ecology research experiences at a variety of national forests and parks (Dresner & Worley, 2006). Fifteen teachers who had participated in the programme, four to five years previously, were interviewed. Results found that 75% of the teachers continued to benefit from the knowledge and skills acquired during their participation (Dresner & Worley, 2006). Similar to Willcuts (2009) study, the scientist-teacher partnership was seen as beneficial, in this case, to sustaining change in practice. The collegiality established between the scientists and teachers, as well as among the participating teachers was identified as the most beneficial aspect of the program. This collegiality provided the confidence for teachers to try new teaching approaches, practical opportunities to share ideas and problems, and led to “a sense of being part of a larger movement” (Dresner & Worley, 2006, p. 11).

In New Zealand, teachers are rarely given the opportunity to work alongside scientists as part of their professional learning. For 20 years, the Primary Science Teacher Fellowship Programme (PSTF) provided New Zealand primary teachers the opportunity to work fulltime in a science-based organisation over a six-month period. During this time the teachers complete six days of targeted PD focussing on the NoS strand of the New Zealand Curriculum (Ministry of Education, 2007), as well as a week-long leadership course provided by the Otago University School of Business. In 2014, this programme ended and was replaced the year later by the Science Teacher Leadership Programme (STLP). This programme is one of the PD programmes involved in this study, and has yet to be researched.

Research has shown the impacts of the PSTF, concluding that most teachers changed their views around what was important to teach in science, with a reduced emphasis on teaching content knowledge and using fair tests, to a focus on the NoS and the multiple ways of investigating scientific ideas (Anderson & Moeed, 2013, 2017). Teachers' written reports, showed that the opportunity to work alongside scientists was crucial to this learning because it provided authentic examples of the NoS, and opportunities to understand “how science works in practice” (p. 291). Another common factor identified by participants, contributing to these changes in beliefs, was the opportunity to discuss their observations and ideas with other participant teachers. Given that the STLP is similar to the PSTF, this study will be able to ascertain whether similar changes are found in the participant teacher of the current study.

2.5 Summary

The above synthesis of the literature indicates that by raising science teaching efficacy in primary teachers, the amount of science taught in the classroom is increased. PD that provides teachers with mastery and vicarious experiences, as well as verbal persuasion is more likely to increase science teaching efficacy. Furthermore, this review highlighted that generalist primary teachers tend to draw on their life experiences, collegial discourse, content knowledge, and outside experiences to help develop their science teaching practice. Understanding the NoS is regarded as key to the development of scientific literacy in students and affects science teaching and learning. Despite teachers regarding the NoS as important to teach, it continues to be neglected. Most primary teachers hold naïve views of the NoS and lack the PCK needed to teach it.

Targeted PD can improve primary teachers' content and pedagogical content knowledge of the NoS, and lead to increases in teaching efficacy. The PD needs to be of sufficient duration, as well as provide hands-on experiences, reflective practice, and opportunities for collegiality to be successful. The use of mentors and professional learning communities have both been successful in meeting these requirements. Scientist-teacher partnerships have also led to changes in teachers' practice, leading to more student-centred approaches focussed on NoS aspects and multiple different scientific investigations. These authentic and collegial experiences allow teachers to conceptualise science as a creative process, and enable them to see the NoS 'in action'.

The sustainability of PD outcomes can be hindered by both personal and contextual barriers. Factors that contribute to sustained changes in science teaching practice as a result of professional development include adequate resourcing, in particular time to reflect on practice and embed new learning, support from school leadership, and collegial support.

A key idea to emerge from this literature review is the provision of the right combination of professional development to change a teacher's NoS teaching efficacy. Development of a teacher's PCK of the NoS is crucial in order to make changes to their practice and efficacy, and this requires an adequate understanding of the content knowledge of the NoS. The effectiveness of PD on NoS teaching efficacy needs to use a range of tools to collect and analyse data to determine changes in content knowledge, PCK, and teaching efficacy.

Chapter Three - Study Design and Methodology

3.1 Introduction

The focus of this research project is to carry out a case study of one New Zealand primary school teacher in order, to examine the impact on his teaching efficacy of the nature of science after his involvement in three professional development programmes.

This chapter begins by explaining the theory behind the research methods used in this study, their limitations, and potential ethical issues. It provides detail about the specific methods used, including information about the participant, data collection and analysis processes.

3.2 Type of Research

Qualitative and quantitative research create new knowledge, by observing phenomena, and seeking meaning from the research results. Both produce data, but the data produced is either in the form of words (qualitative) or numbers (quantitative). According to Stake (1995), the distinction between them is not directly related to the data collected, but rather to a difference in searching for happenings (qualitative) versus searching for causes (quantitative).

Qualitative research is based on the philosophical viewpoint that social reality is unique (Ary et al, 2014), and seeks to understand and interpret phenomenon from the perspective of the participant. This approach means that qualitative research is diverse, using a multitude of different methodologies and research practices.

Quantitative research is based on the philosophical view of positivism, and is often considered as the traditional scientific method, involving hypothesis testing and data that lead to generalisations (Ary, Jacobs et al., 2014). Quantitative research neglects the social and cultural context of the research, and instead relies heavily on concepts in pursuit of measurable phenomena.

This study aims to identify changes in science teaching efficacy of one primary school teacher after his involvement in three different professional development programmes. A qualitative approach is suitable because the study does not search for causes, but rather to gather data from the teacher to help us understand the impact of the different professional development programmes on science teaching efficacy. The addition of numerical data is recognised as a benefit to qualitative studies, enriching the contextualisation and understanding of the research (Hamilton & Corbett-Whittier, 2013). For this reason, quantitative data will also be collected to supplement the qualitative data collected, with the qualitative data remaining central to the case study (Yin, 2009).

3.3 Research Questions

The over-arching question to focus this study is:

'How does a primary teacher's professional development participation impact his teaching efficacy for the nature of science?'

3.3.1 Research Sub-Questions

The following sub-questions guide the research:

1. How does the teacher's efficacy for teaching the nature of science change as a result of participation in professional development programmes?
2. How does the teacher's content knowledge of the nature of science change as a result of participation in the professional development programmes?
3. How does the teacher's pedagogical content knowledge of the nature of science change as a result of participation in professional development programmes?

3.4 Case Study

The current study asks a 'how' question and is exploratory in nature, indicating the value of a case study design. In comparing different qualitative approaches, Yin (2009) states that case study is the preferred research method when the research question is a 'how' or a 'why', as these questions deal with operational links that require time to be traced. Case study design facilitates an in-depth exploration of a phenomenon within its natural setting (Stake, 1995, Merriam, 1998, Yin, 2009), using a variety of data sources. It allows the researcher to use multiple lens to reveal and understand the many aspects of the phenomenon.

By definition the case is "a thing, a single entity, a unit around which there are boundaries" (Merriam, 1998, p. 27). The term bounded refers to factors such as personnel, time, place, activity and context. This 'boundedness' is important to case study, as it delineates what is 'inside' the case and what is 'outside' (or excluded from the case).

3.4.1 Category of Case Study

Several categories of case study design have been described by Stake (1995), Merriam (1998) and Yin (2009). Firstly, explanatory, or causal case study design examines data both at the surface and deep level, to explain the possible causal links in the data (Yin, 2009). Yin's (2009) exploratory case study, is commonly used to determine the feasibility of an intervention and may be a precursor to large-scale research projects. In contrast, multiple-case or collective case study design (Stake, 1995; Yin, 2009) explore differences between and within cases, allowing analytical generalisability. Descriptive case studies (Merriam, 1998; Yin, 2009) on the other hand, provide detail of the phenomena being studied using narrative accounts.

Merriam's (1998) interpretive and Stake's (1995) intrinsic case study designs, focus on the case itself, allowing the researcher to gain a better understanding of its uniqueness. In comparison, by focussing on a single aspect, concern, or issue within a particular case, instrumental case study design provides insights into a phenomenon, or helps to refine theory.

The intent of the current research is to gain an understanding of how three professional development programmes impact science teaching efficacy for one teacher. The literature review indicates that similar studies have not been completed, therefore this research may contribute to a new aspect of the research literature. The research is studying one teacher as he operates within his normal, real-life context, attempting to understand what the data shows, rather than quantifying or justifying it. As such the current research is instrumental in nature, and an instrumental case study design will be employed. The role of the researcher in this study will be to explore in depth and gain a greater understanding of the impact of the professional development programmes on the teacher's efficacy.

3.4.2 Limitations of Case Studies

Despite its strengths, case study design has limitations. Firstly, case studies cannot directly address causal relationships. Causal relationships are commonly found through experiments, and seek to explain whether a particular strategy or treatment has been effective in producing a particular 'effect', namely does A cause B to occur. Nevertheless, case studies offer important evidence to complement experiments, and therefore should be valued for this reason (Yin, 2009).

According to Yin (2009), the second limitation of case studies is their lack of rigour, however, according to Houghton et al. (2013) and Ary et al. (2014) different criteria can be used to assess the rigour of qualitative research – credibility, transferability, dependability, and confirmability. Credibility can be impaired when the researcher fails to transcribe interviews correctly, however this can be overcome through member checking. If the researcher fails to record thick descriptions of classroom observations, transferability of the data to another situation cannot occur. Dependability or trustworthiness of data can be lost if records of data collection and analysis are not kept, however by using programmes such as *NVivo12* an audit trail can be kept. While confirmability will be undermined if the researcher fails to be objective, by focussing their attention and awareness on ethical nuances as they arise, this can be avoided.

In order to ensure rigour is maintained within the current study the following strategies are employed:

- Credibility
  - the study takes place over 11 months allowing prolonged engagement and persistent observation
  - triangulation of data using at least two different data collection methods to obtain data on each research question
  - member checking of transcripts and classroom observations will be completed by the teacher before analysis
- Transferability
  - thick descriptions will be recorded to provide a robust and detailed account of the researchers experience during data collection
- Dependability and Confirmability
  - NVivo12 will be used to provide a comprehensive audit trail
  - the researcher will apply a reflexive approach to data collection, assessing the effect of their presence and research techniques on the data collected.

The last, and most discussed limitation refers to the generalisability of case study, and whether a single case can be used to generalise the findings across other situations. Stake (1995) refers to "the real business of case study as *particularisation*, not generalisation" (p. 8). Stake describes this as taking a particular case, getting to know it really well, allowing you to not only see the differences to other cases but also its uniqueness. By developing a rich narrative, the researcher may provide insights, contributing to practical wisdom (Punch & Oancea, 2014), expanding on and generalising theories rather than replicating existing findings (Yin, 2009).

The goal of this case study is not to produce generalisable results, rather to contribute new insights into the impact of multiple professional development programmes on improving science teaching efficacy.

3.5 Data Collection and Types of Evidence

Evidence for case studies can come from a variety of sources and is usually selected in relation to the nature of the case and the research question posed (Luck, Jackson, & Usher, 2006). According to Yin (2009) there are six commonly used sources of evidence in case studies – documentation, archival records, interviews, direct observations, participant-observation, and physical artefacts, while Luck et al. (2006), adds surveys and questionnaires to this list, to provide a diverse range of data collection methods.

It is important for the researcher to choose the most appropriate data sources to address the problem or question. By using a variety of collection tools, such as interviews, observations and questionnaires, data triangulation is achieved, increasing the likelihood of the phenomenon under study being corroborated.

The following three data collection tools have been chosen in the current case study as they provide multiple sources of evidence allowing the researcher to address a broader range of issues, and develop "converging lines of inquiry" (Yin, 2009, p. 115) through data triangulation.

3.5.1 Questionnaires

3.5.1.1 Questionnaires in Theory

Questionnaires are a useful tool for obtaining information from an individual about their views, perceptions and beliefs about a topic. Questionnaires provide an effective way of obtaining data in a structured and manageable form, producing rich data in a format that can be easily analysed and interpreted (Wilkinson & Birmingham, 2003). Effective questionnaires enable the respondent to provide useful and accurate information (Wilkinson & Birmingham, 2003). To achieve this, questions posed must be presented in a clear and unambiguous way so the respondent can interpret, articulate their response, and the transmit it to the researcher.

As can be seen in Table 3.1, there are three main approaches used in questionnaires to ask questions. In terms of my case study, scale items have been chosen as the approach to use for the two questionnaires, as the teacher is being asked about his beliefs. Scale items provide a number of possible responses providing the teacher with greater flexibility to respond as well as greater accuracy in recording their views (Wilkinson & Birmingham, 2003).

Table 3.1:
Approaches Used to ask Questions in Questionnaires

Approach	Description of approach	Example
Closed Questions	Questions where all possible responses are provided	*Do you wear a hearing aid?* *Yes No*
Multichoice or Scale item questions	Questions which provide a number of pre-defined responses for the respondent to choose from	*How likely are you to recommend … to others?* *Very likely* *Likely* *Not sure* *Unlikely* *Very unlikely*
Open-ended questions	Questions which allow for any response to be given by the respondent	*Tell us about the school you attend?*

In my case study, two questionnaires, will be used with the teacher to provide supplementary evidence to the other qualitative evidence collected. Benefits of using questionnaires to collect data, include the ability to:

- identify relationships between data easily (in this case it will provide evidence which can be compared with interviews and observations)
- repeatedly measure any differences over time (in this case allowing any changes over the 10 months of the case to be measured).

3.5.1.2 Questionnaires in Practice

An adapted version of the Nature of Science as Argument Questionnaire (NSAAQ) was administered to the teacher in the form of a paper-based questionnaire. The teacher completed this on his return from the Royal Society PD programme, and then again at the end of the case study period, ten-months later.

This survey, developed by Sampson (2006), was designed to identify an individual's epistemological understanding of science related to argumentation, as argumentation plays a central role in the teaching and learning of science (Sampson & Clark, 2006). The survey provides information on four aspects of the NoS, namely:

1. the nature of scientific knowledge,
2. methods used to generate scientific knowledge,
3. what counts as reliable and valid scientific knowledge, and
4. the social and cultural embedded NoS practice.

These four aspects link closely to three of the NoS strands identified in the *New Zealand Curriculum* (Ministry of Education, 2007), (i) understanding in science, (ii) investigating in science and (iii) participating and contributing in science.

The survey was validated using content, translational, face, convergent, discriminant, concurrent and criterion validity, with satisfactory reliability being established using a Cronbach alpha and a test-retest analysis (Sampson & Clark, 2006). Based on the validity and reliability of the questionnaire, valid conclusions can be made about the teacher's NoS beliefs.

The questionnaire consists of twenty questions (refer to Appendix D(i)). Each question required the teacher to choose between two contrasting viewpoints, using a 5-point Likert scale. At one end of the scale is a more naïve epistemological belief about the aspect of the NoS, while the other represents a consistent view of science as a process of explanation and argument (Sampson & Clark, 2006). The use of contrasting viewpoints within a single item is used to allow an individual's response to be internally normalised, as there is a point of reference (Sampson & Clark, 2006). For example, rather than indicating their level of agreement with a single predefined theoretical position, such as 'science knowledge is tentative', the participant compares two alterative viewpoints and indicates their perspective. Choosing either a 1 or 5 indicated that the teacher agreed with the specific viewpoint, while a score of 2, 3, or 4 indicated a weighted response to either view. The maximum possible score is 100, with a high score reflecting a more consistent understanding of the NoS as a process of explanation and argument.

A second questionnaire, the adapted Science Teaching Efficacy Belief Instrument (STEBI), was provided to the teacher as a Google form to complete online at the same time as the NSAAQ. The STEBI instrument, developed by Riggs and Enochs (1989, 1990), is designed to measure science teaching efficacy of elementary school teachers. The questionnaire produces measurements for two subscales – personal science teaching efficacy (PSTE) and science teaching outcome expectancy (STOE). The PSTE scale measured beliefs about the teacher's ability to effectively teach science, while the STOE scale measured his beliefs related to his capability to positively affect student achievement in science.

The STEBI questionnaire has frequently been used in science education "due to its capacity to measure relevant, complex constructs in a reliable way" (Deehan, 2017, p. 7). Enochs and Riggs (1990) found the PSTE scale to have a Cronbach alpha reliability coefficient of 0.92, and the STOE scale to have 0.77, though a study by Aslan, Taş and Oğu (2016) found the STOE produced a Cronbach alpha of 0.79. Construct validity was determined using factor analysis, and revealed all final items used were loaded highly with their scale (Enochs & Riggs,1990).

The adapted version of the STEBI consisted of 23 items (refer to Appendix D(ii)) focused specifically on beliefs around teacher efficacy of the NoS, and included both positive and negative statements. The PSTE subscale consists of 13 items (5 positive, 8 negative), while the STOE has 10 (8 positive, 2 negative). The survey required the teacher to rate his level of agreement with the statements using a 5-point Likert scale: 1 (strongly disagree), 2 (disagree), 3 (uncertain), 4 (agree), 5 (strongly agree). The maximum possible PSTE score is 65; a high score for this factor would indicate the teacher believed he could effectively teach the NoS. The maximum possible score for the STOE subscale is 50; a high score for this factor would indicate that the teacher believed he had a strong influence on students' NoS achievement.

3.5.2 Interviews

3.5.2.1 Interviews in theory

According to Punch and Oancea (2014) the most prominent data collection tool used in qualitative research is the interview. Not everything can be observed when doing a case study, and interpretations made by one person may not in fact match those of others present. The interview allows the researcher to investigate the multiple views of the case

(Stake, 1995), while including the unique perspectives and understandings of the participant, providing greater depth to the study. Qualitative interviews build on naturalistic, interpretive philosophy, by extending normal conversations, and enabling the interviewee to become a partner in the research process (Punch & Oancea, 2014).

Yin (2009) identified four key weaknesses associated with interviews. The first two weaknesses refer to possible sources of bias; poorly expressed questions, and response bias. The other two weaknesses link to the interviewee; poor recall by the interviewee leading to inaccuracies, and the interviewee answering questions to meet perceived interviewer expectations. In order to overcome these weaknesses, the researcher should select an appropriate type of interview, aligned to the purpose, using carefully crafted questions that have been tested.

Interview types vary according to the level of structure and depth of the interview. Figure 3.1 shows an adaptation of the Interview Structure Continuum provided by Merriam (1998). At the far-left hand side are the highly structured or standardised forms of interview, where the questions and coding categories are predetermined. These types of interview do not provide the opportunity to investigate the participant's perspectives and understandings. In comparison, there is the unstructured or informal interview where a few general questions start the interview, but follow-up questions emerge as it unfolds (Punch & Oancea, 2014), providing the opportunity for more thoughtful responses.

Highly Structured	Semi-structured	Unstructured/informal
• Closed questions • Wording of question predetermined • Order of questions predetermined • Similar to survey	• Mix of more- and less-structured questions • Flexible wording of questions • Answers develop according to interviewee	• Open-ended questions • Flexible, exploratory • Conversational • More personal

Figure 3.1. Interview structure continuum. (Adapted from Merriam, 1998, p.73).

Semi-structured interviews will be utilised with the teacher participant throughout the time of this study as this type of interview "allows the researcher to respond to the situation at hand" (Merriam, 1998, p. 74), enabling the worldview of the teacher to emerge, and new ideas on the topic to be developed.

3.5.2.2 Interviews in Practice

Three individual semi-structured interviews were conducted with the participant teacher – one at the completion of the Royal Society professional development (PD) programme, one after six-months back in the classroom, and the last eleven-months after returning to the classroom. The inclusion of the second interview mid-way through the case study, was due to the teacher's resignation from his current school, as this marked an end to support from two of the PD programmes, though he continued to participate in the third PD. The third interview was designed to measure the impact of the professional development over the extended time period of ten months. Each interview was conducted either at the teacher's or researcher's school, and was audio-recorded, and transcribed. There were no time constraints given to the interviews, allowing the opportunity for discussion to be free-flowing. The first interview lasted 61 minutes, the second 43 minutes, and the third 66 minutes. Transcripts of interviews were checked by the teacher after each interview.

3.5.3 Classroom Observations

3.5.3.1 Observations in Theory

Observation is a common qualitative data collection tool. Naturalistic observation occurs in the natural setting of the case and where the observer does not manipulate or stimulate behaviour in those being observed. Observations can be both structured and unstructured. Structured observations are commonly used to observe changes over time, tending to be very detailed, using predetermined observational schedules. An unstructured approach to observations involves the observer recording a stream of actions and events, as they naturally occur (Punch & Oancea, 2014). A key advantage for a researcher using unstructured observation is "the ability to focus on larger patterns of behaviour, more holistically" (Punch & Oancea, 2014, p. 197).

Despite the obvious advantages of observations, there are several weaknesses (Yin, 2009). Firstly, the process of observation is time-consuming, leading to a high cost in terms of researcher hours. Secondly, it is very difficult for a single observer to achieve the broad coverage needed, possibly leading to selectivity, and a reduction in the reliability of the data collected. Yin (2009), therefore, advocates that where possible, and resources permit, multiple observers should be used in case studies. Lastly, Yin (2009) warns that the researcher must be sensitive to the possible effects their presence has on the observation, and account for any possible effects.

In my study, unstructured, naturalistic observation will be employed to observe the teacher in his classroom. The focus of the observations will be on the classroom discourse strategies used by the teacher, and the content of the lesson. Given that I will be in a classroom with the teacher, my role as the observer will be as a participant observer. In this role I will be able to observe and interact closely with the class, as an "insider's identity" (Merriam, 1998, p. 101) without participating as a member of the class in the activities.

3.5.3.2 Observations in Practice

Two classroom observations of the teacher were conducted during the case study, in the two different schools he worked in during this time. For each, the science curriculum strand being taught, and science capability used were identified. The focus of each observation was on the classroom discourse between the teacher and his students. Detailed notes of the actions and discourse occurring throughout the lesson were taken, and then transcribed. Each lesson lasted 50 minutes and was targeted at a similar year level (Year 5/6), and focussed on the same NoS strand of the curriculum – communicating in science.

3.6 Validity and Dependability of Data

For any research to be of use to others, the study must be conducted rigorously, producing valid and dependable data. Validity refers to the accuracy and credibility of evidence collected, and is dependent on the steps taken by the researcher to ensure this has been maximised (Hamilton & Corbett-Whittier, 2013). There are three types of validity which can be applied to qualitative research – construct, internal and external. In terms of my instrumental case study, construct validity is the key area of concern. Construct validity refers to the ability to identify correct operational measures for the concepts being studied (Yin, 2009).

According to Yin (2009) three guiding principles help to deal with establishing construct validity and dependability of evidence in case studies, (i) the use of multiple sources of evidence such as interviews and observations, (ii) creating a case study data base such as using *NVivo12*, and (iii) maintaining a chain of evidence stating who, where and when data were collected.

The advantage of using multiple sources of evidence, is that findings from one source can be confirmed or supported from another source, allowing the development of common ideas which are more convincing and accurate than those from a single source (Yin, 2009). Two types of triangulation are relevant to this study:

1. data triangulation – the use of different sources of evidence (e.g. interviews, observations and questionnaires), and
2. methodological triangulation – the use of different methods.

Data source triangulation, ascertains if what is observed and reported carries the same meaning under different circumstances (Stake, 1995). For example, in this particular study it will be important to see whether data collected about the teacher's pedagogical content knowledge of the NoS from the NSAAQ questionnaire matches what is being observed in the classroom, and how the teacher answers questions about this in interviews.

Methodological triangulation is the most recognised form of triangulation, involving the use of multiple approaches within a single case study, allowing extraneous influences to be illuminated or nullified (Stake, 1995). In my study, methodological triangulation may involve observing the teacher teaching, then following this up with an open-ended interview with the teacher for his perspectives about the lesson.

Yin's (2009) second guiding principle refers to the organising and documentation of collected data. In order to achieve transparency and data credibility, Yin (2009) recommends the development of a formal, presentable database, so that others can review the data directly, and derive similar interpretations to the researcher. To meet this requirement, the qualitative tool *NVivo12* will be used to store and analyse all data.

The third principle identified by Yin (2009) to increase dependability of data, refers to the importance of maintaining a chain of evidence. An outside observer should be able to follow the origins of any evidence from the initial research questions through to the final conclusions (refer to Figure 3.2). *NVivo12* again can be used to maintain a chain of evidence by ensuring that no original evidence is lost or biased. A chain of evidence in a case study addresses construct validity, helping increase the overall quality of the study.

Case Study Questions

Case Study Protocol
(linking questions to protocol topics)

Citations to Specific Evidentiary Sources
in the Case Study Database

Case Study Database

Case Study Report

Figure 3.2. Maintaining a chain of evidence (Adapted from Yin, 2009, p. 123)

3.7 Ethical Issues

In any research, ethical considerations are important, but they are of even more significance in a case study, as the researcher will be working closely with their research participant over a long period, which potentially increases the possibility of doing harm. In these situations, the researcher temporarily enters the participant's world, assessing experiences and reflections that may be of a sensitive nature or involve unforeseen risk to the participant and others (Damianakis & Woodford, 2012). Ethical practices are therefore essential at all stages of a case study (Hamilton & Corbett-Whittier, 2013).

In this study, the Massey University Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants (2017) was applied, and the research deemed as low risk. This code applies a 'high trust' approach to low risk research, meaning that the university expects the researcher to take responsibility for thoughtfully applying the principles to their research.

Three potential ethical issues were identified, and strategies put in place to mitigate them: autonomy, confidentiality, and avoidance of harm. The issue of autonomy was addressed by providing the teacher with an overview of the research project and his role at the time of consent. Consent was voluntary, and the teacher had the right to decline or withdraw at all stages of the study.

To minimise issues around the privacy and confidentiality of the participant, a pseudonym was used for the teacher, and school names not included. A confidentiality agreement was by the researcher, to protect against disclosure of any confidential information. As the researcher was known to the teacher, there was an increased risk of breaching confidentiality and possible conflict of interest, which was reduced through reflexivity and collaboration. Reflexivity permeates the whole research process, requiring the researcher to be self-reflective at all times, looking for possible biases and controlling them. Data collection methods were selected based on their adequacy for the purpose, and to reduce bias. Relevant thoughts, experiences, favoured theories, and possible biases were recorded during data collection and analysis, and reflected on individually and then discussed with supervisors. Collaboration was achieved by positioning the teacher as a research partner, involving him in discussions around the methodology used, when data collection would take place, and the interpretation of results.

To avoid possible harm to the teacher, interview questions were designed to protect his privacy and to avoid emotional distress. The teacher was always debriefed after each observation, and interview transcripts returned allowing him the right to ask for material to be removed in order to protect his privacy and/or reputation. Anonymity of the participant throughout the research helps to guarantee that there will be no negative impact on his reputation.

In order to meet the obligations of the Treaty of Waitangi, the principles of mana and manākitanga were also addressed. Mana refers to the power, authority or prestige of the participant and their community, and must be respected and upheld during the research process. As both the researcher and teacher worked within the same community, information shared belonged not only to them, but also their community. By allowing the teacher to be able to critique the research, and his role within it at all stages, mana was protected. Manākitanga, requires the researcher to show respect and care to the participant throughout the research process. Manākitanga was addressed through informed consent and the ability to opt out at any time, discussions around the timing of data collection, and the researcher's choice to follow the teacher to their new school six-months into the study. A sense of ownership for the teacher was also achieved by allowing him to member check transcripts, and critique interpretations.

3.8 Background to the Participant

This case study focussed on one NZ primary school teacher. This teacher was selected because he belonged to the same Kāhui Ako as the researcher, and had just completed the Royal Society's science PD programme. Kāhui Ako are communities of learning, which were introduced in NZ in 2014 as a key component of the Investing in Educational Success (IES) initiative of the NZ government (PPTA, 2017). This initiative aimed to lift student achievement as well as offer new career opportunities for teachers and principals (ERO, 2016), by grouping education and training providers in a local area. The Kāhui Ako that the teacher belongs to consists of one high school, one intermediate, eight primary schools and several early learning centres, and works collaboratively with the local council, tertiary providers and businesses.

The teacher was a middle-aged European male teacher who, for the purposes of this study, is known as Rick. Rick has taught in NZ primary schools for twenty years. He has a Bachelor of Business Studies, a Graduate Diploma of Teaching and a Postgraduate Diploma in Educational Administration and Leadership. At the start of the case study he was teaching a Year 5/6 combined class in a Year 1-6 decile 4 primary school, where he remained for six months before changing schools to work in a Year 1-6 decile 7 primary school, in the same Kāhui Ako.

3.9 Professional Development Programmes Involved

Rick participated in three different PD programmes prior to and during the case study research. Details of each of these programmes is provided below.

3.9.1 Science Teaching Leaderships Programme (STLP)

The STLP programme is run by the NZ Royal Society (RSNZ) and funded by the Ministry of Business and Innovation (MBI). The programme was launched in 2015 and aims to enhance science programmes for Years 1-10, by providing professional science learning, leadership development, as well as partnerships with the science community.

The STLP programme is divided into two phases. Phase one, lasting six months, involved Rick working alongside a scientist in a host organisation, in this case a University Institute of Agriculture and Environment, to experience the NoS in a natural setting and build community links. Rick also participated in twelve days of professional learning specifically focussed on developing pedagogical content knowledge of the NOS. Finally, Rick completed a five-day university residential course in leadership. Phase two of programme usually lasts between twelve and eighteen months, but because Rick resigned, he only received this support for six months. During this time, Rick worked alongside his principal and colleagues to complete a school self-review.

3.9.2 Ministry of Education Professional Learning and Development

The Kāhui Ako, in which Rick taught, received funding for Science PLD in 2017, which was ongoing throughout the time of this case study. An outside provider, with a science teaching background, was contracted to complete this work, working with each school for two days per term, as well as supporting Kāhui Ako professional learning community meetings.

At the start of the case study the school where Rick was teaching had been regularly receiving support from the provider. When he changed schools, six months into the study, the new school did not receive this support as they had opted out at the end of the first two years of the contract.

3.9.3 Kāhui Ako Professional Learning Community

The Kāhui Ako involved in this study initially had developed a challenge focussed around improving the engagement and achievement of students as active and self-directed learners using science and technology. As a result of this challenge, numerous teachers participated in the Royal Society STLP, and funding for science PD was approved by the Ministry of Education to support schools. A professional learning community was also established within the Kāhui Ako to support science teaching and the STLP teachers. This group initially met fortnightly in 2017, however midway through 2017 the tumuaki (principal) decided that they did not like the direction in which the Kāhui Ako was going, and as a result these meetings were temporarily stopped. As so many teachers had already embarked on the STLP, and PLD had been awarded for science, it was later decided to continue to support science with a reduced frequency to termly meetings, facilitated by an Across School Leader and at times the external PLD provider. Rick joined this group at the start of 2019 as a result of being accepted onto the STLP programme.

3.10 Data Analysis

The following analysis process was used to interpret data collected through interviews, classroom observations and questionnaires.

3.10.1 Analysis of Questionnaires

Quantifiable data collected from both the NSAAQ and STEBI questionnaires was analysed using EXCEL. For the NSAAQ survey, a mean response score for each of the four factors was calculated, along with an overall score for all questions. For the STEBI, an overall score for each of the subscales – personal science teaching efficacy and science teaching outcome expectancy – was calculated.

3.10.2 Analysis of Interviews

Thematic analysis of the three interviews was completed using the qualitative data analysis programme *NVivo12*, to allow the researcher the ability to identify themes within the data. An inductive approach to the analysis was adopted to ensure that themes were determined from the data collected (Braun & Clarke, 2006). Figure 3.3 outlines the six steps involved in the thematic analysis.

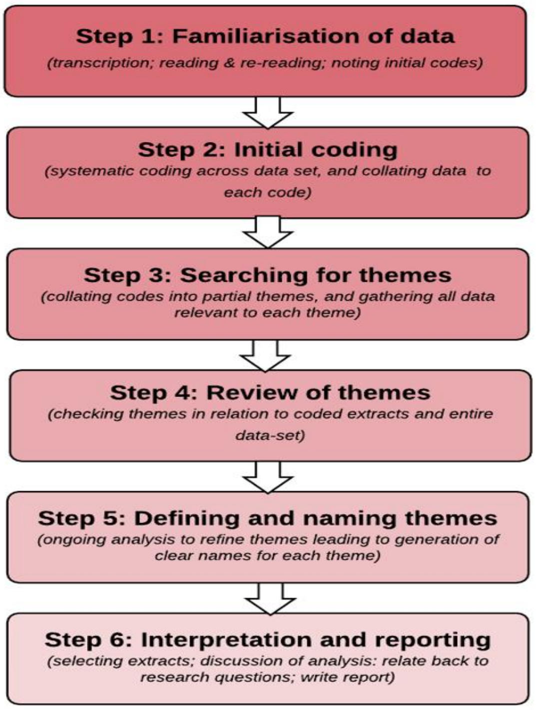


Figure 3.3. Steps used in thematic analysis (Adapted from Braun & Clarke, 2006, p. 87)

Each interview was transcribed, with reference made back to the original recorded interviews where necessary, and member checked by Rick. Data from the interviews were initially open coded allowing the researcher the ability to classify data fragments (e.g. words, phrases, sentences, or paragraphs) into groups based around ideas that addressed the research questions. Once open coding was completed an axial coding process was carried out to identify relationships between the open codes and start the process of establishing themes. Analytic coding was finally used to decide on the central themes, and sub-themes which are reported in the following chapter. Throughout this process peer debriefing was completed with my supervisors to ensure the consistency and accuracy of the coding process. At the completion of analysis of each interview, a graphical representation of the themes selected was produced (refer to Appendix F). A final thematic map was produced at the completion of the third interview indicating the final themes and categories that emerged through the analysis of all three interviews.

3.10.3 Analysis of Classroom Observations

The quantitative Classroom Discourse Observation Protocol - CDOP (Kranzfelder et al., 2019), was used for the analysis of the two classroom observations. CDOP was specifically designed for use in science classrooms, to capture the impact of teacher's instructional practices on his student's learning. The researcher recorded notes during each observation focussing on the teacher discourse with the students. Observation notes were subsequently transcribed and analysis completed using the qualitative data analysis programme *NVivo*12.

Transcripts were coded using the CDOP coding scheme that consists of sixteen codes, as shown in Table 3.2. The first five codes relate to teacher-centric discourse, while the next ten relate to student-centric discourse, where the teacher engaged the learner in conversation on the topic. The last code, 'other', related to non-content focussed discourse, and was not used as it did not relate to the research questions. Once the coding process was completed, a tabulated result was produced for each code allowing a comparative analysis to be made between the use of each category.

Table 3.2: CDOP Coding Scheme		
Teacher-centric	**Student-centric**	**Other**
Evaluating Forecasting Linking Real-worlding Sharing	Generative Checking-in Clarifying Connecting Contextualising Representing Constructing Requesting Explaining Challenging	No content discourse

(Table from Kranzfelder et al., 2019, p.7)

3.11 Summary

Based on the research questions guiding this study, and the nature of the collected data, an instrumental case study design was the most appropriate as it focuses on a 'how' question, explores the phenomenon in depth, and provides insights rather than generalisations. To ensure rigour throughout the study, strategies such as triangulation of data, prolonged engagement, member checking, reflexivity and collaboration were used. Potential ethical issues concerning autonomy, privacy and confidentiality, the possibility of doing harm, and the Treaty of Waitangi obligations were addressed through informed, voluntary consent, the right to decline or withdraw from the research at any time, the use of a pseudonym, and the positioning of the teacher as a research partner allowing him a sense of ownership around the research process and data collected, while maintaining his mana and manākitanga.

This case study is based on the experiences of Rick, a European primary school teacher in NZ, who participated in three different science professional development programmes. The study was completed over a period of eleven months following Rick's completion of the science teaching leadership programme, and his return to school.

Two surveys, three interviews and two classroom observations provided evidence to address the research questions. Triangulation of the multiple data sources, and use of *NVivo12* to maintain an audit trail and chain of evidence, were used to ensure validity and dependability of the data collected. Thematic analysis was used to analyse the interviews, an adapted version of the classroom discourse observation protocol used to code the classroom observations, while data from the surveys were analysed using EXCEL. Findings based on this data analysis are found in the next chapter.

Chapter Four - Results

4.1 Introduction

The purpose of this chapter is to report the findings in response to the study's main research question:

"How one primary teacher's participation in professional development impacted his efficacy beliefs for teaching about the nature of science?"

Data were gathered between July 2019 and May 2020, starting with Rick's return from his STLP placement. The teacher returned to his original school, after completion of the STLP programme, where he remained for two terms before leaving and moving to another school within the same Kāhui Ako. Data were gathered using two questionnaires, three interviews and two classroom observations, as shown in Table 4.1 below.

Table 4.1.
Timing of Data Collection Methods, and Codes.

Time after return from STLP placement	Data gathering technique employed	Data gathering technique codes
On immediate return to school after STLP	• Adapted form of the Nature of Science as Argument Questionnaire (NSAAQ) • Adapted form of the Science Teaching Efficacy Belief Instrument (STEBI) • Teacher Interview (1)	• NSAAQ 1 • STEBI1 • INT1
5 months after return to school	• Classroom observation of Teacher (1) • Teacher Interview (2)	• CO1 • INT2
9 months after return to school	• Classroom observation of Teacher (2)	• CO2
10 months after return to school	• NSAAQ • STEBI	• NSAAQ2 • STEBI2
11 months after return to school	• Teacher Interview (3)	• INT3

This chapter reports the findings for this study, grouped according to the instrument used. It begins by presenting the data collected from the two questionnaires, used to evaluate Rick's NoS content understanding, and NoS teaching efficacy. This is then followed by reporting the themes identified for each of the three interviews with Rick, where he discussed his involvement in professional development (PD) and its impact on his teaching, changes in his NoS understanding, and teaching efficacy. Eight themes derived from the three interviews are reported, namely changes in NoS beliefs, affirmations, self-awareness, time, discourse, support needed, leadership and cultural links to science. The next section provides a breakdown of the classroom discourse codes produced during the two classroom observations, with an evaluation of the teaching approaches used. The chapter finishes with a summary of the findings.

4.2 Questionnaires

4.2.1 Findings of the NSAAQ

The adapted form of the NSAAQ questionnaire (see Appendix D(i)) was used to measure key aspects of Rick's epistemological understanding of the NoS after participation in the three PD programmes. A 5-point Likert scale was used, where a naive view of the NoS was indicated by a score of 1, 2, or 3, while an informed view of the NoS was indicated with a score of 4 or 5. A maximum possible score of 100 can be achieved, with a score of ≥ 60 (Rice, 2012) indicating an overall informed view of the NoS.

4.2.1.1 Factor 1 – What is the nature of scientific knowledge?

As shown in Table 4.2, the mean response score for factor 1 was 3.8 immediately after Rick returned from the STLP.

Table 4.2.
Factor 1 Analysis for NSAAQ1 and NSAAQ2

Question number	Question Informed viewpoint statement	Score in NSAAQ1	Score in NSAAQ2
Qn1	Scientific knowledge represents only one possible explanation or description of the natural world	3	4
Qn2	Scientific knowledge should be considered tentative	4	5
Qn3	Scientific knowledge is subjective (based on personal feelings and opinions)	2	2
Qn4	Scientific knowledge usually changes over time as a result of new evidence and interpretations	5	5
Qn5	Scientific knowledge is best described as an attempt to describe and explain how the world works	5	5
	Mean response score	**3.8**	**4.2**

The NSAAQ survey used a bipolar semantic scale, a rating scale used to measure the difference between two opposing ideas, in this case, informed and naive views of the NoS. A score of 3.8 indicates that Rick tended towards an informed view of the nature of scientific knowledge on his immediate return to school following his professional learning experiences. Rick's mean response score improved to 4.2, when he completed the NSAAQ2 after ten months back in the classroom. This new score indicated that Rick now held an informed view of factor 1 (the nature of scientific knowledge).

Questions 1 and 3, for NSAAQ1 were answered with a score of less than 3. The score of 3 for question 1 indicated that Rick believed scientific knowledge represents multiple explanations or descriptions of the natural world. The score of 2 for question 2 indicated that Rick believed science knowledge is objective, based on facts and observations only.

In NSAAQ2, Rick's responses for question 1 and 2, ten months later had improved. He now held the informed view that scientific knowledge represents only one possible explanation or description of the natural world. Interestingly, his response to question 3 had not changed, showing that he still considered science knowledge to be factual.

4.2.1.2 Factor 2 – How is scientific knowledge generated?

The mean response score of 4.4 for NSAAQ1 factor 2 (refer to Table 4.3), indicated that Rick had an informed view of how science knowledge is generated.

Table 4.3.
Factor 2 Analysis for NSAAQ1 and NSAAQ2

Question number	**Question** **Informed viewpoint statement**	**Score in NSAAQ1**	**Score in NSAAQ2**
Qn 6	Experiments are important in science because they can be used to generate reliable evidence	5	5
Qn 7	The methods used by scientists vary based on the purpose of the research and the discipline	5	5
Qn 8	Science is best described as a process of explanation and argument	2	4
Qn 9	An experiment is used to test an idea	5	4
Qn 10	Within the scientific community, debates and discussions that focus on the context, processes, and products of inquiry are common	5	3
	Mean response score	**4.4**	**4.2**

Rick answered four of the five questions within this factor with a score of 5, while scoring question 8 with a 2. A score of 2 in this question indicated that he believed science is a process involving exploration and experimentation.

Ten months after completing the STLP, Rick's mean response score for factor 2 (NSAAQ2) had dropped slightly, but still indicated an informed view. Of interest was a radical change in response for question 8, where Rick had moved from a naïve view about how the process of science could be described to an informed one, indicating he now believed science was a process of explanation and argument, rather than exploration and experiment. In NSAAQ1 Rick had scored a 5 for question 10, indicating an informed view, while in NSAAQ2 he scored a 3, indicating a tendency towards the naïve view that debates within science communities are rare.

4.2.1.3 Factor 3 – What counts as reliable and valid scientific knowledge?

As shown in Table 4.4, Rick's mean response score for factor 3 for NSAAQ1 was 4.2, indicating an overall informed view of the reliability and validity of scientific knowledge.

Table 4.4.
Factor 3 Analysis for NSAAQ1 and NSAAQ2

Question number	Question Informed viewpoint statement	Score in NSAAQ1	Score in NSAAQ2
Qn 11	Scientific knowledge can only be considered trustworthy if the methods, data, and interpretations of the study have been shared and critiqued	5	4
Qn 12	It is impossible to gather enough evidence to prove something true	4	4
Qn 13	The reliability and trustworthiness of the data should always be questioned	5	4
Qn 14	Biases and errors are unavoidable during a scientific investigation	2	5
Qn 15	A theory can still be useful even if one or more facts contradict that theory	5	5
	Mean response score	**4.2**	**4.4**

Ten months later Rick's mean response score had increased to 4.4 in the NSAAQ2. In NSAAQ1 question 14 was answered with a score of 2, a naive view, indicating Rick's belief that bias and error can be removed from scientific investigations. Interestingly, for the same question in NSAAQ2 he scored a 5, indicating a shift to the informed view that bias and error were unavoidable in scientific investigations. Rick's responses to questions 11 and 13 in NSAAQ2, showed a slight drop from NSAAQ1, but still indicated an informed view.

4.2.1.4 Factor 4 – What role do scientists play in the generation of scientific knowledge?

Factor 4 scored the highest mean response of all four factors for NSAAQ1 (refer to Table 4.5), with a score of 4.8. Four of the five questions were scored at 5, while the remaining question was scored 4. These responses indicated that Rick had a highly informed view of the role of scientists in generating scientific knowledge at the completion of his STLP placement.

Table 4.5.
Factor 4 Analysis for NSAAQ1 and NSAAQ2

Question number	Question Informed viewpoint statement	Score in NSAAQ1	Score in NSAAQ2
Qn 16	In order to interpret the data, they gather scientists rely on logic, their creativity, and prior knowledge	4	4
Qn 17	Two scientists (with the same expertise) reviewing the same data will often reach different conclusions	5	2
Qn 18	A scientist's personal beliefs and training influence what they believe counts as evidence	5	4
Qn 19	The observations made by two scientists about the same phenomenon can be different	5	5
Qn 20	A scientist's conclusions can be wrong even though scientists are experts in their field	5	5
	Mean response score	**4.8**	**4.0**

In comparison, Rick's mean response score for factor 4 had dropped to 4.0, when he completed the NSAAQ2, ten months later. This score still indicates an overall informed view of this factor. Of significance in NSAAQ2, was the change in response to question 17. Having previously held the informed view that different conclusions could be reached by different scientists, he now held the naïve view that all scientists would reach the same conclusion from the same set of data; this indicates a radical change in view.

4.2.1.5 Summary of Findings for NSAAQ

Rick's overall score for NSAAQ1 was 86, indicating that at the completion of the STLP placement he had an overall informed view of the NoS, indicating a high level of understanding of the content knowledge of the NoS. Rick still held four naive viewpoints about:

(i) science knowledge represents multiple explanations
(ii) science knowledge is objective
(iii) science is a process of exploration and experimentation
(iv) bias and error can be removed in scientific investigations.

Ten months after completing the STLP, back in the classroom, Rick still held this overall informed view of the NoS, scoring 84 in the NSAAQ2. Of the four naïve views held at the completion of NSAAQ1, he now only held one, namely the view that science knowledge was objective. However, he now held two new naïve viewpoints:

(i) debates and discussions within a science community are rare
(ii) scientists will reach the same conclusions from the same data set.

4.2.2 Adapted STEBI Questionnaire

An adapted version of the Science Teaching Efficacy Belief Instrument Form B (STEBI), (see Appendix D(ii)) was used to investigate changes in Rick's efficacy beliefs about his capability to teach the NoS. Rick completed this questionnaire on his return from the STLP programme, and again ten months after his return to school.

The adapted STEBI questionnaire uses a 5-point Likert scale, with a score of 5 corresponding to strongly agree, and a score of 1 corresponding to strongly disagree. The instrument consists of 23 statements with scores for the personal NoS teaching efficacy beliefs ranging between 13 and 65, and scores for the NoS teacher outcome expectancy beliefs ranging between 10 and 50.

4.2.2.1 Personal NoS Teaching Efficacy

The first sub-scale within this questionnaire, called the Personal NoS Teaching Efficacy scale, included 13 items that relate to Rick's confidence in his own teaching abilities about teaching the NoS. The items are either written positively, or negatively (indicated with an

R in Table 4.6); those written negatively are reverse scored when calculating the overall score.

Table 4.6.
Summary of Responses for Personal NoS Teaching Efficacy Scale

Item Number	Item Description	STEBI1 Response	STEBI2 Response
1	*I will continually find better ways to teach the nature of science*	5	4
2R	*Even if I try very hard, I will not teach the nature of science as well as I will most other subjects*	1	1
4	*I know the strategies necessary to teach the nature of science concepts effectively*	4	4
5R	*I will not be very effective at monitoring progression in student's nature of science skills*	2	2
7R	*I will generally teach the nature of science ineffectively*	1	1
11	*I understand the nature of science concepts well enough to be effective in teaching it to my students*	4	3
17R	*I will find it difficult to explain to students why science experiments work*	2	4
18	*I will typically be able to answer students' nature of science questions*	4	4
19R	*I wonder whether I will have the necessary skills to teach the nature of science*	2	2
20R	*Given a choice, I will not invite the principal to evaluate my nature of science teaching*	2	2
21R	*When a student has difficulty understanding a nature of science concept, I will usually be at a loss as to how to help the student understand it better*	2	2
22	*When teaching the nature of science, I will usually welcome student questions*	5	5
23R	*I do not know what to do to turn students on to the nature of science*	2	2

The maximum possible score for this sub-scale is 65. Rick's overall Personal NoS Teaching Efficacy score at the completion of the STLP was high at 56 (STEBI1), indicating that he had a high level of confidence in his ability to teach the NoS on his immediate return from his STLP placement. Ten months later, after being back in the classroom, Rick scored 52 (STEBI2). This lowered total indicated a slight drop in his confidence levels over this time, though it is still regarded as a high score.

Looking at Rick's individual responses to questions (see Table 4.6), only three responses changed over the ten-month period. Although Rick still agreed with question 1, it showed a slight drop in confidence around his ability to continue to seek different ways to teach the NoS. In question 11, Rick was confident in his understanding of the NoS at the completion of the STLP, but expressed uncertainty in this area in STEBI2. Of particular interest, was the complete change in response for question 17. Having previously felt confident in explaining how science experiments work, Rick expressed a lack of confidence ten months later.

4.2.2.2 NoS Teacher Outcome Expectancy

The second sub-scale included within the STEBI questionnaire relates to Rick's belief in his ability to influence his students' learning of the NoS through his teaching. The subscale included 10 items, which were again either written positively or negatively (indicated with an R in Table 4.7).

Table 4.7.
Summary of Responses for the NoS Teacher Outcome Expectancy Scale.

Item Number	Item Description	STEBI1 Response	STEBI2 Response
3	*When the nature of science skills of students improve, it is often due to their teacher having found a more effective teaching approach*	4	5
6	*If students are not making progress in their nature of science skills, it is more likely due to ineffective science teaching*	4	4
8R	*The inadequacy of a student's nature of science background cannot be overcome by good teaching*	2	2
9R	*Low nature of science skills of some students cannot generally be blamed on their teachers*	3	2
10	*When a low-achieving child progresses in the nature of science, it is usually due to extra attention given by the teacher*	3	4
12R	*Increased effort in nature of science teaching produces little change in some students' understanding*	2	2
13	*When a student does better than usual at the nature of science, it is often because the teacher exerted a little extra effort*	2	4
14	*The teacher is generally responsible for the nature of science achievement of students*	4	4
15	*Students' achievement in the nature of science is directly related to their teacher's effectiveness in teaching the nature of science*	4	3
16	*If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher*	2	3

The maximum possible score for this sub-scale is 50. Rick's calculated score based on his STEBI1 NoS outcome expectancy belief responses was average at 34. Interpretation of this result indicates that Rick believed his actions would have some impact on the performance of his students, but would not be the sole source on his immediate return from the STLP programme.

Ten months later, when Rick completed the STEBI2, he scored 39; a 10% increase in score from STEBI1. Rick's outcome expectancy beliefs grew to above average, indicating he believed he had a greater impact on the performance of his students now that he was back in the classroom.

Six of Rick's responses changed between STEBI1 and STEBI2. Responses from STEBI2 to questions 3, 10, and 13, indicated that Rick now believed that his teaching approach, as well as the effort he put in to his NoS teaching led to improved outcomes for student. In STEBI1, Rick did not believe he had a role in generating students' interest in the NoS, but now in the classroom, he expressed some uncertainty around this area. On his return from the STLP, Rick was uncertain about whether he could be blamed for low student skills in the NoS, but in STEBI2 this view had changed, and Rick now believed he could be blamed.

4.2.2.3 Summary of Findings for STEBI

On return from the STLP, Rick had a high level of confidence in his ability to teach the NoS, scoring 56 in the Personal NoS Teaching Efficacy Belief (PTEB) scale of STEBI1. However, he scored 34 in NoS Teacher Outcome Expectancy (STOE) scale indicating he believed he only had some impact on his students NoS outcomes. After being back in the classroom for ten months, Rick's PTEB score had decreased to 52, while his STOE score had increased to 39. These trends were explored during Rick's interviews and are reported in section 4.3.5.2.

Changes in the PTEB score over a ten-month period indicated that his confidence dropped slightly, though it was still considered high. He now expressed uncertainty around his confidence in his understanding of the NoS, and a lack of confidence to explain scientific experiments, possibly due to being more aware of what he did not know. In contrast, his STOE score showed a marked improvement over the same period, indicating that Rick now believed his teaching had an impact on his students NoS outcomes.

4.3 Interviews

Three interviews with Rick were completed during this case study, at different times as shown in Table 4.8.

Table 4.8.
Timing of Interviews Conducted on Teacher

Interview	Date	When the interview took place
1	24 July 19	On immediate return to school after completing the STLP
2	5 Dec. 19	During Rick's second term back in the classroom after the STLP placement
3	26 May 20	During the fourth term in the classroom after Rick's STLP placement, in his new school

Three interviews were completed, rather than the proposed two, because Rick left his original school six months after he completed the STLP programme. This shift meant that Rick no longer received support in the way of PD nor release time from the Royal Society, which was promised as part of his STLP involvement. This shift also meant that he no longer received the external PD from the Ministry. The only PD that he continued to receive during the last two terms of the research study was from his participation in the Kāhui Ako professional learning group. Due to this change in circumstances a third interview was conducted to gauge changes in Rick's perceptions and beliefs during this transition period.

4.3.1 Findings from First Interview

The purpose of the first interview with Rick, on his return to school after completing the STLP programme, was aimed at:

1. collecting information about his understanding of the content knowledge of the NoS gained from his STLP placement, to support the data collected in the NSAAQ(1) questionnaire,
2. reflecting on his STLP involvement,
3. gathering information about his current perceived NoS teaching efficacy after his STLP involvement, to support data collected by the STEBI (1) questionnaire, and to discover sources of information leading to this efficacy.

Coding of the interview was completed according to the process outlined in section 3.10.1. This analysis process revealed four key themes, changes in Rick's NoS beliefs, the influence of culture on his NoS understanding, the importance of discourse, and leadership. Each of these themes were further broken down as shown in thematic map 1 (see Appendix F, Figure F1).

4.3.1.1 Changes in NoS beliefs

Beliefs about the NoS refer to changes in Rick's understanding of the content and pedagogical content knowledge of the NoS, as well as changes to his teaching efficacy beliefs.

4.3.1.1.1 Changes to Rick's NoS Content Understanding

Prior to Rick's involvement in the STLP programme he lacked understanding about the NoS, having had limited previous exposure to the science capabilities through the external PLD provider, stating "*pretty much zilch, nil. I would say that it was basically non-existent"* (INT1). Rick believed that science was all about science knowledge - the facts and figures, and he did not like being a transmitter of knowledge.

Rick believed that scientists started with an idea which they then went out to prove. He explained this by saying *"I went into my work at the host thinking that scientists pretty much had a hunch and worked towards proving that hunch, proving that theory"* (INT1). This idea about science being based on facts or hunches changed as a result of his time at his host placement. He discovered that although scientists did start with ideas, their knowledge was generated through the process of investigation. He argued this by saying *"they've got a bit of an idea ... but then the actual knowledge ... is generated through the process as they go along ... and sometimes that knowledge ... may not be what* they are *anticipating"* (INT1).

Another development in Rick's understanding of the content of NoS related to fair testing - a method requiring one variable to be changed and the others controlled. Prior to his host placement, Rick believed that there was only one type of experimentation, namely fair testing, stating *"my idea of what a fair test was, was turned on its head"* (INT1). Rick realised that being aware of the variables, rather than controlling them or eliminating them, was more important in a scientific investigation.

Findings also showed some misconceptions about the concepts of reliability and validity, expressing reliability related to the process, while validity referred to the outcome. Rick explained this by stating *"reliability would be … has my process been reliable … and then here is my … discovery … is it valid"* (INT1). His reversal of terms shows that he has not gained a clear understanding of reliability and validity. Reliability, in terms of the NoS, refers to how close repeated results are to one another, and whether the results can in fact be replicated, therefore it relates to the outcome, not the process as stated by the teacher. Validity, in contrast, relates to the process, its suitability to what is being investigated, and whether the correct form of measurement is being used.

4.3.1.1.2 Changes in Rick's pedagogical approach to the NoS

Prior to his involvement in the STLP, Rick believed that science teaching should be based on the content strands of the New Zealand Curriculum (NZC) (Ministry of Education, 2007), and that fair testing was the only type of scientific investigation students should engage in. He believed, at the outset that students needed to be doing *"busy science stuff"* (INT1) describing this busy work as *"putting them [seeds] in different cupboards, or water, or dry, or windows … and we were seeing what happened"* (INT1). However, by the end of the STLP Rick's beliefs about pedagogy had changed. He now believed that science teaching was a balance of building knowledge and developing capabilities, with a higher focus on the capabilities, stating that he would *"focus on the process, skills, and ways of being a scientist, rather than … just the knowledge"* (INT1).

Furthermore, he expressed a desire to be 'invisible' within the class when he did teach the NoS, meaning he was not at the front of the class rather working alongside students. He preferred to be actively participating with his students in a learning community, so they could learn together as part of a group, together asking the right sorts of questions. He reflected on the fact that he had observed scientists challenging one another's thinking during his host placement, and that *"through science capabilities and the nature of science"* (INT1) he would like to encourage a similar debate with his students.

This change in his pedagogical approach was reflected in his desire to discontinue fair testing in their scientific investigations, saying *"I think I'd like to see kids doing some different things, and not worrying about that it has to be a fair test"* (INT1). Rick was keen for students to be thinking about why things happen, justifying the claims they made, rather than just following a recipe given for a practical lesson. He now saw his role when teaching the NoS as being more student-centred *"orchestrating, guiding, challenging, [and] affirming"* (INT1) students, rather than the teacher-centred transmitter of knowledge which he believed he was before his participation in the STLP. This shift suggests that his enhanced efficacy beliefs to teach science, contributed to his ability to teach in new ways that aligned with his learning community philosophy.

4.3.1.2 Changes in Rick's NoS Teaching Efficacy

At the start of the study, Rick expressed a lack of confidence to teach the NoS, indicating that he had a low personal science teaching efficacy. He stated that *"as of now, I'm not that confident"* (INT1). The difficulties managing his new class on his return to school, meant he had a lot of work to do to develop a learning community, so his focus was on developing an environment for learning rather than teaching the NoS. However, Rick argued that once he had developed a learning community, he was confident to start teaching the NoS.

In terms of outcome expectancy, Rick believed there was a direct correlation between his content and pedagogical content knowledge of the NoS, and his students' learning outcomes. However, he believed he was not the only factor influencing his students' outcomes, stating "*Am I the sole influencer? … no. Am I a significant influencer? … yes, but the kids are also exposed and bring a whole lot of things with them that adds and builds to what I can do" (*INT1).

These findings support those found in STEBI1, where the teacher scored a high score in personal science teaching efficacy, and an average score in outcome expectancy.

4.3.1.3 The Influence of Culture on Rick's NoS Understanding

As part of Rick's STLP he was placed with the Institute of Agriculture and Environment in a College of Sciences for fifteen weeks. His host studied Ethnobotany - the traditional knowledge and customs of people concerning plants. In terms of this case study, culture refers to Rick's experiences in this institute. Rick identified connections between culture and science as the one aspect of his host placement that had changed his understanding of the NoS.

At the start of his placement Rick believed that his hosts placed a higher value on science knowledge, than they did on cultural knowledge. He found himself challenging his host, asking *"how is this science? This is social science"* (INT1) to which they replied, *"cultural knowledge is as important or different, but it's not one's better or worse than the other, it's just different knowledge"* (INT1). By engaging in reflective discourse with his host, he made connections between cultural knowledge and the NoS, describing the links as *"cultural knowledge may not be represented and shown in the ways that you think in terms of the NoS ... similar conclusions and the same ways of being [have] happened ... which is exactly what scientists do"* (INT1). Rick had used his social science background to understand the links between the two knowledge systems, and gain a greater understanding of the NoS.

Rick's placement also led to a transformation in his efficacy beliefs around teaching the NoS, and a realisation that he could teach the sort of science he was observing. Prior to this placement he had believed knowledge transmission was the approach to use when teaching science, however by the end of his placement after observing his host in action, he described his new teaching approach as "*Let's just act like scientists ... cos the nature of science isn't about teaching ... knowledge"* (INT1). This change in thinking contributed to his enhanced personal science teaching efficacy beliefs at the end of the STLP.

4.3.1.4 The Importance of Discourse to promote Rick's Learning

Discourse refers to the interchange of ideas either through written or verbal communication. In this instance, discourse refers to the interchange of verbal communication around the material being presented at workshops, and also between the providers and presenters of the PD, and the teacher who contributed to Rick's learning. Rick identified engagement in reflective discourse as a key learning approach needed for his own personal development.

4.3.1.5 Lack of Discourse impacted Rick's Learning

Part of the requirements for the STLP is attendance at twelve PD days run by the Royal Society. Rick described the teaching approach used on these days as being teacher-centred, with the participants in a passive role. He expressed frustration stating *"They were difficult for me… I was really struggling, and I was pushing against it"* (INT1). However, when the providers entered into discussions with him and treated him more collegially, Rick began to enjoy his learning.

During these days participants also visited schools. Rick described these as *"show and tell"* (INT1*)* sessions, and was again frustrated by the lack of discourse, stating *"I need a conversation ... I need a why are you doing this, what's going on here"* (INT1). He described critiquing the classroom teacher's approach, rather than learning about how to deliver the NoS.

4.3.1.6 The Importance of Respect for Rick's Learning

Another interesting finding related to discourse was Rick's requirement of respect for the individual engaged in discourse with him. Respect in an individual equated to a person who Rick believed knew what they were talking about, and were *"talking the language [he] like[d] to talk"* (INT1). He explained that once he respected someone he could listen and learn from them quite easily, stating *"once I started to respect (the provider) ... I could listen to, I could hear what she was saying"* (INT1). The position someone held appeared to help Rick decide if he thought they knew what they were talking about. He talked about his host's PhD, and a secondary teacher within the Kāhui Ako being the Head of Department, as meaning their *"knowledge is valid"* (INT1) and therefore worth listening to and engaging with.

Rick realised that by deciding whether he would respect someone, and engage in discourse with them, was a bias, and that he was *"looking for stuff that reinforce[d]"* (INT1) him.

4.3.1.7 Development of Leadership Capability

As well as being a programme to improve teachers' understanding of the NoS and how to teach it, a key aim of the STLP was to provide leadership development. Rick identified leadership as the key capability he had gained from the STLP, after being exposed to a leadership model which resonated with his own beliefs.

4.3.1.8 Importance of Community

Prior to his STLP placement, Rick believed developing a sense of community was a requirement for effective leadership. This belief was reinforced by his observations of his host, stating *"I was exposed to a world of leadership where [the host] had created this whānau, this community"* (INT1). He described how observing his host nurture, develop, challenge and guide his students, many of whom were from the Pacific Islands, was a wonderful experience. The strong impact of this experience connected and affirmed

Rick's own beliefs about the importance of a teacher developing a sense of community in the classroom in order to lead his students through learning.

4.3.1.9 Importance of Co-Construction

Another finding that related to leadership was the importance of co-constructing learning. On return from the STLP, Rick was to lead his school through a self-review and development of a science programme. Prior to the STLP he had used a pedagogy of co-construction in the classroom, but now realised the importance of this in leading adults after observing it in action with his host, stating *"knowledge is created in the talk between you and me or us"* (INT1). Rick explained how he would use co-construction to achieve the aims of the STLP in school by stating *"If I can get my colleagues to talk, and engage, then we will build ... a shared idea about what science is, that's been co-constructed"* (INT1). He believed that without this co-construction of knowledge the transmission to teachers would not be sustainable, as past efforts where knowledge and meaning had not been co-constructed, had failed.

4.3.1.10 Use of Appreciative Inquiry

Rick was exposed to the model of appreciative inquiry while in Dunedin doing his one-week leadership course for the STLP. This model resonated with him as he realised that this was *"how [he] operate[d] with kids, and ... how [he] used to operate with adults"* (INT1). He now believed that he had permission to use this model as it had come from the world of academia, and therefore had validity. As well as having validity, it matched his practice, and he therefore wanted to use it with his staff, stating *"I'm going to use that way of building on people, instead of hole filling"* (INT1).

These findings indicate that Rick's time on the STLP reinforced his past beliefs and practices regarding leadership, and provided the validity he needed to use them in his school in his new leadership position.

4.3.2 Summary of Interview One

Prior to any PD Rick's NoS understanding was non-existent, with him believing science teaching related to the transmission of declarative knowledge only; as a result, he had avoided it in the past. After involvement in the PD programmes, Rick's efficacy beliefs had changed quite noticeably, to a point where he felt confident to teach it to his students, and he had developed a sound understanding of the NoS.

Due to his social science background, Rick's involvement in the Institute of Agriculture and Environment, allowed him to make connections between culture and science. These connections helped to develop his understanding of the NoS, in particular scientific investigation, and the realisation that fair testing is not the only approach used by scientists. During this time, he was also exposed to a leadership model which resonated with him, and affirmed his beliefs about how he liked to teach.

Rick articulated the need for reflective discourse for his own personal learning, attributing a lack of learning to the absence of sufficient amounts of discourse during his days of PD on the STLP. Respect was a factor identified by Rick, as a contributing factor to his willingness to engage and learn from others. Respect appeared to be clearly linked to two things – the credentials of the person and whether they had similar beliefs to him concerning teaching.

Over the course of the STLP Rick identified three key requirements for effective leadership – a sense of community, co-construction of knowledge, and appreciative inquiry. Prior to the STLP he had employed all these methods within his classroom, but his experience on the STLP had reinforced and given validity to these methods being used both with students and adults alike.

4.3.3 Findings from the Second Interview

The purpose of the second interview, with Rick after six months back in the classroom, was for Rick to reflect on:

1. PD he had been involved in over this time, and
2. his experiences of teaching the NoS in the classroom.

Coding of this interview was completed using a similar process to that already outlined. Analysis of the interview revealed two new themes, the importance of time and self-awareness, and some sub-themes as shown in thematic map 2 (see Appendix F, Figure F2).

4.3.3.1 Changes in Rick's Pedagogical Approach to the NoS

Prior to the STLP, Rick's science lessons were infrequent, and content focussed, with some use of the science capabilities as a result of working with the external PLD provider and the Kāhui Ako in the previous year. Now six months on from the STLP, science lessons were happening more frequently and on a regular basis.

Changes to Rick's pedagogical approach included teaching through a *"science lens"* (INT2), using science dispositions, and having conversations focussed around the interpretation of the science capabilities. He described using resources such as models, and stated *"I wouldn't have thought about doing that before [the] STLP"* (INT2). He stated that he now looked for ways to engage with science rather than just doing science 'busy stuff' as he had done in the past.

4.3.3.2 Changes in Rick's NoS Teaching Efficacy

Prior to Rick's involvement in the PD programmes his science teaching had focussed on the content strands of the curriculum document, with no consideration given to the NoS. As a result, he considered his science teaching efficacy to be fairly high because he *"didn't know what [he] didn't know"* (INT2). Now, six months after completing the STLP, Rick reported a drop in this teaching efficacy.

Rick reported feeling good about the NoS and the science capabilities, stating *"it fits with me naturally ... it makes sense"* (INT2), and explained how he wanted to use it as his vehicle into science. He described feeling high efficacy in talking to his colleagues about teaching the NoS, stating *"I can do it from an instructional basis"* (INT2). He talked about being at a stage in his own learning about the teaching of the NoS where he knew there was still things he didn't know, and needed to have a go at, stating *"[I just need to] keep learning"* (INT2). However, when it came to teaching efficacy related to the classroom, he expressed a lack of confidence due to certain factors that were making him question his effectiveness as a teacher.

4.3.3.3 Effect of Dispositional Barriers on Teaching Efficacy

Dispositional barriers in this case study are taken as obstacles, such as low motivation, lack of energy, lack of support, and/or fear of failure, that impacted Rick's ability to make progress in the development of his NoS teaching efficacy in the classroom.

In the first interview Rick had expressed a desire to develop a learning community within the class he had taken over on his return from the STLP, however, at the time of this interview he had yet to establish this. Rick identified a need to work from a *"sense of competency"* (INT2), and that his perceived lack of control of the current class, and the flow on effects of this, were leading to a lack of motivation and energy to take risks within his teaching.

A second factor was also identified by Rick as contributing to his drop-in confidence, namely a lack of support from senior leadership within his school, stating *"I'm just sick of just managing without support"* (INT2). He believed that if he did have this support he could take risks with his teaching, and take his students with him, but stated that currently he *"didn't have the capacity to do that"* (INT2).

4.3.3.4 The Continued Importance of Discourse

In the first interview Rick expressed the importance of discourse as a personal learning strategy, and again emphasised the importance of it as he discussed PD he had been involved in over the last six months. Once again, he had been frustrated by the lack of discourse used in a two-day workshop presented by the Royal Society, stating *"don't just give me stuff"* (INT2). This lack of discourse around the material presented made him feel like there was no *"thinking about what [they were] doing and how [to] do it"* (INT2), and as a result he could not see the transferability to the classroom.

In comparison, ongoing conversations between Rick and both the external PLD provider, and teachers within the Kāhui Ako, were helping him clarify his thoughts around the role of the science capabilities, and how he could engage with them. He talked about becoming more aware of the importance of using conversations and discussions with his colleagues through his work with the provider, stating *"it's made me talk, use the talk, … think about it and engage"* (INT2).

4.3.3.5 Changed Personal Views about Leadership

Rick identified that the most important thing he had learned was the *"beautiful model of leadership"* (INT2) he had experienced on his STLP placement. Prior to the STLP he had been pretty much autonomous in his school, regarded as an effective teacher, and left to his own devices by senior management. He now realised that he wanted to be led, and that this would be quite a challenge for him. He believed that his current school lacked vision, as well as a whole school sense of community, and stated *"I want a vision of why we're here … why are the kids coming to [our] school?... What is it that we want for our community as a whole?"* (INT2). He talked about needing to be believed in, and provided with both direction and empowerment so he could develop himself further.

Findings also identified another significant change around leadership, with Rick now expressing a desire to take on a more senior leadership role at school. For three years prior to the STLP he had not been interested in leadership roles, even though he had been on a leadership path prior to that. He stated that in the past he had believed he needed to be a principal because he was a *"white ... middle aged (man)"* (INT2), and that was the expectation of success in education. He now believed that he had the skills and ability to have a wider influence over adults, leading to a greater impact on education. This shift in motivation was clearly linked to the model of leadership he had observed at his hosts, where a sense of community and vision were modelled by the leader; both values that Rick holds dear.

4.3.3.6 The Importance of Time to Rick's Development

Time is a factor that many teachers struggle to have enough of due to the large number of demands on them during the school day and year. In this case study time refers to time out of the classroom, where there are no school or student expectations on Rick.

Prior to the STLP Rick described himself as being exhausted, stating *"I was a jiggered man"* (INT2), and how the time away on STLP had provided him with the respite he had needed. He found the different timelines and expectations of the STLP refreshing, describing it as *"six-months of difference"* (INT2).

The Royal Society, as part of the STLP, continued to provide funding to Rick's school for the first two terms back, for release time for him to carry out the school self-review, and start the development of a new science programme. Rick believed that having the space and time to do the work that was required was *"invaluable"* (INT2). Rick talked about how the release time had allowed him both time to think and do what was needed, and how without this *"it just wouldn't have got done"* (INT2).

4.3.3.7 Development of Self-Awareness

In this case study the theme of self-awareness refers to Rick focussing on himself and how his actions, thoughts, and at times emotions, did or did not align with his own values, and beliefs about teaching.

In the past Rick had worked with early years educators, describing these experiences as being *"some of [his] best learning"* (INT2) due to the integration. He now recognised similar opportunities arising as a result of his interactions with the Kāhui Ako professional learning community, and the ability to now work alongside secondary science teachers. He believed that as a ‘generalist’ teacher he sometimes lost the specific nature of science required, and that by working alongside his secondary colleagues, who he viewed as *“experts”* (INT2), he could avoid this.

Rick had struggled to see the progress he was making with his class during his six months back in school. He articulated that he had been relying on others visiting his class to highlight improvements, stating *“I haven’t been able to do that for myself”* (INT2). When he was made aware, he was able to realise the hard work that he had put in and what he had accomplished.

At the time of the second interview Rick described himself as frustrated, lacking energy and motivation, and just not having the internal capacity to take risks. He realised that since his return from the STLP he had had to *“rely back ... on what [he] believed”* (INT2), namely effective teaching and learning. He now recognised that he needed *“to (be) happy”* (INT2), and within a community where *“making do [was] not enough”* (INT2). These self-revelations had led Rick to submit his resignation, and accept a position at a school where he believed he could achieve professional fulfilment.

4.3.4 Summary of Interview Two

Six months after completing the STLP, and back in the classroom Rick was able to reflect on the impact of his involvement in the PD both personally and on his students. He described a drop in his NoS teaching efficacy due to the realisation of what he still did not know, though he expressed confidence in sharing his learning with his colleagues through conversation and discussion.

Rick’s focus in the classroom for the previous six months had been on classroom management in an aim to create a learning community. His perceived lack of control, along with a lack of support from senior management, had contributed to a decrease in efficacy. He expressed having difficulty being able to see improvements within his classroom, and needing others to identify them.

Having been autonomous in his current school for a long time, he now realised that he wanted to be challenged, empowered and led. Having not been personally interested in leadership for the last three years, Rick now expressed interest in taking on this role, stating he had the skills and ability to have a wider influence on adults.

As Rick reflected on the year, he stressed the importance of the time out of the classroom afforded by the STLP, and then having the required time to complete the tasks set on his return to school, as invaluable. Through the Kāhui Ako Rick had begun to establish meaningful working relationships with his secondary teaching colleagues, helping him with the specifics of the NoS. He now realised that he needed to be happy in his teaching, and to achieve this he needed to find a school environment where there was a clear vision, a sense of community, and support.

4.3.5 Findings of the Third Interview

The purpose of the third interview with Rick, 11 months after his completion of the STLP, was for him to reflect on:

1. changes in his NoS content knowledge and pedagogical content knowledge over the last 18 months
2. his NoS teaching efficacy, and what factors have influenced this the most over the last 18 months
3. the PD he has been involved in over the last 18 months.

Coding of this last interview was completed using the same process as for the first and second interviews. Analysis of the interview revealed two new themes relating to support needed, and affirmations, as well as a number of sub-themes as shown in thematic map 3 (see Appendix F, Figure F3).

4.3.5.1 Changes in Rick's NoS Content Knowledge

When first interviewed eleven months ago, Rick believed that science was all about the generation of new knowledge through the process of investigations. His understanding had developed and now incorporated the tentative nature of scientific knowledge, with Rick realising that the knowledge generated was subject to change. He explained this by stating *"scientists do experiments and … all they're trying to do is create the best understanding of the truth that they know right now … they're not trying to … get to the solution"* (INT3).

He explained that the content knowledge of the NoS referred to the skills, attributes and dispositions used by scientists in their work, stating *"the content knowledge (is) how (scientists) collect data, or how they interpret a graph, or … how they critique something"* (INT3). He saw a clear link between the content knowledge of the NoS and the science capabilities, stating *"science capabilities [are] a synonym for … the nature of science"* (INT3), though he admitted he still needed to explore the NoS further in order to develop a broader understanding of it.

4.3.5.2 Changes in Rick's Pedagogical Approach to the NoS

Prior to the STLP, Rick had believed science teaching related solely to the content strands of the NZC (Ministry of Education, 2007) and as a result had avoided teaching it. Now eighteen months after the start of the STLP, he had taught more science lessons than he had in the last five years. He described his science pedagogy as focussed on developing learners, rather than focussed on the transmission of knowledge. Unlike six months ago, when he saw the NoS as the only focus, he now talked about using the science content strands *"as the vehicle or … context for exploring and developing the NoS"* (INT3), indicating an understanding of the link between the NoS strand, and the content strands of the curriculum document.

Reflecting back six months, he described himself as being *"outcome process focussed"* (INT3), feeling he needed to get through the material, and get the particular science capability across to his students. His approach had now changed, with a realisation that he was now thinking about why scientists do a particular thing, such as use models, rather than thinking this is what they do. He described this change by stating *"[I'm] trying to get to a place where the kids [get] the idea that scientists use models and diagrams to understand stuff, and to show their understanding to other people"* (INT3). This complete change in emphasis, had resulted in him using the science capabilities as a tool, and student-centred discourse to elicit the change in understanding he sought.

4.3.5.3 Rick's NoS Teaching Efficacy

At the completion of the STLP, Rick reported a low personal science teaching efficacy, attributing this to the lack of community within his classroom, meaning he was spending more time on classroom management, than on managing learning. Eleven months later, in a different school, he described himself as more confident in both his own knowledge and his understanding of the science capabilities, stating *"I'm way more comfortable using science"* (INT3). He now regarded himself as *"scientifically literate"* (INT3), attributing this change to the time he had had to think, and receiving similar information from the three different PD programmes, allowing him to know he was on the right track, and making the right decisions.

Another change in Rick's teaching efficacy related to his outcome expectancy. Eleven months earlier he had believed he was not the sole influence on his students' NoS outcomes, whereas now he saw a direct relationship between his teaching abilities and his students' success. He attributed this change to the fact he now knew what he was trying to teach, and was aware of what he was looking for, stating *"if you [are] able and knowledgeable as a teacher, then … that's what you're going to plan for, and nourish"* (INT3). Rick's outcome expectancy score in his STEBI2 showed an increase from his STEBI1 score, supporting this finding.

4.3.5.4 The Importance of Time to Rick's Development

Reflecting on his involvement in the PD, Rick identified time as the key factor that had impacted his learning. He described how the STLP had provided him with the time to think about things, and construct new meanings, stating *"[the] STLP gave me that longitudinal space and time just to ponder, …think, …mould and develop"* (INT3). He saw this opportunity as a luxury, helping him to build on his teaching practice and develop his learning. This time afforded him the opportunity to reflect on his current teaching practices and make changes that he believed he would not have made otherwise, stating *"I probably would have just kept the mouse wheel turning"* (INT3).

4.3.5.5 How Affirmations Impacted Rick's Development

Rick described his experiences on the STLP as *"more affirming, than learning"* (INT3), stating it had strengthened and deepened his pedagogy. Watching his STLP host interact with his students had allowed him to reconnect with the values he saw as important in the classroom. Attending the STLP leadership course, he found he knew a lot of the material enabling him to see where they were taking him, stating *"I could see where … they wanted us to get to … and that was affirming and … made me feel good about myself"* (INT3).

His NoS teaching efficacy had also been affirmed through an interaction with an external provider at his new school. While sharing his understanding of the science capabilities and how progress could be assessed, the external provider confirmed that this was similar to what another school was doing in the country. This affirmation led to an increase in confidence, with Rick stating *"here I am thinking this is a really good idea, … and then the guy says …I think so too"* (INT3). These findings suggest that affirmations are important in building efficacy during and after PD.

4.3.5.6 Importance of Support from School Leadership and Colleagues

Prior to his involvement in the PD Rick was aware that research stated support from school leadership was vital to the successful enactment of any learning; over the last six months, his experiences had confirmed the theory. In contrast to his previous school, where he believed his principal lacked the capacity to support him, he now described having a principal who expected him to engage in science and share his learning. Rick felt trusted by his principal, and felt he was receptive to new ideas, stating *"I don't have to convince him ... I just need to build his knowledge"* (INT3). As well as his principal he also experienced support from his team leader. Once again there was an expectation from her for science to occur in the classroom, and a willingness to engage in conversations around the science capabilities.

As well as leadership support, Rick reported experiencing collegial support from his team. The team's willingness to trial the science capabilities, as well as school leader's expectation that science be taught, helped support Rick to enact his learning, teach more science, and increase his NoS teaching efficacy.

4.3.5.7 Importance of School Structure to Support Professional Learning

School structure, in terms of this case study, refers to how a primary school organises its learning programme – in the allocation of time for science teaching, and who decides the teaching programmes used, and when they will occur.

At Rick's current school he was given some freedom around designing his learning programme, which allowed him greater opportunities to teach science, as well as more time to teach it. In comparison, six months ago at his previous school, he experienced a more rigid structure, with less time and space made available for areas such as science. Rick believed this rigidity constricted and reduced his opportunities to engage in the NoS, stating "*if you're told this is what you do ... then you don't stop and think about it yourself, and create your own opportunities"* (INT3). This lack of flexibility in programme design had de-professionalised him, and acted as a barrier to his enactment of his learning.

4.3.5.8 Self-awareness having Engaged in PD

Rick resigned from his teaching position due his desire to be part of a strong school community. He now recognised that his STLP host placement had made him realise he was not teaching the way he wanted to, stating *"[I was] being the teacher I didn't want* *to be"* (INT3). By providing space out of the system, as well as the opportunity to reconnect with his values, the STLP experience had afforded him the opportunity to re-align his teaching practice with his aspirations.

Rick recognised that he was now implementing what he had learnt, rather than learning new material. As a result, he believed he had not missed the support of the Royal Society and external science provider over last six months, stating *"right now, I think it's been okay, because ... I've shifted context"* (INT3). He did acknowledge that working with the external provider later in the year could be valuable in order to provide a reality check, and more ideas on which to build.

4.3.6 Summary of Interview Three

Eleven months after completing the STLP, Rick's NoS teaching efficacy is high, he is teaching more science than he had in the last five years, and now believes he can impact the success of his student's science achievement. He understands the relationship between the NoS strand of the NZC (Ministry of Education, 2007), and the content strands and how this is enacted in the classroom. His NoS content knowledge has evolved further, to now reflect the tentative nature of scientific knowledge.

Over the last six months Rick entered an implementation stage of his learning. His classroom management changed from behaviour management to learning management, and his NoS teaching changed from a focus on what scientists do, to a focus on why they do it.

The time afforded by the STLP, was identified by Rick as the key factor impacting his development, as it provided him the opportunity to think, ponder, and develop his ideas. Similar information provided by the three PD programmes helped affirm his understandings, along with other positive interactions. Support was also vital for the enactment of Rick's learning with three forms identified – school leadership, collegial, and school structure.

Over the course of the six months Rick came to realise that his involvement in the STLP had helped him to reconnect with what was important to him in teaching, and that without that opportunity he may well have become stuck being a teacher he did not want to be.

4.3.7 Overall Summary of Interview Findings

Rick's involvement in the science PD over eleven months led to an increase in NoS teaching efficacy, where Rick felt confident to lead others, and to deliver effective NoS lessons. He developed a clear understanding of how the NoS strand of the curriculum interwove with the content strands, and he understood most of the NoS aspects.

Reflective discourse was a crucial component of his personal development. However, his willingness to engage and learn depended on how well he respected the provider. Back in school, support from school leadership, colleagues, and the school structure was pivotal in Rick being able to move into an implementation stage of his learning.

Rick's involvement in the three PD programmes empowered him to teach in the way he likes, and affirmed his understandings of the NoS by providing similar information in different ways. He had a clear understanding of what effective leadership looked like, and what he wanted from a leader. On top of this, he had established new relationships with colleagues across the primary and secondary sector of his Kāhui Ako.

4.4 Classroom Observations

Two classroom observations were completed of Rick's teaching (refer to Table 4.9). The first observation was conducted five months after his completion of the STLP programme, and the second was conducted after eight months. These two observations were completed in order to ascertain changes in Rick's approach to teaching the NoS in the eight-month period, following his involvement in the three different PD opportunities. The second observation occurred slightly earlier than planned due to the COVID-19 outbreak and the imminent closure of schools.

Table 4.9.
Details of Classroom Observations

Observation	Date	NoS aspect being taught
1	2 Dec. 19	Communicating in Science – Interpreting representations
2	19 Mar. 20	Communicating in Science – Interpreting representations

Coding of the observations was completed using an adapted version of the Classroom Discourse Observation Protocol (CDOP), according to the process outlined in section 3.10.2. CDOP is an instrument that identifies strategies used by the teacher to engage students in the construction, justification and evaluation of knowledge, rather than simply relaying factual knowledge. This tool categorises teacher dialogue as either teacher-centred, where the teacher is talking about content, or student-centred, where the instructor supports students to talk about the content. Both classroom observations were written up, and then each example of dialogue was coded using the codes identified in Table 4.10.

Table 4.10.
Adapted CDOP Coding Scheme Used for Classroom Observations

Codes	Code description	Examples of the teacher's talk
Teacher-centred: Teacher talking about content		
Evaluating	Teacher repeats, accepts and/or rejects students' response	*"So, it's showing a water system, from the mountain to river to big sea"*
Linking	Teacher associates current topic to previous learning	*"So, remember we did a peer assessment of representations and decided what a good representation was*
Sharing	Teacher shares information.	*"Last year I spent 6 months with a scientist, and the biggest thing he liked was getting things wrong."*
Student-centred: Teacher asks students to talk about content		
Generative	Teacher asks students to recall facts, basic concepts, or related information	*"What does interpret mean?"*
Checking-in	Teacher seeks clarification from student or checks understanding	*"Anyone want to change your position?"*
Clarifying	Teacher asks students to elaborate on condensed, cryptic, or inexplicit statement	*"Did it help you to understand it a bit more?"*
Connecting	Teacher asks students to associate past lessons to current	*"From your knowledge do you think ..."*
Contextual-ising	Teachers asks students to connect ideas to conventional knowledge, broader perspective, or personal experiences	*"Do you go home and ask mum what's for tea?"*
Constructing	Teacher asks students to build knowledge by interpreting, critiquing, justifying evidence, data, or models	*"Pick a representation/model/diagram from one of the books provided, and critique it."*
Requesting	Teacher asks student to justify or explain their reasoning	*"What helped you to learn a bit from it?"*
Explaining	Teacher asks student to explain their reasoning to group	*"Why do you think it is only the one on the right?"*

4.4.1 Findings from the First Classroom Observation

The first observation was completed in a Year 5/6 class in the school Rick returned to after his STLP. During the lesson he used seven different student-centred approaches of questioning 79% of the time. Three different teacher-centred approaches were also observed, in particular sharing. The one-hour lesson was based around the NZC (Ministry of Education, 2007) NoS communicating strand, looking at how scientists represent their ideas in a variety of ways. Prior to the observation the students had watched a time lapsed video of a seed growing, and used this to create representations to show how seeds grow. They peer reviewed their representations and established as a class what they considered was a good representation. In the observed lesson, the students applied what they had learnt to unfamiliar representations in booklets, focussing on the purpose of the representation, what was missing from it, how it got its message across, and why it was presented in this way. Throughout the lesson Rick made explicit references to the NoS.

Analysis of the coding of the classroom discourse used by Rick, as shown in Figure 4.1, shows the use of seven different student-centred approaches, with generative questioning being the predominant mode observed fourteen times. Clarifying, requesting and explaining approaches were observed six or more times each within the lesson. The use of checking-in, connecting and constructing were poorly used, while at no time did Rick use contextualising.

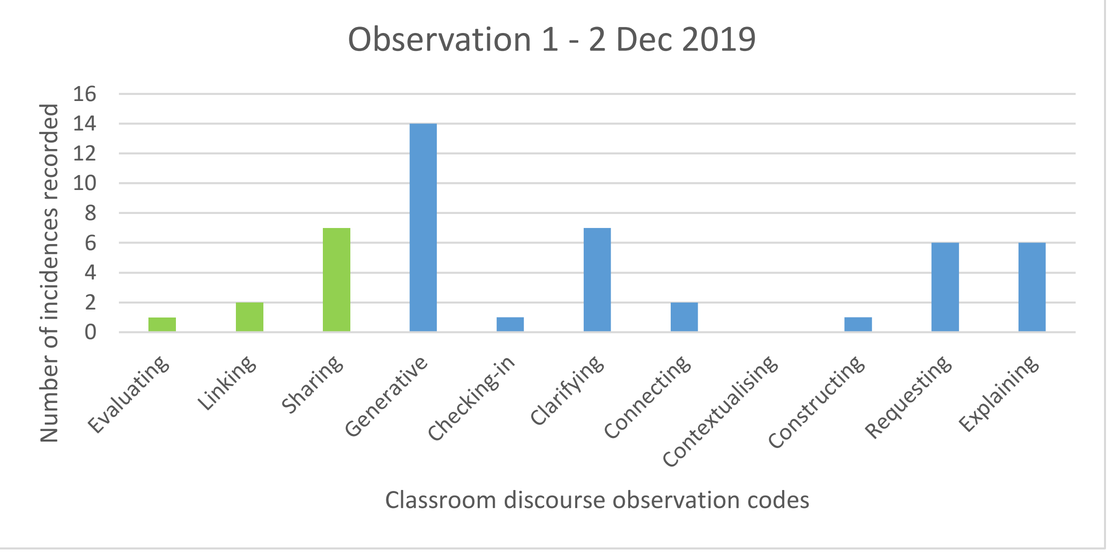


Figure 4.1. Summary of classroom discourse approaches used during observation 1.

Three teacher-centred approaches were used by Rick during the lesson. Sharing was used most frequently with seven incidences recorded, while evaluating and linking were rarely used.

Figure 4.2 shows that Rick predominantly used a student-centred approach to questioning during the observed lesson, though a teacher-centred approach was used 21% of the time.

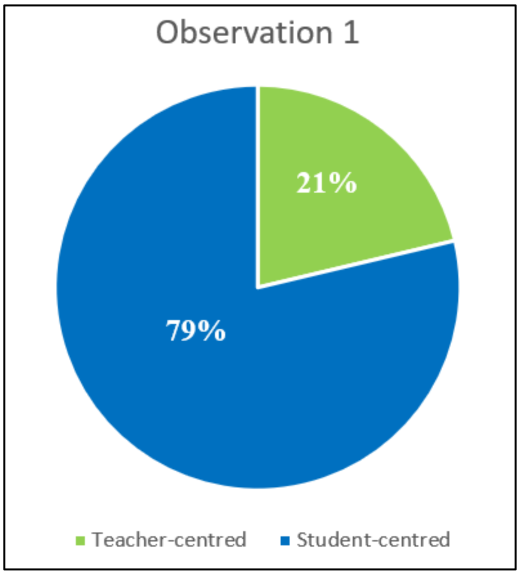


Figure 4.2. Pie graph showing approaches used by teacher during observation 1.

4.4.2 Findings from the Second Classroom Observation

The second observation was completed in a Year 5 class in the new school that Rick moved to at the start of 2020. During the lesson Rick used six different student-centred approaches to questioning 80% of the time, with a predominant use of generative and clarifying questions. Two student-centred approaches were not used at all during the lesson. He also used two of the three teacher-centred approaches, more frequently than four of the student-centred approaches.

The fifty-minute lesson took place in the final session of the day. As with the first observation, the focus of this lesson was the NoS communicating strand from the *New Zealand Curriculum* (Ministry of Education, 2007), focussing on why scientists use models. Students had not completed any prior lessons on this topic and they were introduced to representations for the first time. Rick conducted a discussion about the meaning of a representation, and why these were used before getting students to look at two representations of the river system and the water cycle. Students were asked to work out the purpose of the representations and how the two were different. Throughout the lesson Rick made explicit reference to the NoS.

Coding of the observation, as shown in Figure 4.3, showed a high use of two student-centred approaches – generative and clarifying questioning. Contextualising was used eight times within the lesson and explaining five times. Checking-in and requesting were poorly used, while both connecting and constructing were not used at all.

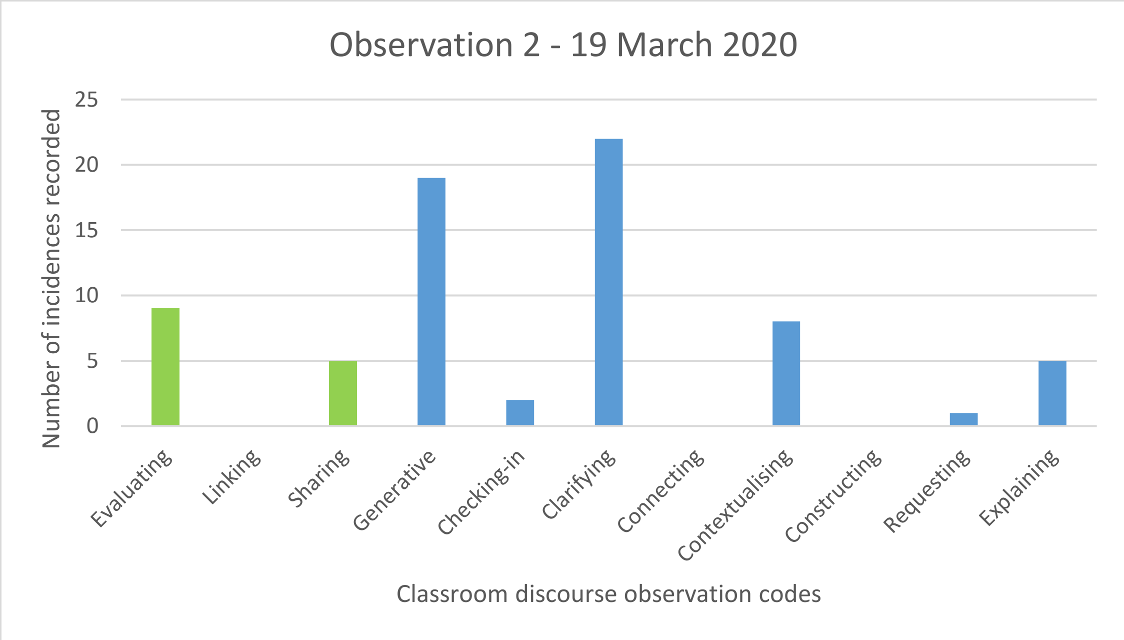


Figure 4.3. Summary of classroom discourse approaches used during observation 2.

The teacher-centred approach of evaluating was used more frequently than six of the student-centred approaches, with an incidence of nine. Sharing was used with the same frequency as explaining, and used more than four of the student-centred approaches.

Figure 4.4 shows that Rick used a student-centred approach to questioning 80% of the time during the observed lesson, compared to using a teacher-centred approach 20% of the time.

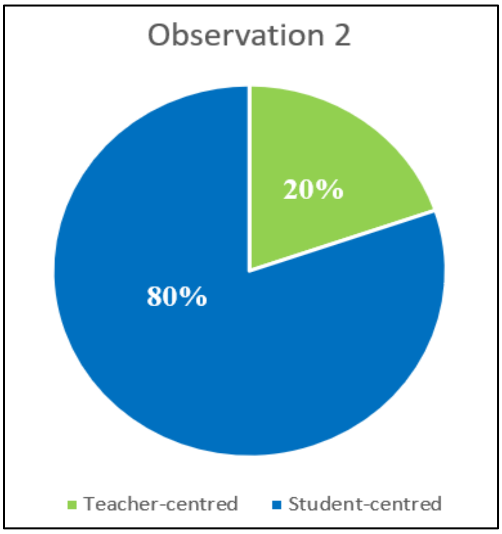


Figure 4.4. Pie graph showing approaches used by the teacher during observation 2.

4.4.3 Summary of Findings from Observations

Both classroom observations involved lessons focussed on the NoS strand – communication in science – looking at different ways in which scientists represent information. The students were asked to identify the purpose of representations, why they were presented in a particular way, and how they got the message across. Rick made explicit reference to NoS ideas throughout both lessons.

Analysis of Figure 4.5 shows that the teacher consistently used student-centred classroom discourse approaches in both lessons. The teacher used three different teacher-centred approaches to classroom discourse over the two lessons observed – evaluating, linking and sharing. All three were observed during the first lesson but linking was not observed in the second.

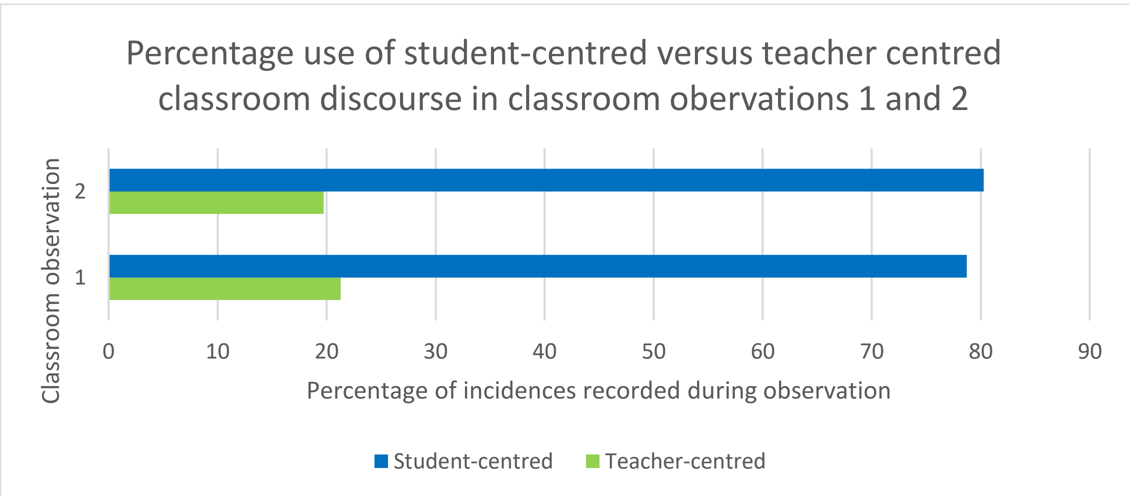


Figure 4.5. Comparison of classroom discourse approaches used in both observations.

Analysis of the student-centred approaches, shown in Figure 4.6, shows an increased use of clarifying, checking-in and contextualising in the second classroom observation, while a decrease was seen in the use of generative, requesting and explaining. Both connecting and constructing approaches were used in observation 1, but not 2, while contextualising was used in observation 2, but not 1. Seven different approaches were used in classroom observation one, compared to six in observation 2.

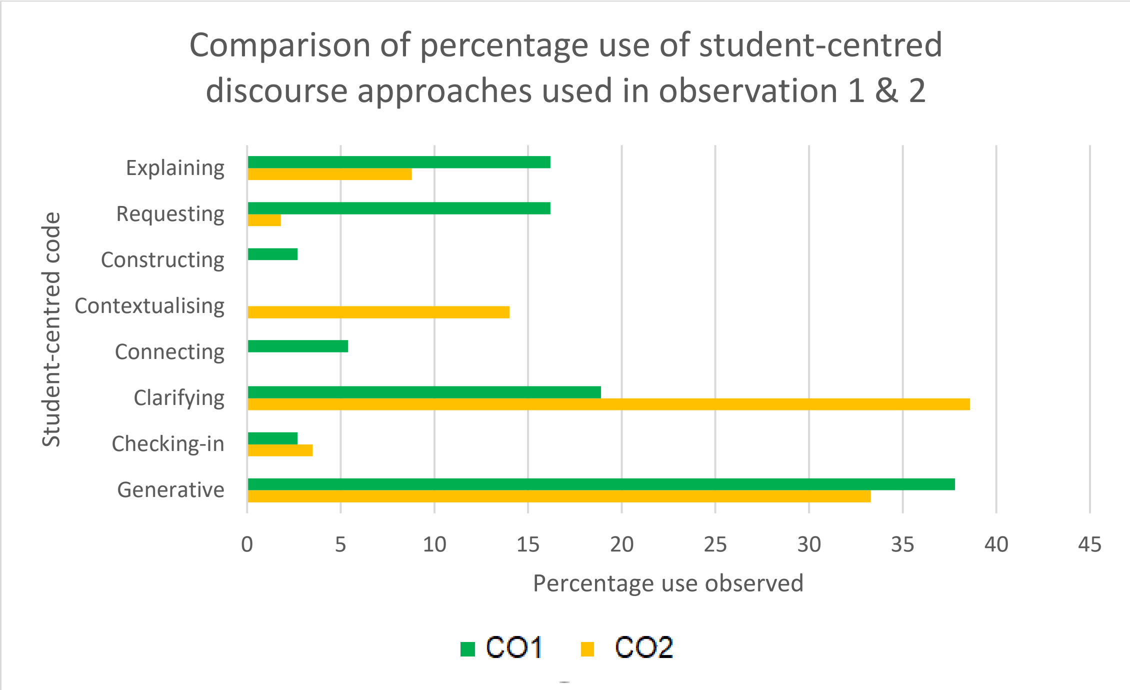


Figure 4.6. Comparison of student-centred approaches used in both observations

4.5 Overall Summary of Findings

Findings from the three different data collection instruments have been presented in this chapter, to provide evidence of the impact of Rick's participation in three science PD programmes.

The data show that Rick had high personal NoS teaching efficacy beliefs after his involvement in the PD. His NoS teacher outcome expectancy score improved over the 11 months of the study, indicating he believed his teaching could influence students' learning of the NoS. Prior to Rick's involvement in the PD, he reported having no understanding of the NoS. The research data show that at the completion of the STLP programme he had developed an informed view of the NoS. Over the course of the study this understanding grew, with only three areas showing limited understanding by the end of the study period. The findings also indicate a shift in Rick's pedagogical approach to teaching science, from transmission of declarative knowledge, to teaching about the dispositions of scientists. By the end of the study Rick showed an understanding of how the science capabilities could be used as a tool to access the NoS, and develop students' NoS understanding. His science lessons had a NoS focus and consistently used student-centred discourse strategies. Prior to the STLP his student science investigations had always been fair tests, whereas now he was aware that fair tests were just one of many types of science investigations which could be utilised.

Triangulation of the data revealed four key themes (refer to Figure 5.1), namely changes to Rick's NoS beliefs, changes in his classroom practice, increased leadership efficacy, and changes in his teaching identity. The following chapter examines each of these themes in relation to the current literature, identifying areas of convergence and divergence between the findings and the literature.

Chapter Five - Discussion

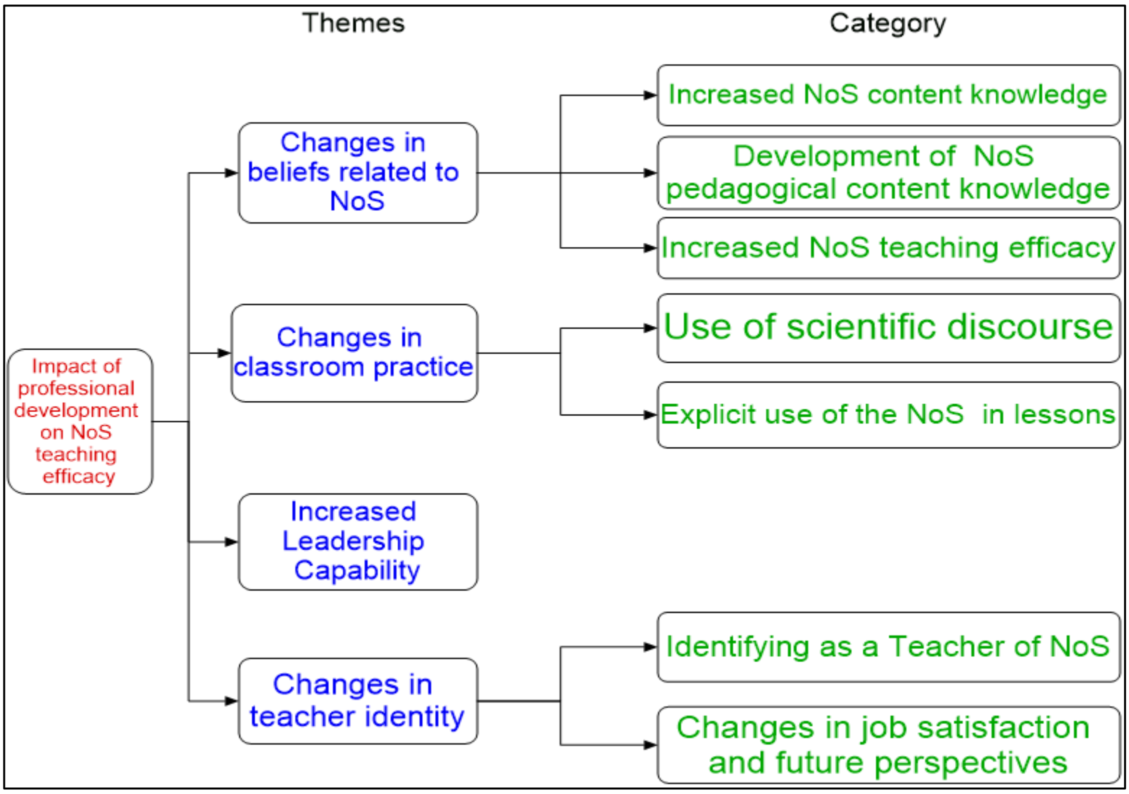
5.1 Introduction

New Zealand primary teachers are expected to develop scientific literacy as one part of the curriculum, however, recent official reports (Education Review Office, 2012; New Zealand Council for Educational Research, 2018) indicate that approximately 20% of primary teachers have low confidence levels in teaching the Nature of Science (NoS), the one compulsory science strand of *The New Zealand Curriculum* (MOE, 2007). Research indicates that targeted professional development (PD) aimed at developing teachers' pedagogical content knowledge of the NoS can lead to positive changes in their NoS teaching efficacy (Murphy et al., 2015). To date, no research has been published in New Zealand about the development of practicing primary teachers' NoS teaching efficacy, after participation in structured PD programmes.

The current case study aimed to investigate how the NoS teaching efficacy of one New Zealand primary teacher (Rick) was impacted as a result of his involvement in three interrelated PD programmes. This chapter discusses the findings presented in Chapter Four.

Four broad themes (see Figure 5.1) are examined in relation to contemporary literature, considering areas of convergence and divergence. Firstly, an overview of the changes in Rick's beliefs related to the NoS is provided. Changes occurred in three different types of belief - NoS content knowledge, NoS pedagogical content knowledge, and NoS teaching efficacy. A discussion about the impact of the PD on each of these belief areas is provided. The second impact discussed relates to specific changes in Rick's classroom practice, in particular his use of student-centred discourse strategies, and his explicit use of the NoS. The discussion then considers two other impacts of the PD. Firstly, the development of leadership capability, and finally changes in teacher identity. Two changes in identity are discussed, namely the development of a teacher of NoS identity, and secondly changes in job satisfaction and future perspectives.

Figure 5.1: Final thematic map of case study



5.2 Changes in Beliefs Related to the NoS

International studies show that primary teachers' beliefs about the NoS are commonly uninformed (Abd-El-Khalick & Lederman, 2000; Cofré et al, 2019; Koksal & Cakiroglu, 2010). However, teacher beliefs about the NoS are one of the strongest influencing factors on NoS classroom practice (Anderson, 2015; Anderson & Moeed, 2017; Mansour, 2009). In order to change or enhance teachers' existing beliefs about the NoS, a teacher must examine and transform their existing beliefs. Beliefs are a psychological construct, which are defined for the purposes of this study to include epistemic beliefs (NoS content knowledge), beliefs about teaching and learning (NoS pedagogical content knowledge), and NoS teaching efficacy beliefs.

PD has proved to be effective in transforming teachers' NoS beliefs (Anderson & Moeed, 2013, 2017), pedagogical content knowledge (PCK) (Piliouras et al, 2017), and teaching efficacy (Murphy et al, 2015). Over the course of this study, Rick developed an informed view of the NoS, understanding its relevance to science teaching, and was confident in using the science capabilities to access it in his teaching practice. Each of the three PD programmes contributed to these changes, with Rick stating *"if I had had [only] one then I wouldn't have had the benefit of the other, and leveraged off it"* (INT3). The following discussion explains specific changes in Rick's epistemic beliefs, teaching and learning beliefs, and teaching efficacy, and explains how the PD impacted these changes.

5.2.1 Increased NoS Content Knowledge

Understanding the NoS is essential if teachers are to intentionally teach and assess it in the classroom (Lederman & Lederman, 2019). A robust understanding of the NoS is also a requirement for developing NoS pedagogical content knowledge (Deniz & Adibelli, 2015). For the purposes of this study, epistemic beliefs about the NoS relate to Rick's content knowledge of the NoS, comprised of his conceptual knowledge (e.g. NoS beliefs) and procedural knowledge (e.g. the science capabilities). Changes in each of these areas are discussed below.

Primary teachers' generally do not possess an adequate understanding of the NoS (Cofré et al., 2014, 2019; Koksul & Cakiroglu, 2010; Lunn, 2002), tending to draw on their own life experiences to develop their science teaching practice (Lunn, 2002). This statement was true for Rick prior to the PD. With a social science degree, the only science background he had was his own personal and children's experiences at school, as well as a short science block during his Graduate Diploma of Teaching, which focussed on the content strands of an earlier curriculum.

At the completion of this study, Rick held an overall informed view of the NoS, demonstrating positive shifts in his understanding of certain NoS beliefs over the course of the study. Rick's understanding of each NoS belief was not assessed prior to the beginning of this study; therefore, attributing changes in his understanding of the targeted NoS beliefs as a result of his involvement in the PD is inappropriate. However, various studies have shown that primary teachers' NoS beliefs change as a result of explicit instruction through PD (see Cofré et al., 2019 for a review), indicating that it is likely the PD had a positive influence on his overall informed view.

In order to change a person's beliefs, they must examine, question and then revise their perceptions (Cranton & Taylor, 2012). PD aimed at developing a primary teachers' NoS understanding requires sufficient time for teachers to reflect, discuss and challenge their NoS conceptions (Akerson & Hanuscin, 2007). At the completion of the STLP (2nd of three PD programmes), Rick believed science was a process of exploration and experimentation; an uninformed belief commonly held by primary teachers, due to the fact they believe learning should be student-centred (Appleton as cited in Anderson &

Moeed, 2017). With time to reflect on his conversations with scientists, and other teachers, by the end of the study Rick believed that explanations had a greater focus than experimentation; a change in thinking indicating a shift to an informed view. Critical reflection was key to this shift, and was not just mulling things over, rather it is was a "systematic, rigorous, disciplined way of thinking" (Rodgers, 2002, p. 845), resulting in a change in belief.

One of the most important strategies used in PD to transform primary teachers' views about the NoS, is reflective discourse with other teachers (Akerson et al., 2009) and a more knowledgeable other (Hanuscin, 2013), as this exchange enables gaps in knowledge to be identified and challenged. Teachers as learners need to engage in dialogue to assess and fully understand the ways others are interpreting things, in order to transform their existing beliefs (Mezirow, 2012). Through the use of reflective discourse with the PLD provider, Rick shifted his understanding about the place of biases and errors in scientific investigations, from the naïve view that they could be eliminated, to the more informed view of needing to be aware of them, over the eleven months of the study. The findings suggest that PD seeking to change or enhance primary teachers existing beliefs about the NoS, would benefit from the deliberate inclusion of adequate time for critical reflection and reflective discourse.

Primary teachers commonly believe there is only one type of scientific investigation, namely fair testing (Anderson & Moeed, 2013, 2017; Koksul & Cakiroglu, 2010). Rick held this belief prior to the STLP. PD programmes which see teachers work in partnership with scientists, have allowed primary teachers to realise there are multiple ways to do scientific investigations (Anderson & Moeed, 2013, 2017; Buxner, 2014; McLaughlin & MacFadden, 2014). Subsequent to his host placement, Rick significantly changed his views about fair testing, realising there was no universally accepted way to engage in science. During his placement Rick assisted scientists with experiments, and had numerous conversations with them about the scientific method, allowing him to see that an awareness of variables was important, rather than controlling or eliminating them, in fair testing. Rick's changed view about scientific investigations is consistent with the research, and illustrates the benefit of engaging in authentic science investigation over an extended period.

Changes in beliefs and practices require a minimum of six months to several years (Timperley et al., 2007), as fundamental change is a gradual and challenging process (Drits-Eser et al., 2017). During the study, Rick's views about two beliefs moved from informed to uninformed, namely his beliefs about scientists reaching the different conclusions from the same data, and the role of debates and discussions in the science community. Given that Rick only spent 15 weeks with his host, he may not have had enough opportunity to observe different scientists interpreting the same findings in different ways, or to ascertain how common it was for scientists to debate and discuss their findings. Insufficient opportunities appear to hinder the development of new teacher beliefs, implying that when scientist-teacher partnerships are utilised to improve NoS understanding, engagement in the partnership should be over an extended time period greater than 15 weeks.

Throughout the study, Rick maintained one naïve viewpoint relating to the subjectivity of science; consistently believing science knowledge was based on facts. Primary teachers commonly hold this belief (Koksul & Cakiroglu, 2010), and it is argued to be particularly hard to shift through PD (Cofré et al., 2014). Given that Rick believed science was about facts and figures for the twenty years of his teaching career prior to the PD, it is not surprising that this was a deeply held belief. The PD had not shifted this view, implying that it may not have specifically focused on this area. Primary teachers who have been teaching a prolonged period of time with no experience in the NoS, may require a more intensive focus to help them realise the subjectivity of science.

Despite the *New Zealand Curriculum* (NZC) (Ministry of Education, 2007) being clear about the purposes for learning science, it does not explain how to combine the NoS and the content-strands in such a way as to develop student capability (Hipkins & Bull, 2015). In an attempt to support teachers to focus their teaching on the NoS, a number of science capabilities were introduced "as a set of ideas for teachers to think with" (Bull, 2015), serving as prompts for classroom NoS conversations and experiences (Hipkins & Bull, 2015). The capabilities attempt to 'join the dots' between the overarching NoS strand, the content strands, the science essence statement, and the key competencies (Hipkins, 2014).

Despite being exposed to the science capabilities through the PLD provider, prior to his STLP placement, Rick did not understand how they related to the NoS, instead seeing them as more science content needing to be taught. Bull (2019) warned of this risk, stating that as long as teachers see the purpose of school science as acquisition of abstract knowledge, they will simply regard the science capabilities as more things to be learnt. By the end of the study, Rick now regarded the science capabilities as a tool allowing him to access the NoS, and he recognised their dispositional focus, clearly showing a shift towards the intended use of them. The findings of this study suggest that once a primary teacher can see the dispositional focus of the science capabilities, they can connect with them more easily, and use them in the way they were designed.

Research to date, argues that primary teachers are more comfortable engaging with the capability "gather and interpret data", and tend to miss potential opportunities to develop the other capabilities (Hipkins & Bull, 2015). In both classroom observations, Rick's learning focus was to develop the capability of "interpreting representations", using discourse strategies aimed at developing students thinking. He was able to explain to students the links between the science capability, the NoS strand of the curriculum, and most importantly why scientists use this skill. Rick also described seeing the links between the science capabilities and the key competencies, and talked about making these connections when he was teaching; again, showing a greater understanding of the science capabilities and how they formed part of his teaching. Targeted PD aimed at developing a primary teachers' understanding and enactment of the science capabilities, can promote the use of the science capabilities in a way that develops students NoS understanding.

5.2.2 Development of NoS Pedagogical Content Knowledge

In order for teachers to teach the NoS, they need some form of NoS pedagogical content knowledge (PCK) (Appleton, 2006, Lederman & Lederman, 2019). In the current study, NoS PCK is defined as the integration of NoS content knowledge, science content knowledge, and the teachers' ability to make connections between them in their teaching using appropriate pedagogical knowledge (Lederman et al., 2007).

Many primary teachers focus their science teaching on the acquisition of content knowledge, classroom experiments and hands-on activities (Appleton, 2003; Bull, 2019), despite the fact that in most other learning areas, they actively engage their students using pedagogical approaches that would contribute to quality science learning (Fitzgerald & Smith, 2016). This statement was true for Rick prior to the PD. Rick's science teaching revolved around transmission of science facts, fair testing, and 'busy stuff'. As a result, he avoided teaching science as this pedagogical approach did not match what he used in other areas of his teaching, and how he liked to teach. Development of teachers' PCK involves a dramatic shift in understanding, away from just comprehending the content knowledge, to transforming it into forms that are pedagogically powerful and adaptive to the learners in front of them (Shulman, as cited in Park & Oliver, 2008).

Through Rick's involvement in the PD programmes, he was provided with alternative ways of thinking about science teaching and learning, enabling him to see how he could transform his science classroom practice to utilise pedagogical approaches that were more comfortable for him. A key contributing factor to this change was working with his host on the STLP. Having been hosted by the Institute of Agriculture and Environment, he was exposed to a science experience that connected with his social science background, and reaffirmed the sociocultural teaching pedagogy he preferred to use. This experience allowed Rick to see that science was not all about the transmission of knowledge, and instead had a dispositional focus which would allow him the ability to use the pedagogy he was more familiar with, in his science teaching. This connection was profound for Rick, and suggests that productive PD needs to enable teachers (as learners) to make connections to what they bring with them, and what interests them. Primary teachers' NoS content knowledge and teaching efficacy have been found to improve when PD integrates the NoS teaching with an area the teacher feels more comfortable in (Deniz & Akerson, 2013). The findings from this study, imply that NoS PCK can also be developed by connecting authentic learning experiences to an area where a teacher feels more comfortable.

Mentors are a valuable source of PCK, and can lead to sustained changes in teachers' practice (Appleton, 2008; Hanuscin, 2013). By matching their mentoring approach to the mentee's way of learning, mentors identify 'teachable moments' as they arise in practical contexts, enabling the mentee to learn and grow from the experience (van Ginkel et al., 2016). In this study, the PLD provider worked alongside Rick in his classroom over a period of two years, as a mentor, sharing his experiences and teaching practice. The provider assumed various roles at different times, including mentor, expert, supporter, and critical friend. She was able to present alternative ideas, as well as challenge his thinking, empowering him to develop a deeper understanding, since she worked beside him in class. Rick stated that the provider had been instrumental in helping him to develop his NoS PCK. PD that seeks to improve a teacher's NoS PCK may benefit more from a mentor-mentee relationship than formal PD workshops.

Mutual respect and trust are crucial for a successful mentor-mentee relationship to be developed (Appleton, 2008; Hudson, 2016), to ensure open-honest two-way communication about professional practice can occur (Hudson, 2016). A mentor's perceived credibility is important for establishing mutual respect (Ertmer et al., 2005), as is their personal-professional attributes and practices (Hudson, 2016). The findings of my study support this research, as Rick referred to the importance of respect in establishing effective working relationships with those involved in the PD. Two factors determined whether Rick respected an individual; firstly, the assumption of expertise granted by a title, for example PhD, which provided credibility, and secondly, whether they shared similar ideas about teaching and learning. Mutual respect and trust of the mentor were critical to improving Rick's NoS PCK, as it allowed open and honest conversations about pedagogical approaches.

Primary teachers' development of NoS PCK can be hindered by both contextual and personal factors (Deniz & Adibelli, 2015; Hanuscin, 2013). Pressure to cover content, institutional and time constraints, and classroom management have all been found to negatively impact the development of NoS PCK (Hanuscin, 2013). A teacher's personal motivation is not enough to overcome these contextual constraints (Sandholtz et al., 2019). Findings from my study support this, showing that contextual constraints limited opportunities for Rick to teach the NoS, and therefore develop his PCK. A key personal difference for Rick, was a shift from behaviour management, to learning management, allowing him to spend more time teaching science, focusing on developing his understanding of the science capabilities. Rigid daily schedules can impede long term changes in primary teachers' classroom practice after PD (Sandholtz & Ringstaff, 2016). The flexible structure of the school day at Rick's new school, provided more opportunities for him to teach science, helping him to solidify his new learning, try new teaching approaches, and develop his PCK. School principals play a central role in facilitating science instruction after PD, by providing either formal or informal expectations that science be incorporated into the teacher's daily teaching programme (Anderson, 2013; Sandholtz & Ringstaff, 2016; Timperley et al., 2007). Rick believed that science was valued as a subject area by his new principal, and that he was expected to teach it. These findings align with the research, indicating that contextual factors such as behaviour management, and rigid school timetables can act as barriers to teachers developing their

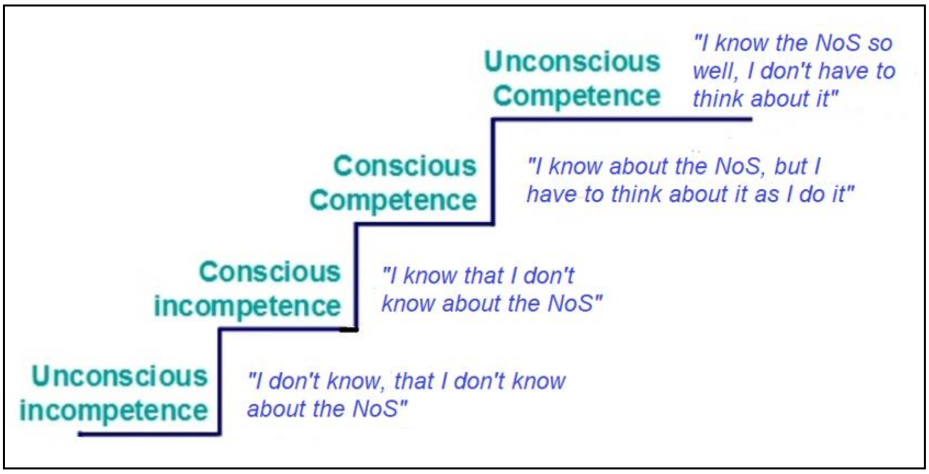
NoS PCK. In contrast, principal support facilitates science teaching after PD, by providing expectations that it will be taught, and taught well.

5.2.3 Increased NoS Teaching Efficacy

Teaching efficacy is a key motivating belief that influences teachers' classroom behaviour and relates to the level of confidence a teacher has in their ability to influence student learning in a particular subject (Klassen et al., 2011; Yangin & Sidekli, 2016), and indicates a teacher's willingness to implement new instructional ideas (Ross & Bruce, 2007). According to Riggs and Enochs (1990), science teaching efficacy involves two discrete, homogeneous constructs – personal science teaching efficacy (PSTE), and science teaching outcome expectancy (STOE). In this study, Rick's PSTE refers to the beliefs that he has about his skills and knowledge to teach the NoS, while his STOE refers to his beliefs related to the impact of his teaching on his students' learning of the NoS.

Prior to Rick's involvement in the PD he described himself as having a high science teaching efficacy. Findings from the 2018 National Monitoring Study of Student Achievement (NMSSA) report support this finding, showing that approximately 66% of New Zealand primary teachers surveyed, regarded themselves as confident to teach the NoS. After Rick's involvement in the PD, he came to realise that his efficacy had been high because he did not understand the NoS, and its relevance to his science teaching and learning. Applying the 'conscious competence' learning model (Cannon et al., 2010), Rick displayed unconscious incompetence (refer to Figure 5.2) prior to the PD, as 'he didn't know, what he didn't know'; namely he had a deficit in understanding of the NoS and how to implement it in his science teaching practice.

Figure 5.2: The 'conscious competence' learning model for the NoS



After completing the STLP, he became aware of what he did not know, displaying conscious incompetence. This finding suggests that New Zealand primary teachers may consider themselves to have a high science teaching efficacy, because they are unaware of the gaps in their own knowledge about the NoS and how it relates to science teaching and learning, and therefore base it on their overall teaching efficacy.

PD has been found to improve primary teachers' science teaching efficacy (Deniz & Akerson, 2013; Lakshmanan et al., 2010; Murphy et al., 2015). Personal teacher efficacy can increase as a result of PD that includes authentic mastery experiences embedded in a teacher's classroom, accompanied by individualised verbal persuasion in the form of feedback (Tschannen-Moran & McMaster, 2009). Self-efficacy theory emphasises the importance of enactive mastery as a major source of efficacy information (Bandura, 1997), as "only in the real setting can a teacher experience a true test of his or her capabilities" (Tschannen-Moran & McMaster, 2009, p. 242). Enactive mastery experiences have been found to be a main source of efficacy for experienced teachers, such as Rick (Tschannen-Moran & Woolfolk Hoy, 2007).

Rick's involvement in the STLP, provided two main sources of efficacy. Firstly, cognitive mastery, in the form of workshops, and secondly, vicarious experiences through observing his host, and classroom observations of other teachers. Rick found the teacher-centred approach of the STLP workshops, and the 'show and tell' classroom observations frustrating, due to the lack of opportunities for effective discourse. Although he increased his content knowledge, these experiences did not increase his efficacy for teaching the NoS. In comparison, the time spent working collaboratively with the PLD provider in his classroom, provided meaningful enactive mastery experiences, and on the spot feedback and encouragement promoting an increase in his efficacy. These findings are consistent with the findings of Tschannen-Moran and McMaster (2007). PD programmes that aim to develop a teacher's PSTE could incorporate enactive mastery experiences embedded in a teacher's own classroom, and provide continued support from a coach or mentor.

PCK is a combination of understanding and enactment. Science PCK and teacher efficacy have been found to influence one another (Park & Oliver, 2008). As Rick continued to develop his personal efficacy through repeated enactive mastery experiences over the course of the study, his personal efficacy grew. His increased efficacy, in turn provided more encouragement for him to enact his understanding, leading to a development of his

PCK. It might, therefore, be hypothesised that PD that aims to develop a primary teachers' NoS PCK, will also develop a teachers' teaching efficacy, or vice versa.

Changes in a teacher's personal teaching efficacy, do not always match changes in their outcome expectancy. For example, increases in primary teachers' PSTE after PD, do not always correlate to improvements in teachers' STOE (Lakshaman et al., 2010). Other studies have found improvements in STOE, where there has been no significant change in the PSTE (Deniz & Akerson, 2013). According to the social cognitive theory, personal efficacy causally influences outcome expectancy (Williams, 2010), meaning improvements in outcome expectancy, may only manifest after personal efficacy does. A teacher's beliefs about outcomes are dependent on their judgement of their capability to perform in a given situation (Klassen et al., 2011). Rick's PSTE score did not significantly change over the course of the study; remaining high throughout. Rick's outcome expectancy however, increased by 10% over the 10-month period, rising to above average. An increase in Rick's STOE score after the development of his PSTE is consistent with what is expected from social cognitive theory – a finding that extends existing literature related to the relationship between the two constructs (e.g. Deniz & Akerson, 2013; Lakshaman et al., 2011).

The development of teacher efficacy does not follow a simple process of incremental improvements (Tschannen-Moran & McMaster, 2009), instead many teachers experience an 'implementation dip' as they begin to make changes in their classroom practice after PD (Woolfolk Hoy & Burke-Spero, 2005). Five months after completing the STLP, back in the classroom, Rick reported a dip in his confidence levels to teach the NoS. Two key factors contributed to this dip. Firstly, having to focus on behaviour management with the class he had taken over, and secondly, a lack of support from school leadership. As well as negatively impacting Rick's teaching efficacy, both his motivation to teach the NoS, and overall energy levels, dropped. Personal teaching efficacy plays a critical role in regulating a teacher's motivation, thought processes, and willingness to expend energy (Wheatley, 2002). When a teacher perceives a greater need for classroom management, they are more likely to be inefficacious (Perera et al., 2019). Teacher efficacy beliefs can be enhanced by providing a nurturing and stimulating culture that fosters and rewards continuous learning and development (Bandura, 1997).

A requirement of the STLP programme was support from the principal. School principals play a key role in building a positive and supportive learning environment within their schools, and therefore can play a role in predicting a teachers' efficacy (Ma & Marion, 2019). When teachers can successfully implement the desired changes in their classroom practice, teaching efficacy beliefs tend to rebound (Tschannen-Moran & McMaster, 2009). By the end of the study, Rick's teaching efficacy had rebounded due to changes in context. Being in a new school, with different expectations, had reignited Rick's confidence and efficacy, allowing him to focus on his NoS teaching and learning. His perception of the positive learning climate in his new school, and a new principal, played a part in shaping his enhanced teaching efficacy. These findings imply that even with a requirement of principal support, unless a positive learning climate within the school is established, a teacher may struggle to develop their NoS teaching efficacy.

5.3 Changes in Classroom Practice

Teacher beliefs strongly influence classroom practice (Keys, 2005). In 2012, a report released by the Education Review Office (ERO) on primary science teaching in New Zealand, found that less than a third of the schools reviewed provided opportunities for students to learn about the NoS, instead focusing their teaching on the acquisition of science knowledge. This finding was true for Rick prior to his involvement in the PD, as he believed he needed to transmit science knowledge to his students. His classroom practice was teacher-directed, relying on contrived learning experiences, which were often disconnected from student's life experiences.

Carefully designed PD is widely recognised as a central feature in aligning classroom practice to the goals of curriculum documents (Granger et al., 2019). Targeted PD can change a primary teacher's classroom practice away from teacher-led expositions of science knowledge, to a more student-centred approach focussed on the application and development of scientific skills (Anderson & Moeed, 2017; Murphy et al., 2015). As a result of Rick's involvement in the PD, his science teaching had become student centred, focussed on encouraging students to come up with their own scientific understandings through scientific discourse. He now used an explicit, reflective approach to his planning and teaching, specifically addressing aspects of the NoS during his instruction and reflective discussion. These two areas are discussed further below.

5.3.1 Use of Scientific Discourse Strategies

Engaging students in the construction, justification and evaluation of knowledge, as opposed to providing factual knowledge, promotes the development of knowledge and understanding (Kranzfelder et al., 2019). Engaging learners in argumentation, using scientific discourse, helps to develop a more informed understanding of the NoS (Khishfe, 2014). Scientific discourse, or what Rick called *"science conversations"* (INT3), in this study are defined as talking about scientific practices as they relate to the NoS, and the science capabilities.

Teachers need to develop the skills required to help students learn how to differentiate between everyday ways of talking about things, and scientific ways of talking, if they are to improve student inquiry and reasoning skills, and enhance engagement in scientific practices (Lee & Irving, 2018). By combining PD with classroom enactment, a primary teacher can improve their science understanding to a point where it influences their classroom instruction (Granger et al., 2019). In situ modelling, as well as on the spot feedback from the PLD provider, helped Rick to refine his scientific discourse in the classroom. However, it was the observation of his students discussing with and using scientific discourse that made him realise the benefits of scientific discourse. Rick's students were asking more questions, and were exploring and figuring things out for themselves. When teachers observe positive behaviour in their students, having made changes in response to PD, they are more likely to have the desire to continue teaching this way (Sandholtz et al., 2019). The observation of students engaging in scientific discourse, highlights the importance of learning interactions as a motivational factor for primary teachers.

Despite positive reinforcement from students throughout the course of the study, Rick's motivation levels were not consistent over the 11 months. Five months after completing the STLP, Rick reported low motivation levels, while five months later his motivation was high. Context is an important mediating factor determining the extent to which PD leads to change in instructional practice, and also to the extent to which those practices persist over time (Sandholtz & Ringstaff, 2016). Despite low motivation five months after completing the STLP, a change in school helped Rick to persist with making changes in his science teaching practice. Students at his new school were confident in themselves, with positive peer pressure being the norm, leading to a more receptive and interested audience for Rick to practice the changes he had learnt from his PD. The contextual differences between students at both schools, support the research that context mediates and influences the implementation of new approaches in classroom practice.

5.3.2 Explicit Use of the NoS in Lessons

According to Abd-El-Khalick and Lederman (as cited in Lederman & Lederman, 2019), the NoS needs to be explicitly taught to students, and should be intentionally planned for and assessed in classroom instruction. Explicit teaching of the NoS, "refers to students being fully immersed in the cognitive, epistemic and social enactments and practices of science that involve building and refining questions, measurements, representations, models and explanations" (Duschl & Grandy, 2013, p. 2126). In order to learn how to teach the NoS, PD efforts need to focus on teachers shifting their pedagogical practices, from implicit teaching of the NoS (i.e. inferred) to explicit (i.e. direct), and didactic to explicit, reflective (Lederman & Lederman, 2019). Five months after the completion of the STLP, Rick planned NoS lessons, which incorporated the explicit use of the NoS, however his practice remained didactic, focussed on what scientists do. Four months later, his NoS lessons focussed on why scientists did what they did, incorporating explicit and reflective discussions of NoS aspects.

Understanding the NoS, although essential, is not sufficient on its own, to productively lead to effective NoS teaching (Lederman & Lederman, 2019). PD should help teachers to develop knowledge of how to assess students' NoS understanding to support effective NoS teaching practice (Hanuscin et al., 2011; Lederman & Lederman, 2019). Assessment allows teachers to gain an understanding of how students learn, and also allows them to evaluate their own effectiveness (Hanuscin et al., 2011; Jones & Moreland, 2015). Prior to the first classroom observation Rick's PD had focussed on developing NoS understanding and knowledge of effective instructional practices. However, it was not until he understood what he was looking for in his students learning, that led him to adopt an explicit, reflective approach to his NoS teaching. The development of Rick's knowledge around assessment of students' NoS understanding, supports the literature, that PD needs to incorporate ways to assess students' NoS understanding.

Rick's involvement in the Kāhui Ako professional learning community (PLC), provided him the opportunity to look at how to assess students understanding of skills being developed through the science capabilities. Using a common task, teachers within the

PLC discussed and assessed student responses, according to curriculum levels. Through looking at how other teachers in the PLC approached the task, including reflecting expectations at different curriculum levels, Rick further developed his NoS instructional practice. He worked out how best to gain the most benefit from a task, and developed an understanding of how to progress students' skills. In alignment with the research, these findings indicate that PD aimed at developing an explicit, reflective approach to teaching the NoS, could incorporate knowledge of how to assess student's understanding.

5.4 Increased Leadership Capability

Rick identified leadership as the key capability he developed as a result of his improvement in the STLP. A key aim of the STLP programme is to develop participant teachers' leadership capabilities, so that they can return to school, and act as science leaders. In essence the programme aims at developing what Gluckman (2011) called 'science champions', namely, primary teachers tasked with the role of developing effective and sustained changes in science teaching and learning. Leadership development is a process which involves strengthening a person's ability to establish a clear vision and achievable goals, and to motivate others to follow the same vision and goals (Davies, 2009).

Self-efficacy beliefs of leaders play a critical role in their leadership development, influencing their motivation, willingness to take on challenges, effort applied, and persistence in the face of difficulties (Machida & Schaubroeck, 2011). Leadership-efficacy in this study, is defined as a leader's confidence in their ability to fulfil the leadership role. Verbal persuasion from a credible other, has been found to be an effective source of leadership self-efficacy (Dwyer, 2019; Machida & Schaubroeck, 2011). As a result of Rick's participation in the one-week university leadership course, he was convinced of the value of appreciative inquiry as a strategy to use with his staff on his return to school. The credibility of the lecturers provided the validity needed to persuade him of its usefulness. Adding to the existing literature, the finding indicates that verbal persuasion from credible others such as university lecturers, can act as an important source of leadership-efficacy in primary teachers.

Good role models, in the form of exceptional leaders, as well as snapshots of leadership behaviour which demonstrates values being played out, has been found to be an effective source of leadership development (Davies, 2009). Vicarious experiences through the process of modelling, are considered a significant source of self-efficacy belief (Bandura, 1997). Rick's leadership-efficacy was strengthened as a result of watching his host interact with his students. The sense of community he observed, along with the co-construction of knowledge, resonated with his own teaching philosophy, allowing him to see its application and usefulness in leadership. Rick's authentic experiences of leadership in action, indicate the importance of vicarious experiences as a source of leadership-efficacy for primary teachers.

5.5 Changes in Teacher Identity

"Identity is an elusive, dynamic, and multidimensional construct" (Richardson & Watt, 2018, p. 38) that changes during an individual's lifespan. Identity has strong ties to the notion of self, and is strongly influenced by context (Akerson et al., 2016). According to the literature, identity is not a singular construct, and in fact individuals have a variety of different identities in different domains (e.g. occupation, spirituality, ethnicity, and gender). According to Ashforth (as cited in Richardson & Watt, 2018) occupational identity, such as teacher identity, is central to an individual's self-worth, and their ability to lead a meaningful, healthy life, as individuals tend to spend the bulk of their life in work.

In examining definitions of teacher identity, it is clear that researchers conceptualise it in different ways, depending on the lens they apply (e.g. Beijaard et al., 2004, Mockler, 2011). Richardson and Watt (2018), define teacher identity as dynamic, being shaped by career choices, reflecting the degree to which an individual categorises themselves personally and occupationally as someone who enacts the role required of a teacher, engaging with the social ties of the profession, and showing commitment to the career into the future. As teachers interact, learn, function, and engage in different contexts with students, other teachers, and educators, they develop sub-identities that influence their main teacher identity (Akerson et al., 2016). As generalists, primary teachers hold many sub-identities such as primary school teacher, teacher of numeracy, teacher of literacy, etc. The following discussion looks at the development of Rick's identity as a teacher of the NoS, and changes in his overall teacher identity with regard to job satisfaction and future perspectives.

5.5.1 Identifying as a Teacher of NoS

Through learning about the NoS, and what science actually "is", teachers can become more confident in their science teaching, and in particular their NoS teaching, leading to the development of a new identity; namely, a teacher of NoS (Akerson et al., 2016). Teachers who enact NoS instruction within their science lessons have developed a NoS identity, and acknowledge that their identity is still changing. By the completion of this study, Rick's science lessons used an explicit-reflective approach to teaching the NoS. Rick acknowledged that he still had gaps in his NoS understanding that he was still developing, indicating the emergence of an identity as a teacher of NoS. In forming an identity, individual's will often come to name themselves (Akerson et al., 2016); at the end of the study Rick referred to himself as scientifically literate.

Both personal and contextual factors contribute to the development of teacher identities. As generalists, primary teachers have many competing identities, such as teacher of literacy or teacher of numeracy. Research has shown that competing ways of seeing themselves can either support or hinder teachers' identity development. Akerson and Hanuscin (2007) found that having a strong identity as a teacher of literacy was supportive, as teaching strategies that were effective in literacy, were also effective in NoS. Akerson et al. (2009) however, found competition from other identities, in terms of pressure to cover content, hindered development. Rick identified himself as a teacher of dispositions, which allowed him to easily identify with the dispositional focus of the science capabilities, assisting his development of identity. He was also able to see connections between teaching the NoS, and how he taught as a social science teacher, and numeracy teacher. By finding connections between other competing identities, Rick was able to develop his NoS identity.

In-service teachers more readily develop NoS identities when PD provides ongoing support. Support provided by other teachers, such as through a community of practice, has led teachers to examine their practice, and to develop their image as a successful teacher (Akerson et al., 2009). Rick's involvement in the Kāhui Ako PLC allowed him to mix with teachers who already had developed a NoS identity, or were developing one, and examine his own practice.

Teacher agency is reciprocally related to teacher identity (Buchanan, 2015), and is a key aspect of teacher identity development (Akerson et al., 2016). Teachers strengthen their

NoS agency by advocating for its inclusion in science teaching practice within their school (Akerson & Hanuscin, 2007); this was what Rick was tasked to do upon his return from the STLP. By holding greater agency, teachers act on their identities to teach the NoS (Akerson et al., 2016). The findings from this study add to the existing literature about the development of a teacher's NoS identity, by showing that competing identities, ongoing support from others, and agency, all positively contribute to a teacher's NoS identity.

5.5.2 Changes in Job Satisfaction and Future Perspectives

Teacher identity incorporates many concepts including self-efficacy, self-esteem, professional commitment, job satisfaction, task orientation, work motivation, and future perspectives (Karaolis & Philippou, 2019). For a teacher, job satisfaction relates to the emotional responses they have to their work and their teaching role. Teachers may become dissatisfied in their job due to many factors. A teacher's identity may or may not fit with their school context or culture (Buchanan, 2015). A poor fit between a teacher and their working environment has the potential to drain a teacher's energy and wear them out, even when they are committed (Pyhältö et al., 2011). Five months after being back in the classroom, Rick reported being frustrated, realising that he 'was not the teacher he wanted to be'. The respite provided by the STLP, had afforded him time to critically self-reflect on his teacher identity and what was important to him. Kelchtermans (2009) explains that without the use of critical, deep reflection, teachers risk maintaining the status quo. Rick believed that without respite, he would not have realised the disconnect between his identity and his school. PD that incorporates time away from a participant's school, may benefit development of teacher identity, by providing time for critical, deep reflection.

Teacher identity is constantly shifting – influenced by meaningful experiences in the past, as well as expectations for the future (Kelchtermans, 2009). Future perspectives of a teacher influence their decisions, feelings, and their behaviour (Karaolis & Philippou, 2019). As a result of observing a model of leadership that resonated with him through his STLP placement, Rick no longer felt satisfied just being a classroom teacher. He expressed the desire to take on a senior leadership role, so he could have a greater impact on education; Rick's new future perspective indicated change in his teacher identity. An indirect result of involvement in authentic PD experiences may be changes in teachers' future perspectives, therefore PD providers need to consider these possible changes when developing their programmes.

5.6 Summary

This case study has shown that one teacher's NoS beliefs can be transformed as a result of involvement in PD which incorporates a period of time working alongside scientists. It has also suggested that some deeply held beliefs may require a more focussed approach to shift them. In order for primary teachers to effectively use the science capabilities as a tool to access the NoS, PD incorporating mentoring could be provided so teachers can see how they could be used, so they avoid just considering them as extra content needing to be taught. The dispositional approach of the science capabilities can make it easier for primary teachers to adopt them, as they tend to already utilise this approach in other areas of their teaching.

Through developing a robust understanding of the NoS, primary teachers can develop their PCK. PD that incorporates authentic learning experiences can develop not only teachers NoS content understanding and teaching efficacy, but also their PCK. When the authentic learning experience is related to a teaching area in which the teacher feels more comfortable, for example social science, the PD impacts appear to be more significant. Both personal and contextual factors can impact a primary teacher's development of their NoS PCK, in particular principal support, flexibility in the daily school structure, and expectations that science will be taught.

The study also showed that enactive mastery experiences, and verbal persuasion were two key sources of NoS teaching efficacy for a primary teacher. Consistent with the social cognitive theory, the study also showed that personal efficacy causally influences outcome expectancy. Teacher efficacy has been strongly linked to PCK. The study showed that with each successful enactment a primary teacher can increase their PCK, which in turn leads to an increase in efficacy. Teachers may suffer an implementation dip after PD if their motivation levels drop. The study showed that classroom management issues can lead to low motivation levels in teachers, and as a result impact their personal efficacy.

Through developing a teacher's NoS understanding, PCK and efficacy, a primary teacher can transform their science teaching practice as a result of targeted PD. The study showed that PD can help a primary teacher develop an explicit, reflective approach to planning and teaching the NoS, using scientific discourse strategies to engage learners in argumentation.

Finally, leadership capability was also shown to have increased as a result of positive role modelling during PD. The study showed that verbal persuasion from a credible other, and modelling help increase a primary teachers' leadership capability. The study also showed that PD can help develop a NoS teacher identity, as well as lead to other changes in teacher identity, such as job satisfaction and future perspectives. The following and final chapter explores the limitations of this study, possible future areas of research highlighted from the findings, and the implications of the conclusions.

Chapter Six - Conclusions

6.1 Introduction

The current study was undertaken to investigate the impact of a unique approach to PD employed by a Kāhui Ako, in an attempt to develop primary teachers' NoS understanding, NoS classroom practice, and efficacy for teaching the NoS. A review of the literature did not reveal research on similar PD approaches, making the findings from this study valuable to those who may be interested in teachers' professional learning in this area. An instrumental case study design was employed, investigating the impact of participation in PD over an 11-month period for one New Zealand (NZ) primary teacher, Rick. Data were collected using questionnaires, semi-structured interviews and classroom observations.

This chapter begins by providing the key conclusions made in this research, followed by a discussion of the implications and recommendations of each. The chapter also discusses the limitations of the study, and suggests possible future research. Finally, a short description of my development as a researcher is provided.

6.2 Key Conclusions

This case study sought to answer the research question:

> 'How does a primary teacher's professional development participation impact his teaching efficacy for the nature of science?'

The conclusions are stated under four broad categories: i) teaching efficacy, ii) changes in teaching practice, iii) leadership-efficacy and identity, and iv) combining PD programmes.

6.2.1 Teaching Efficacy

The first conclusion related to *teaching efficacy* concerns participation in concurrent PD developing personal efficacy and outcome expectancy for teaching the NoS. Instrumental to this was the incorporation of enactive mastery experiences embedded in his classroom, such as teaching his students about interpreting representations using the science capabilities, along with the continual support from his mentor (the PLD provider) who provided 'just-in-time' feedback and encouragement. Despite being exposed to other sources of efficacy, these sources were the most beneficial.

Secondly, the study concludes that primary teachers may struggle to develop their NoS teaching efficacy after PD, unless a positive learning climate is established through instructional leadership within their school. By providing the expectation that science be taught, and a flexible school timetable with time for science teaching, Rick's principal allowed him to enact what he had learnt through his PD, enabling him to develop his NoS teaching efficacy through successful mastery experiences.

Along with the above conclusions to the research question, the study generated a minor conclusion related to changes in NoS beliefs. The study concluded that the deliberate inclusion of adequate time for critical reflection within PD, may help primary teachers to change and enhance their existing beliefs. By examining, questioning and revising his perceptions, Rick was able to enhance his thinking around NoS beliefs after his PD participation.

6.2.2 Changes in Teaching Practice

The study also revealed two conclusions related to *changes in teaching practice*. Firstly, positive learning interactions between students and primary teachers is a key motivational factor for the continual implementation of changes to science teaching practice, after PD participation. As a result of Rick observing his students using strategies he had taught, he was encouraged to persevere with his NoS teaching and learning.

Secondly, primary teachers' NoS classroom practice may be improved by incorporating knowledge of how to assess students NoS understanding into the PD programme. As a result of learning what to look for in his students' NoS responses, Rick was able to further develop his classroom practice.

6.2.3 Leadership-efficacy and Teacher Identity

Two final conclusions related to increased *leadership-efficacy and teacher identity*, were also generated in this study. Firstly, teacher leadership efficacy may be increased as a result of verbal persuasion and vicarious experiences. Rick's leadership efficacy grew as a result of observing his host interact with his students, and through the persuasion of credible lecturers on his university leadership course.

Secondly, the study indicates that primary teachers' may develop a NoS teacher identity by making connections between their other competing teacher identities. By identifying himself as a teacher of dispositions, Rick was able to easily identify with the dispositional focus of the science capabilities, enabling him to develop his NoS teacher identity more easily.

6.2.4 Combining PD Programmes

This study has shown that by combining three different NoS PD programmes, a primary teacher transformed his NoS beliefs, PCK, and efficacy, as a result of leveraging off the benefits of each programme. Each programme had its own merits, and helped Rick develop particular areas, but it was the combination that brought all the individual parts together, leading to an overall transformation, and development of a NoS teacher identity.

6.3 Implications and Recommendations

This case study found that enactive mastery experiences embedded in a teacher's classroom, together with mentoring from a respected other, can develop a primary teacher's personal NoS efficacy, and outcome expectancy. Research has shown that PCK and teaching efficacy influence one another (Park & Oliver, 2008), and this was certainly the case in the current study. Each time Rick successfully enacted a NoS lesson, his efficacy grew, and with this new increased efficacy, he was motivated to try again, leading to further improvements in his PCK. This cycle repeated itself many times over the course of the study. This PD approach was far more successful for Rick than cognitive mastery experiences in the form of workshops, or in situ modelling in the form of 'show and tell' lesson observations. The implication is that in order to increase teaching efficacy, preservice and in-service providers need to provide teachers with multiple opportunities to enact their NoS understanding in the classroom, while providing 'just-in-time' feedback at the same time through the use of mentoring. This finding is beneficial to science advisors and associate teachers, working with pre-service and in-service primary school teachers.

The study also identified the need for instructional leadership within the school, to provide a positive learning culture, that enhances the development of teachers' NoS efficacy both during and after participation in PD. The implication stemming from this conclusion is for senior leadership to be supportive of teachers attending PD, and to continue to provide support and encouragement after their participation. This support might include providing expectations that science will be taught, and that time will be provided within the school timetable for this teaching to occur. School leadership teams need to be mindful of the power of their instructional support to teachers upon their return to school after PD. It is, therefore, recommended that PD providers make these expectations a requirement of a teacher's participation, and to check regularly that this is occurring within the participant's school.

The current study has shown that primary teachers' NoS beliefs can be changed or enhanced, as a result of PD that includes the deliberate inclusion of time for critical reflection. Most New Zealand primary teachers lack background knowledge in science, beyond their own personal education, and therefore require PD if they are to develop an informed view of the NoS. According to Mezirow (2012), critical reflection allows a person to challenge their existing beliefs. Primary teachers who hold uninformed NoS views, such as believing there is only one way to carry out a scientific investigation, would benefit from critically reflecting on what they have observed and learnt about the NoS during PD. Finding time in a busy school day to critically reflect on what you have observed and learnt, after completing PD, is a challenge for most teachers. This study therefore recommends that pre-service and in-service science PD providers, provide sufficient opportunities within their programme, or immediately after, for participants to engage in critical reflection on a regular basis, in order to help primary teachers, gain an informed view of the NoS.

The current study concluded that positive student-teacher interactions are a key motivational factor for the continual implementation of changes to teaching practice after PD. Motivation relates to the inner drive that directs a person's behaviour to achieve a particular goal, and influences their willingness to expend effort to achieve it. In the business of a normal classroom situation teachers may often miss these positive interactions, and, as a result, not benefit from them. In order to successfully enact the NoS in the classroom, a teacher must have the motivation to do so. It is, therefore, recommended that pre-service and in-service mentors for primary teachers, highlight positive student-teacher interactions in the classroom when the NoS is being taught, to help teachers increase their motivation to keep improving their NoS classroom practice.

The study showed that primary teacher NoS classroom practice may be improved when PD incorporates knowledge of how to assess students' NoS understanding. In order to assess a student's understanding, a teacher must first fully understand what they are looking for in a student's response. By understanding what to look for, teachers are also more aware of what they need to teach. This was certainly the case for Rick, who realised that he needed to adapt how he was teaching the NoS, after reviewing student responses to a NoS task. It is, therefore, recommended that both pre-service and in-service science PD providers, include how to assess students' NoS understanding as part of their programme, to help teachers refine their classroom practice. Online teaching resources, such as the Science Learning Hub and the Assessment Resource Bank, could also provide fully annotated exemplars of students' responses to NoS tasks, so that teachers can understand what is required by the student to successfully enact the task, and what pedagogical approaches could be used in the classroom to help students develop the required skills.

As a result of Rick's participation in one of the PD programmes his leadership-efficacy increased. Two sources of efficacy were identified; namely, verbal persuasion from a credible other, in this case a university lecturer, and vicarious experiences, as a result of observing his host working with his students. In order for a primary teacher to be the 'science champion' within their school, they will require a high leadership self-efficacy. It is therefore important, that PD provide opportunities for a teacher to develop their personal leadership efficacy. This finding would be especially useful to PD providers who are striving to develop school science leaders, highlighting the need for participants to observe effective leaders in action, and to have information about leadership presented by credible individuals.

This study concluded that a primary teacher can develop a NoS teacher identity by making connections between their different teaching identities. In order to develop effective science teaching and learning programmes a primary teacher must first develop a NoS teacher identity, so they have a context for evaluating and developing their instructional practice. In order to help pre-service and in-service primary teachers to develop a NoS teacher identity, science PD providers might benefit from helping teachers make connections between different areas of the curriculum, for which the teachers have already developed a teacher identity.

Finally, the unique combination of three NoS PD programmes used in this study, provided an opportunity for each programme to complement and build upon one other, ultimately leading to Rick developing his NoS understanding, PCK and efficacy. Each programme provided different experiences, but all aimed at the same objective. Involvement in the Science Teachers Leadership Programme (STLP) provided Rick respite from the classroom, and authentic science experiences, enabling him to develop an informed view of the NoS. Mentoring supplied by the PLD provider gave him the practical experience of teaching the NoS in his classroom using the science capabilities as a tool to access the NoS, and development of a NoS PCK. The professional learning community (PLC) provided him alternative ideas and approaches from other teachers, and experience in assessing student's NoS understanding, again furthering his classroom practice and PCK. Any one of these programmes on their own may not have provided the overall changes observed in Rick. Based on these findings it is recommended that Ministry funded PD be provided to teachers who have attended other extended PD programmes, such as the STLP, to support and further develop teacher understanding, classroom practice and efficacy. Inservice providers, such as the Royal Society, could recommend Ministry funded PD to participant schools, to help support and further develop participants upon their return to school. Primary teachers could also be encouraged to organise a PLC amongst other PD participants after the completion of the programme, to help support and challenge one another.

6.4 Limitations of the study

Although this case study has highlighted a number of factors for PD designers to consider, in the improvement of primary teacher NoS efficacy, the study is limited by the fact that it is a single case study of one middle-aged, male primary teacher in NZ, making it unsuitable for generalisation to wider populations (Stake, 1995; Yin, 2009). The goal of this case study was not to generalise, rather to attain thick descriptions and contextual information that may shed insights into the impact of PD on NoS teaching efficacy. From the findings of this study, we have no way of knowing, empirically, that the impact of the same PD, on different teachers, would produce similar or different results to that seen in Rick. What the study has done is generate some valuable insights on the possible impacts of three specific PD programmes on the development of a primary teacher's NoS teaching efficacy.

The nature of case studies means that considerable in-depth data are collected; in this study, three interviews, two classroom observations, and four questionnaires. In drawing the findings together, a significant amount of synthesis may occur, and only certain findings will be discussed. It is therefore possible, that by revisiting the data collected different interpretations might be revealed. The interpretations made in this study are however, strengthened by triangulation of data collected from multiple sources, as well as peer checking throughout the process.

The quality of the insights and thinking brought to bear by a researcher, is a key determinant of the quality of a case study. Every researcher is different, bringing unique perspectives, beliefs, and values to their research, and as such the researcher can act as a limitation to their own findings. When this case study is read by another individual, they are reading my construction of the data around the impacts I judged to be important. As a result, this research is not, and cannot be, completely objective. In order to address this issue, a reflexive approach was strived for throughout the entire research process.

Another limitation of this study relates to the selection of Rick as the participant, as he does not represent all primary teachers. Rick's gender, age, ethnicity, and the length of years teaching prior to the PD, as well as his teaching philosophies, will have strongly influenced how he was impacted by the three PD programmes. This individuality was reflected by his change of schools during the case study. This change in context mid-way through the study also impacted the findings, and the direction of the study. To represent all primary teachers a much larger-scale study would be required, involving a variety of different participants of different age, gender, ethnicity, and experience, to capture the common impacts of the PD on the development of primary teacher NoS teaching efficacy.

A further limitation relates to the one-sidedness of the data collected. This case study presents findings only from Rick's perspective. No data were collected from the perspective of Rick's students, from the schools in which he taught or from his PD providers. Student perceptions, for example, may have provided valuable insights regarding the impact of the PD on Rick's effectiveness to teach the NoS.

Another limitation of this study relates to its duration. In order to ascertain the full impact of PD on Rick, a longer time period was required. According to Timperley et al. (2007), teachers need to engage with new ideas learnt from PD, and enact them in their practice, over an extended time period. In this case study, Rick only attended four meetings of the Kāhui Ako PLC over the study period. It is, therefore, hard to judge the true impact of the PLC on Rick's NoS teaching efficacy given the very small amount of participation time involved. The sustainability of any changes to Rick's NoS teaching efficacy as a result of the PD, was also unable to be ascertained over such a short period of time.

This study began after Rick had completed his STLP, and had already had some involvement with the PLD provider, therefore, no baseline data were collected with regard to his NoS understanding, personal NoS teaching efficacy, and NoS outcome expectancy. The findings from the adapted NSAAQ and STEBI questionnaires (refer to 4.2), therefore, provide information relevant only to the time they were taken. The findings have been interpreted based on research that indicates PD can improve teachers' NoS understanding and teaching efficacy, which is a limitation of this study.

A final limitation relates to the two classroom observations of Rick. Both observations completed in this study, addressed only one area of the NoS strand; communicating in science. Findings based on these two observations, may not necessarily be transferrable to other NoS lessons taught by Rick, focussed on different areas, such as investigating in science.

6.5 Recommendations for future research

This study examined the lived experiences and perceptions of Rick, a European, middle-aged experienced primary teacher in NZ. The findings therefore are very specific to Rick. Based on these findings, there are several recommendations for future research.

Firstly, in order to minimise some of the limitations associated with using a single participant case study, future studies could adopt a multiple case study design. Participants could be chosen to provide a wide range of perspectives, based on participant age, gender, ethnicity, and teaching experience, as well as participants from schools in different socioeconomic communities. Baseline data could be collected prior to the participants engaging in any PD, to ascertain their NoS understanding, NoS PCK, and NoS teaching efficacy. Ideally, a future study would extend over a prolonged period of time, preferably greater than two years, to allow sufficient participation in the PD, and time for teachers to reflect and enact the changes in their classroom. Classroom observations could include the teaching of a wider range of NoS aspects.

Secondly, this study looked at the impact of three PD programmes working together to improve primary teachers' NoS teaching efficacy. This combination of concurrent PD programmes was a unique situation, and further research is warranted to investigate whether other such PD collaborations can shape similar changes in teacher knowledge and efficacy. This change would be beneficial to those designing PD programmes aimed at helping teachers develop the efficacy needed to implement curriculum changes.

Thirdly, very little research has been completed on the impact of the science capabilities on the NoS teaching practice of NZ primary teachers. By developing an understanding of these capabilities, Rick was able to develop his understanding of the NoS and change his science teaching practice. Further research is, therefore, warranted to investigate how successful the science capabilities have been in terms of helping NZ teachers implement the NoS into their science teaching practice.

Finally, this study raised some areas that require further investigation:

- the impact of focussed NoS PD programmes on shifting the predominant primary teacher view that science knowledge is objective.
- the role that assessment plays in developing a primary teachers' explicit, reflective approach to teaching the NoS.
- the impact of the teacher's PD on student's achievement in science.
- how student perspectives on their science learning and understanding change, as a result of teacher PD in science.
- the relationship between the reciprocity of learning interactions, and a teacher's motivation to make changes in their science teaching practice as a result of PD.
- the influence on other teachers' thinking, learning and practice in science, as a result of professional conversations with PD participants.
- the relationship between vicarious experiences and leadership efficacy in primary teachers.
- one (or more) primary teachers involved in NoS PD, to investigate the impact of the PD on their NoS teaching identity.

6.6 Becoming a researcher

I began this study as a secondary school teacher with a science background, meaning I was more familiar with a scientific approach to research, than a qualitative case study in education; as a result, it has been a steep learning curve. Throughout the process I had a dual identity; one as a learner, and the other as becoming a researcher.

One of the first challenges I faced was developing my interview questions. Writing open ended questions that would target areas I wanted to explore was not easy, and required multiple attempts. Having chosen to collect data from questionnaires, interviews and classroom observations, I was then faced with a huge amount of data, and trying to figure out how to put it all together. Initially, I struggled with the sheer volume of ideas emerging, and the problem of deciding what to focus on. Despite themes emerging from these data, the final process of reducing them to the key impacts of the PD, became a iterative process of reflection and revision. At times, this was a painful process, and challenged my persistence when I felt like I just couldn't 'see the woods for the trees.' When it all came together, I began to see the value of my findings.

Reflecting on my research experience, I realise that I have developed an identity as a researcher, no longer looking at things the same way. I find myself making observations in my practice, and beginning to wonder why that is happening, and considering investigating further. This case study has changed the way I think about education, my perceptions and my identity.

6.7 Concluding Remarks

I embarked on this research with aim of exploring a practical solution to the continuing challenge of low teaching efficacy in primary teachers, with regard to teaching science. What I have shown is that teacher efficacy for teaching the NoS can be improved to the point where a teacher develops their teaching practice, through participation in concurrent, targeted NoS PD programmes. The study has highlighted the benefits of being involved in three PD programmes, focussed on developing NoS understanding, PCK, classroom practice, and efficacy. The strengths of each programme were able to be leveraged upon leading to greater benefits, than if only one of the three programmes had been employed. By effectively using a combination of scientist-teacher partnerships, enactive mastery experiences embedded in a teacher's classroom, in-class mentoring from a respected expert, and a PLC, NoS understanding and PCK improved, leading to an increase efficacy for teaching in the domain of NoS.

If New Zealand is to reverse the trend of declining interest and poor achievement in science, primary teachers must increase their NoS teaching efficacy. Primary teachers may benefit from challenge and support to change the ways they understand and enact the current science curriculum. This study has provided hope, showing that it can be achieved, through a combination of concurrent PD aimed at deepening a teacher's scientific knowledge, pedagogical knowledge and teaching efficacy.

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Appendices

Appendix A: Low Risk Notification Acknowledgement Letter

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Date: 27 May 2019

Dear Mairi Borthwick

Re: Ethics Notification - **4000021142 - The impact of professional learning on science teaching efficacy: A case study of one New Zealand primary school.**

Thank you for your notification which you have assessed as Low Risk.

Your project has been recorded in our system which is reported in the Annual Report of the Massey University Human Ethics Committee.

The low risk notification for this project is valid for a maximum of three years.

If situations subsequently occur which cause you to reconsider your ethical analysis, please contact a Research Ethics Administrator.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

A reminder to include the following statement on all public documents:
"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document are responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact Professor Craig Johnson, Director - Ethics, telephone 06 3569099 ext 85271, email humanethics@massey.ac.nz."

Please note, if a sponsoring organisation, funding authority or a journal in which you wish to publish requires evidence of committee approval (with an approval number), you will have to complete the application form again, answering "yes" to the publication question to provide more information for one of the University's Human Ethics Committees. You should also note that such an approval can only be provided prior to the commencement of the research.

Yours sincerely

Professor Craig Johnson
Chair, Human Ethics Chairs' Committee and Director (Research Ethics)

Research Ethics Office, Research and Enterprise
Massey University, Private Bag 11 222, Palmerston North, 4442, New Zealand **T** 06 350 5573; 06 350 5575 **F** 06 355 7973
E humanethics@massey.ac.nz **W** http://humanethics.massey.ac.nz

Appendix B: Information Sheet

MASSEY UNIVERSITY

INSTITUTE OF EDUCATION

TE KURA O TE MĀTAURANGA

The impact of professional learning on science teaching efficacy: A case study of one New Zealand primary school.

INFORMATION SHEET

Researcher(s) Introduction

My name is Mairi Borthwick and I am currently enrolled in a MEd (Teaching and Learning) through Massey University, Palmerston North. As part of the requirements for my MEd I am completing a research project which includes writing a thesis.

Project Description and Invitation

My study aims to investigate how a local primary school's participation in three science professional development programmes impact efficacy beliefs about teaching the nature of science. The study will involve one New Zealand Y0-6 primary school in a central North island Kāhui Ako (Community of Learning, made up of ten schools). Professional development has been provided in the form of one teachers' involvement in the six month Royal Society 'Science Teachers Leadership Programme' (STLP), an MOE funded PLD contract, and a professional learning community established within the Kāhui Ako. A case study employing both qualitative and quantitative methods will be used, involving interviews, questionnaires, observations and document analysis.

I would like to invite you to be a participant in this research project.

Participant Identification and Recruitment

- *Participation is completely voluntary, and participants have the right to decline or withdraw from the project at any time.*
- *The STLP participant from the case study school, along with the principal, and up to three other teachers involved in teaching science during the time period of the research project, will be selected for participation.*

Project Procedures

- *Participants may be involved in one or more of the following research procedures – anonymous questionnaires (all teaching staff), individual interviews (STLP participant) of 30 minutes duration at the start and finish of project, a focus group discussion of 30 minutes duration (up to 3 teaching staff), individual interview of Principal at start of project of 30 minute duration, 4 classroom observations of the STLP participant, and analysis of the STLP participant documentation (lesson plans, STLP documentation).*
- *The research will begin on June 14th 2019 and will be completed by the end of Term 2, 2020.*
- *The researcher is known to the participants in her liaison role as Across School Teacher for the Kāhui Ako.*

Data Management

- *Data will be collected to provide information about teacher understanding about the content and associated teaching strategies of the nature of science strand of the New Zealand Curriculum (2007), and primary science teaching efficacy (confidence in teaching science).*
- *Questionnaires will be analysed using SPSS, while all other data will be analysed using qualitative analysis techniques. Questionnaires will be digitally recorded. Interviews will be recorded and then transcribed.*

Te Kunenga ki Pūrehuroa

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- *Data will be stored on a password protected computer and not be identifiable back to the original respondents and will be disposed of in accordance with the regulations of the MUHEC. Electronic information will be securely erased 5 years after completion of the study.*
- *Participants will be debriefed after any observation, and interview transcripts returned, at which time participants have the right to ask for material to be removed, or changed.*
- *All participants will be provided with a summary of the findings at the completion of the project.*
- *Confidentiality will be maintained by anonymizing all participant and participant school names. A confidentiality agreement will be signed by the researcher protecting against disclosure of any confidential information.*

Participant's Rights

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- *decline to answer any particular question;*
- *withdraw from the study at any time;*
- *Completion and return of questionnaires implies consent. You have the right to decline to answer any particular question.*
- *ask for the recorder to be turned off at any time during the interview.*
- *ask any questions about the study at any time during participation;*
- *provide information on the understanding that your name will not be used unless you give permission to the researcher;*
- *be given access to a summary of the project findings when it is concluded.*

Project Contacts

Participants may contact the researcher and/or her supervisor(s) if they have any questions about the project. Contact details are listed below.

- *Mairi Borthwick (Massey University Med student/researcher)*

  [redacted]

  Phone (wk) [redacted]
  (mob) [redacted]
  (hm) [redacted]

  Associate Professor Alison Sewell (Massey University Supervisor)
  A.M.Sewell@massey.ac.nz

  Associate Professor Jenny Poskitt (Massey University Supervisor)
  j.m.poskitt@massey.ac.nz

Compulsory Statements

1. **LOW RISK NOTIFICATIONS**

"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Prof Craig Johnson, Director, Research Ethics, telephone 06 356 9099 x 85271, email humanethics@massey.ac.nz".

Appendix C(i): Participant Consent Form

MASSEY UNIVERSITY
INSTITUTE OF EDUCATION
TE KURA O TE MĀTAURANGA

The impact of professional learning on science teaching efficacy: A case study of one New Zealand primary school.

PARTICIPANT CONSENT FORM - INDIVIDUAL

I have read, and I understand, the Information Sheet attached as Appendix I. I have had the details of the study explained to me, any questions I had have been answered to my satisfaction, and I understand that I may ask further questions at any time. I have been given sufficient time to consider whether to participate in this study and I understand participation is voluntary and that I may withdraw from the study at any time.

1. I agree/do not agree to any interview being audio recorded.
2. I wish/do not wish to have my transcripts returned to me.
3. I agree/do not agree to being observed while teaching or in meetings related to this research project.
4. I agree to participate in this study under the conditions set out in the Information Sheet.

Declaration by Participant:

I __________ [print full name]__________ hereby consent to take part in this study.

Signature: ______________________ Date: _______________

Participant Consent Form (2019) Page 1 of 2

Te Kunenga ki Pūrehuroa

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Appendix C(ii): Authority for the Release of Transcripts

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

The impact of professional learning on science teaching efficacy: A case study of one New Zealand primary school.

AUTHORITY FOR THE RELEASE OF TRANSCRIPTS

I confirm that I have had the opportunity to read and amend the transcript of the interview(s) conducted with me.

I agree that the edited transcript and extracts from this may be used in reports and publications arising from the research.

Signature: .... **Date:** ....

Full Name - printed ....

Authority for Release of Transcripts Format (2015) Page 1 of 1

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Appendix D(i): Adapted Nature of Science as Argument Questionnaire

The Nature of Science Questionnaire

This is a survey of teachers' Nature of Science understanding to establish baseline data for research into the effectiveness of science professional development focused on building teachers' Nature of Science understanding. Professional development will be supplied by your STLP staff member and the Kāhui Ako PLD providers over the next year.

The survey consists of a few demographic questions followed by 20 questions, divided into four parts, one part per page.

Participation in this survey is completely voluntary. By completing the survey you give your consent. All survey data will be kept anonymous and confidential.

Thank you for participating in this survey of the primary teachers at your school.

DEMOGRAPHIC INFORMATION:

What year level are you currently teaching?

How many years have you been teaching?

What is your current level of perceived confidence in the nature of science strand of the New Zealand Curriculum?

Low		Average		High
☐	☐	☐	☐	☐

How confident are you currently in teaching science in your classroom?

Low		Average		High
☐	☐	☐	☐	☐

DIRECTIONS FOR QUESTIONNAIRE:

Read each of the pairs of statements in each question and select the number on the continuum that best describes your position on the issue described. The numbers on the continuum mean:

1. I completely agree with viewpoint A and I completely disagree with viewpoint B.
2. I agree with both viewpoints, but I agree with viewpoint A more than I agree with viewpoint B.
3. I agree with both viewpoints equally.
4. I agree with both viewpoints, but I agree with viewpoint B more than I agree with viewpoint A.

5. I completely agree with viewpoint B and I completely disagree with viewpoint A.

Part One: What is the nature of scientific knowledge?

When you think of the body of knowledge that has been generated by the work of scientists, how would you describe it?

Indicate which viewpoint you agree with the most by checking the box below the number in the table.

	Viewpoint A	1	2	3	4	5	Viewpoint B
1	Scientific knowledge describes what reality is really like and how it actually works.	☐	☐	☐	☐	☐	Scientific knowledge represents only one possible explanation or description of the natural world.
2	Scientific knowledge should be considered tentative.	☐	☐	☐	☐	☐	Scientific knowledge should be considered certain.
3	Scientific knowledge is subjective (based on personal feelings and opinions).	☐	☐	☐	☐	☐	Scientific knowledge is objective (based on facts).
4	Scientific knowledge does not change over time once it has been discovered.	☐	☐	☐	☐	☐	Scientific knowledge usually changes over time as a result of new evidence and interpretations.
5	Scientific knowledge is best described as being a collection of facts about the world.	☐	☐	☐	☐	☐	Scientific knowledge is best described as an attempt to describe and explain how the world works.

Part Two: How is scientific knowledge generated?

When you think of what scientists do in order to produce scientific knowledge, how would you describe this process?

Indicate which viewpoint you agree with the most by checking the box below the number in the table.

	Viewpoint A	1	2	3	4	5	Viewpoint B
6	Experiments are important in science because they can be used to generate reliable evidence.	☐	☐	☐	☐	☐	Experiments are important in science because they prove ideas right or wrong.
7	All science is based on a single scientific method.	☐	☐	☐	☐	☐	The methods used by scientists vary based on the purpose of the research and the discipline.
8	Science is best described as a process of exploration and experiment.	☐	☐	☐	☐	☐	Science is best described as a process of explanation and argument.
9	An experiment is used to test an idea.	☐	☐	☐	☐	☐	An experiment is used to make a new discovery.
10	Within the scientific community, debates and discussions that focus on the context, processes, and products of inquiry are common.	☐	☐	☐	☐	☐	Within the scientific community, debates and discussions that focus on the context, processes and products of inquiry are rare.

Part Three: What counts as reliable and valid scientific knowledge?

A central claim of science is that it produces reliable and valid knowledge about the natural world.

Indicate which viewpoint you agree with the most by checking the box below the number in the table.

	Viewpoint A	1	2	3	4	5	Viewpoint B
11	Scientific knowledge can only be considered trustworthy if the methods, data, and interpretations of the study have been shared and critiqued.	☐	☐	☐	☐	☐	Scientific knowledge can be considered trustworthy if it is well supported by evidence.
12	The scientific method can provide absolute proof.	☐	☐	☐	☐	☐	It is impossible to gather enough evidence to prove something true.
13	If data was gathered during an experiment it can be considered reliable and trustworthy.	☐	☐	☐	☐	☐	The reliability and trustworthiness of data should always be questioned.
14	Biases and errors are unavoidable during a scientific investigation.	☐	☐	☐	☐	☐	When a scientific investigation is done correctly errors and biases are eliminated.
15	A theory should be considered inaccurate if a single fact exists that contradicts that theory.	☐	☐	☐	☐	☐	A theory can still be useful even if one or more facts contradict that theory.

Part Four: What role do scientists play in the generation of scientific knowledge?

Indicate which viewpoint you agree with the most by checking the box below the number in the table.

	Viewpoint A	**1**	**2**	**3**	**4**	**5**	**Viewpoint B**
16	In order to interpret the data they gather scientists rely on logic, their creativity, and prior knowledge.	☐	☐	☐	☐	☐	In order to interpret the data they gather scientists rely on logic only and avoid using creativity or prior knowledge.
17	Two scientists (with the same expertise) reviewing the same data will reach the same conclusion.	☐	☐	☐	☐	☐	Two scientists (with the same expertise) reviewing the same data will often reach different conclusions.
18	A scientist's personal beliefs and training influence what they believe counts as evidence.	☐	☐	☐	☐	☐	What counts as evidence is the same for all scientists.
19	The observations made by two different scientists about the same phenomenon will be the same.	☐	☐	☐	☐	☐	The observations made by two different scientists about the same phenomenon can be different.
20	It is safe to assume that a scientist's conclusions are accurate because they are an expert in their field.	☐	☐	☐	☐	☐	A scientist's conclusions can be wrong even though scientists are experts in their field.

Thank you for your time.

Appendix D(ii): Adapted Science Teaching Efficacy Belief Survey

Science Teaching Efficacy Belief Survey

This instrument is designed to measure your self-efficacy and outcome expectancy with regard to your Nature of Science teaching and learning.

Please indicate the degree to which you agree or disagree with each statement below by selecting the appropriate statement.

1. 1. I will continually find better ways to teach the nature of science.

   Mark only one oval.

   - Strongly agreee
   - Agree
   - Uncertain
   - Disagree
   - Strongly Disagree

2. 2. Even if I try very hard, I will not teach the nature of science as well as I will most other subjects.

   Mark only one oval.

   - Strongly agree
   - Agree
   - Uncertain
   - Disagree
   - Strongly Disagree

3. 3. When the nature of science skills of students improve, it is often due to their teacher having found a more effective teaching approach.

Mark only one oval.

- ( ) Strongly agree
- ( ) Agree
- ( ) Uncertain
- ( ) Disagree
- ( ) Strongly disagree

4. 4. I know the strategies necessary to teach the nature of science concepts effectively.

Mark only one oval.

- ( ) Strongly agree
- ( ) Agree
- ( ) Uncertain
- ( ) Disagree
- ( ) Strongly Disagree

5. 5. I will not be very effective at monitoring progression in student's nature of science skills.

Mark only one oval.

- ( ) Strongly agree
- ( ) Agree
- ( ) Uncertain
- ( ) Disagree
- ( ) Strongly disagree

6. 6. If students are not making progress in their nature of science skills, it is most likely due to ineffective science teaching.

Mark only one oval.

- Strongly agree
- Agree
- Uncertain
- Disagree
- Strongly disagree

7. 7. I will generally teach the nature of science ineffectively.

Mark only one oval.

- Strongly agree
- Agree
- Uncertain
- Disagree
- Strongly disagree

8. 8. The inadequacy of a student's nature of science background cannot be overcome by good teaching.

Mark only one oval.

- Strongly agree
- Agree
- Uncertain
- Disagree
- Strongly disagree

9. 9. Low nature of science skills of some students cannot generally be blamed on their teachers.

Mark only one oval.

- Strongly agree
- Agree
- Uncertain
- Disagree
- Strongly disagree

10. 10. When a low-achieving child progresses in the nature of science, it is usually due to extra attention given by the teacher.

Mark only one oval.

- Strongly agree
- Agree
- Uncertain
- Disagree
- Strongly disagree

11. 11. I understand the nature of science concepts well enough to be effective in teaching it to my students.

Mark only one oval.

- Strongly agree
- Agree
- Uncertain
- Disagree
- Strongly disagree

12. 12. Increased effort in nature of science teaching produces little change in some students' understanding.

Mark only one oval.

- Strongly agree
- Agree
- Uncertain
- Disagree
- Strongly disagree

13. 13. When a student does better than usual at the nature of science, it is often because the teacher exerted a little extra effort.

Mark only one oval.

- Strongly agree
- Agree
- Uncertain
- Disagree
- Strongly Disagree

14. 14. The teacher is generally responsible for the nature of science achievement of students

Mark only one oval.

- Strongly agree
- Agree
- Uncertain
- Disagree
- Strongly Disagree

15. 15. Students' achievement in the nature of science is directly related to their teacher's effectiveness in teaching the nature of science.

Mark only one oval.

- Strongly agree
- Agree
- Uncertain
- Disagree
- Strongly Disagree

16. 16. If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher.

Mark only one oval.

- Strongly agree
- Agree
- Uncertain
- Disagree
- Strongly diagree

17. 17. I will find it difficult to explain to students why science experiments work.

Mark only one oval.

- Strongly agree
- Agree
- Uncertain
- Disagree
- Strongly disagree

18. 18. I will typically be able to answer students' nature of science questions.

Mark only one oval.

- Strongly agree
- Agree
- Uncertain
- Disagree
- Strongly disagree

19. 19. I wonder whether I will have the necessary skills to teach the nature of science.

Mark only one oval.

- Strongly agree
- Agree
- Uncertain
- Disagree
- Strongly Disagree

20. 20. Given a choice, I will not invite the principal to evaluate my nature of science teaching.

Mark only one oval.

- Strongly agree
- Agree
- Uncertain
- Disagree
- Strongly disagree

21. 21. When a student has difficulty understanding a nature of science concept, I will usually be at a loss as to how to help the student understand it better.

Mark only one oval.

- Strongly agree
- Agree
- Uncertain
- Disagree
- Strongly disagree

22. 22. When teaching the nature of science, I will usually welcome student questions.

Mark only one oval.

- Strongly agree
- Agree
- Uncertain
- Disagree
- Strongly disagree

23. 23. I do not know what to do to turn students on to the nature of science.

Mark only one oval.

- Strongly agree
- Agree
- Uncertain
- Disagree
- Strongly disagree

Appendix E(i): First Interview Questions

1. Before taking part in the STLP programme, how would you describe your understanding of the nature of science?
2. How do you believe scientific knowledge is generated, and what role do scientists play in this generation?
3. A central claim of science is the reliability and validity of the knowledge generated. What do you understand by this statement?
4. One of the main aims of the STLP program was for you to work alongside scientists. Can you tell me how this aspect of the programme has changed your understanding of the Nature of Science, and how you see it contributing to your teaching in the future?
5. Reflecting back on the last two terms with the Royal Society, what strategies used were the most effective for your own personal learning? And why were they?
6. Obviously, you are going to be delivering professional development to adults. What is your current understanding around adult learning? And what professional learning approaches do you think you will use with your staff, and why?
7. In what ways has your involvement in the STLP programme changed how you understand the nature of science?
8. There are four sources of information that enhance a teachers efficacy – mastery/failure, verbal persuasion (others encouraging you and believing in your ability), vicarious experiences of watching others teach, and physiological cues such as feeling of excitement/anxiety before teaching.

   Reflecting on your time on the STLP, which of the four sources of information listed, has impacted your personal teaching efficacy for the nature of science? and how?
9. If a student is successful in primary science, what relationship do you see between their success and the teacher's ability in teaching science?
10. How would you rate your current confidence levels in teaching science to primary students? And what influence did the STLP programme have on this?
11. Looking ahead, what could I expect to see if I came in and observed you teaching science, and how would this differ from before your time on the STLP?

Appendix E(ii): Second Interview Questions

1. You have just completed phase two of the STLP programme. Can you tell me a little bit about what that has involved for you? What have you found out from this?
2. As you reflect on the last two terms, can you describe any support you have gained through the Royal Society, in particular with regard to continuing to develop your knowledge of and teaching of the NOS? What was the most helpful and why?
3. You have also received some PLD from Sabina over the last two terms. Can you describe the nature of the support given by Sabina?
4. How effective has this support been in continuing to develop your knowledge and teaching of the NOS?
5. Reflecting on these things what benefit to your own learning and understanding of the NOS do you see in being part of this STLP professional learning community?
6. Thinking about science lessons you have attempted with your class this year; can you describe how these lessons differ to science lessons taught prior to your STLP experience and PLD support?
7. What particular teaching strategies have you been using in these lessons and how do they link to the NOS?
8. What problems did you encounter when you were teaching in relation to the teaching of the NOS?
9. How would you rate your confidence levels in teaching the NOS prior to involvement in the STLP and PLD? And what about now?
10. What has influenced this the most?
11. How have your students responded to your NOS teaching? And, how did their responses make you feel?
12. Thinking ahead to next year, how will you continue to develop your skills and knowledge in the teaching of the NOS?
13. Reflecting on the year what has been the most important thing you have learnt?
14. Is there anything else you have found out over the last two terms, or not already mentioned that you want to share?

Appendix E(iii): Third Interview Questions

1. How has your content knowledge of the Nature of Science changed over the last 18 months?
2. How has your pedagogical approach to teaching science changed over the last 18 months?
3. How do you think your pedagogical approach to teaching science links to your content knowledge of the NOS?
4. When I interviewed you at the end of last year, you stated that your confidence levels for teaching the NOS had taken a bit of a drop. You described feeling confident helping your colleagues, but realised that you now knew what you didn't know. How would you describe your current confidence level in teaching the NOS?
5. What has influenced this the most, and why?
6. What have you noticed about student engagement in science since you applied a NOS lens to your science teaching?
7. What relationship do you see between student success and a teacher's ability in teaching science?
8. What do you see as the key advantages of participating in a combination of three science PLD opportunities?
9. This year you lost the support of the Royal Society and the MOE funded PLD. What impact has this had on your science teaching, both knowledge and pedagogy?
10. How important do you think school support is when you are involved in PLD, like you have been?
11. Reflecting on your STLP experience, your time working with the MOE facilitator, and your participation in the Kāhui Ako STLP network, what had the greatest impact on your learning, and why?
12. What have you learnt about yourself personally and as a teacher, during the last 18 months as a result of your involvement in the science PLD?
13. Is there anything else we have not discussed that you would like to raise?

Appendix F: Thematic Maps

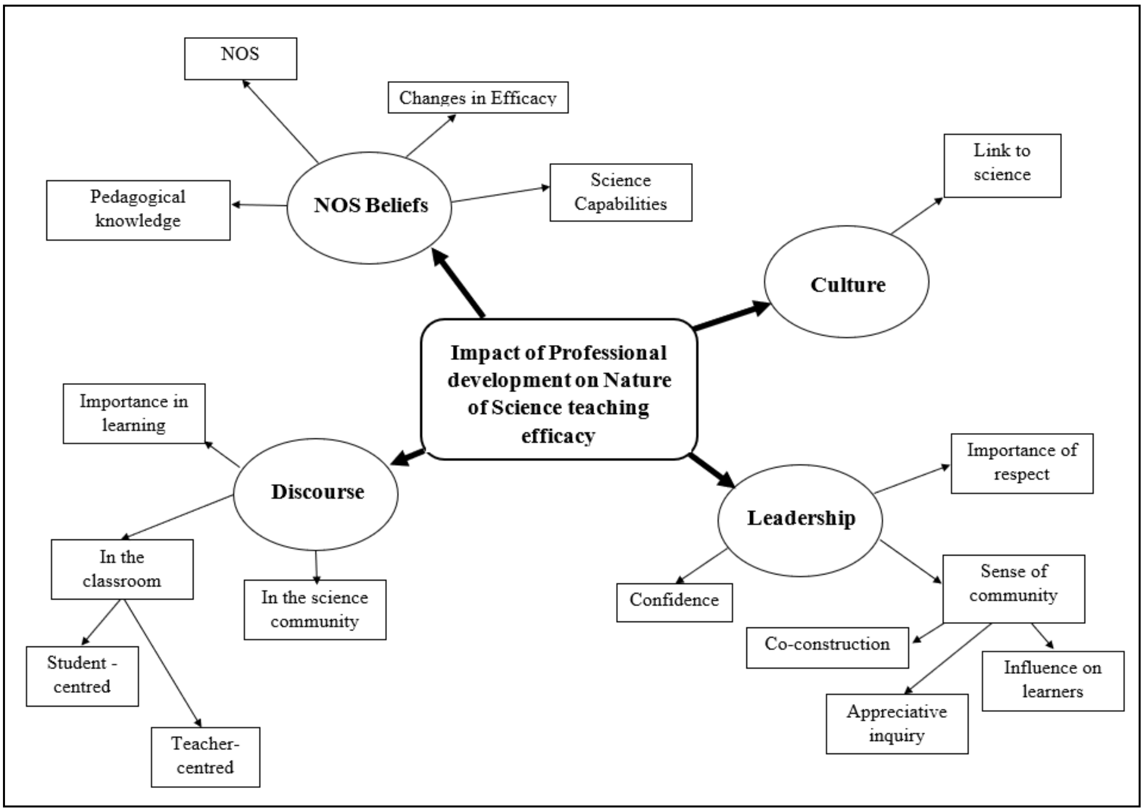

Figure F1. Thematic Map One from Interview 1.

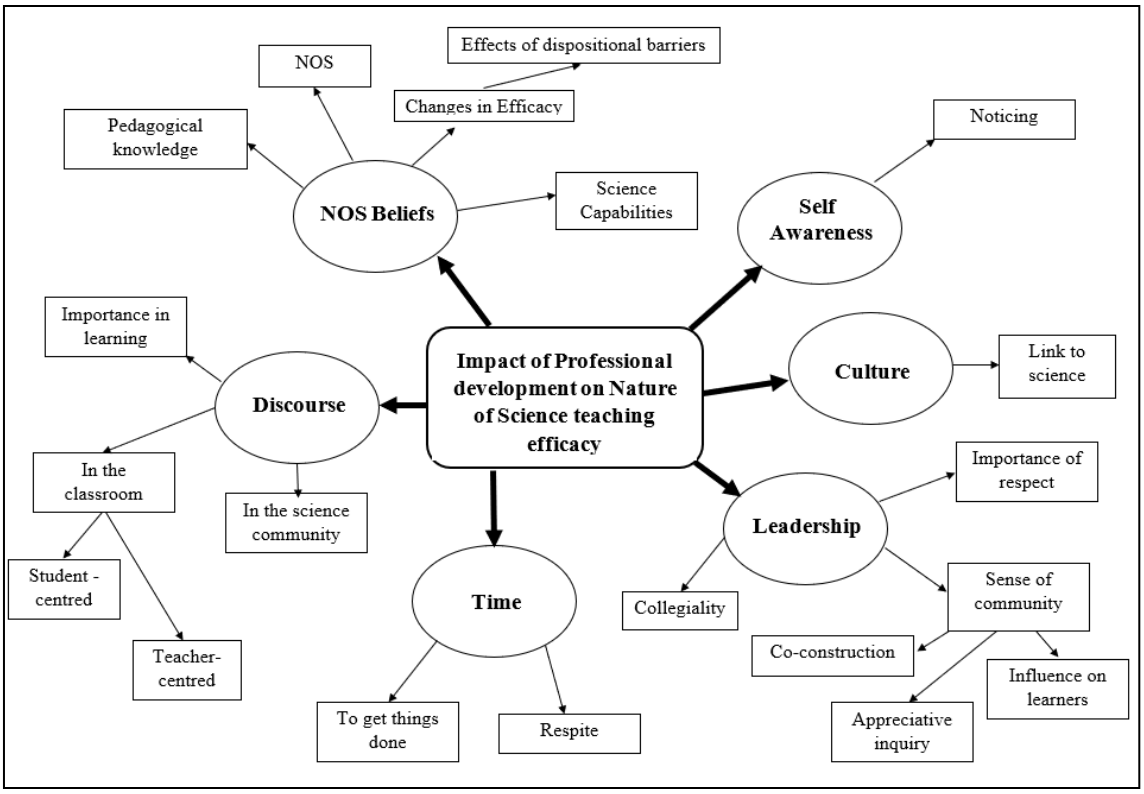

Figure F2. Thematic Map Two from Interview 1 and 2.

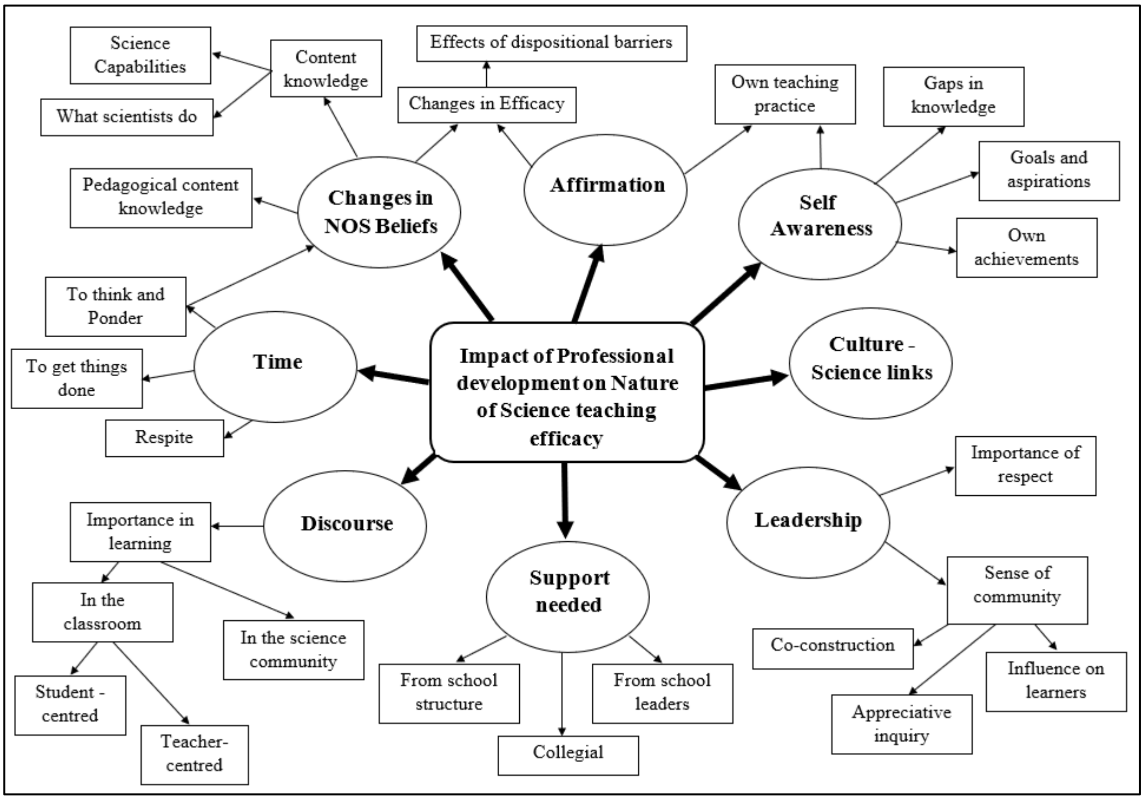

Figure F3. Thematic Map Three from Interview 1, 2 and 3.