

**Building Nature of Science: Professional development
model to enhance teaching practice**

Kathleen I. Rice

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Abstract

The Nature of Science (NoS) has been introduced in the New Zealand Curriculum for English-medium teaching and learning in years 1 - 13 (Ministry of Education, 2007) as the overarching strand through which the contexts of science are developed. This new focus for the teaching of science in New Zealand schools raises the issue of how well developed teachers' understanding of the NoS might be and how to best address the professional development needs of teachers to build this aspect. This study began by exploring the NoS understanding of a sample of teachers, and the results indicated the need for upskilling. A design-based research methodology was used to develop a professional development intervention which was trialled with three groups of teachers. Evidence from participants in the trials showed increased NoS understanding and increased use of activities to develop students' NoS capability in their teaching practice.

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more teachers incorporate approaches to develop the teaching of science through the Nature of Science.

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Glossary of Key Terms

A number of key terms are used in this research. For some terms an abbreviation is provided that is used throughout this thesis after the first presentation of the full term.

Term	Abbreviation	Definition used in this thesis
Behaviourism		Theoretical approach to education that isolates behaviours: their antecedents and consequences in order to manage them (Mutch, 2005, p. 216). Leads to the implication that teachers control the learning process for students.
Best Evidence Synthesis iteration	BES	A synthesis of the available international evidence about a particular aspect of education eg leadership, student achievement, effective professional development. The purpose is to create a shared body of professional knowledge to inform educators' practice. The term "iteration" indicates that the BES will be updated as further information becomes available.
Co-construction		A process of collaborative learning in which two or more people collaborate to jointly construct new knowledge.
Community of practice	CoP	The complex network of relationships within which teachers participate, usually for the purpose of promoting professional learning.
Conceptual framework		A foundation of factual and conceptual knowledge that is organised in ways allowing the retrieval of prior understandings and the integration of new information.
Constructionism		Constructionism is a theory of learning, about the way knowledge is constructed that places emphasis on developing concepts, through a series of active processes, resulting in new ideas being incorporated

		within existing mental models and by refining existing conceptual frameworks. (Crotty, 1998). The theory has been restricted from a science education perspective to work which examines knowledge construction by scientists in laboratories (Hruby, 2001).
Constructivism		A theory of how individuals construct knowledge for themselves from the premise that any new knowledge involves their mental processes so that they acceptably describe and explain the world in light of current considerations (Skamp, 2004, p. 11).
Content Knowledge		Knowledge of the facts, concepts, theories, structures, practices, and beliefs associated with a particular learning area.
Dissonance		The sense of disequilibrium that is created when a learner is confronted with information that challenges their existing ideas, theories, values, or beliefs. Research shows that learners are usually keen to resolve this situation, either by rejecting the new information or by making fundamental changes to their previous beliefs and understandings.
Engaging teachers' theories (of practice)		The process of helping teachers to reflect on their existing theories of action and consider their adequacy so that they can then negotiate, with others, the meaning of new information. Also referred to as engagement with prior knowledge.
Explicit knowledge		Knowledge, ideas, and beliefs that are clearly articulated.
External expert		A provider of professional development who brings expertise from outside the participants' immediate environment.

Humanist view of learning		Belief that individuals make personal choices and decisions that shape their own lives, therefore each student is in control of their own learning process.
Inquiry-based approach		An approach to learning that is based on constructivist and co-constructivist theories of learning. Constructivist theories are based on the belief that learners actively construct meaning for themselves and with others by questioning, thinking critically, and solving problems.
Knowledge base		The complex set of facts, theories, concepts, and beliefs that an individual acquires over time through thinking about new information and using it to make decisions and solve problems.
Mean	M	The mean of a set of scores is the sum of the scores divided by the number of scores. The term “average” is sometimes used instead of mean.
Metacognitive		Metacognitive knowledge, skills, and strategies are those that enable a person to think about and regulate their own thinking and learning. They include reflecting, self-monitoring, and planning.
Methodological approach		A term used to describe the practice and procedures used in carrying out an inquiry.
National Certificate of Educational Achievement	NCEA	Assessments introduced as New Zealand’s main secondary school qualifications between 2002 and 2004, replacing School Certificate, University Entrance, Sixth Form Certificate, and University Bursary qualifications. A range of subject-specific assessments that establish standards for national qualifications that recognise a wider range of skills and knowledge, and provide greater flexibility in teaching and learning, while maintaining consistency in assessment

Nature of Science	NoS	The portraying of science as a way of knowing, including the values and beliefs inherent to the development of scientific knowledge. This views NoS as distinct from science as a body of facts. (Lederman & Neiss, 1997, p. 1). There is no consensus on what constitutes NoS, but some key aspects for students are defined internationally (Duschl & Osborne, 2002, p. 40).
New Zealand Curriculum	<i>NZC</i>	The revised curriculum for English-medium New Zealand schools, released in October 2007, is a statement of official policy relating to teaching and learning. Its principle function is to set the direction for student learning and to provide guidance for schools as they design and review their curriculum. Mandated February 2010.
New Zealand Curriculum Framework	<i>NZCF</i>	The previous curriculum, implemented from 1992 onwards, was New Zealand's first outcomes-focussed curriculum: a curriculum that sets out what students should know and be able to do. Not mandated.
Pedagogical content knowledge	PCK	Pedagogical content knowledge refers to the ability to transform content knowledge in such a way that it is effectively communicated between teachers and students as learners in the classroom (van Driel, Verloop, & de Vos, 1998).
Pedagogical knowledge	PK	The science of teaching with the understanding that teachers need a wide repertoire of approaches relating to organisation, teacher talk, and learning talk to enable effective learning outcomes for students (Alexander, 2005).
Pedagogy		The processes and actions by which teachers engage students in learning.

Professional community of practice		According to the <i>Teacher Professional Learning and Development: Best evidence synthesis iteration (BES)</i> , a professional community of practice is one whose members support each other to process new understandings and consider their implications for teaching.
Professional development	PD PLD	The intentional, ongoing, systemic process designed to build the pedagogical content knowledge, skills, and attitudes of educators to provide better learning outcomes for students (Guskey, 2000). The term currently used by Ministry of Education is Professional Learning Development (PLD).
Professional learning		This is a broad term to describe an internal process by which individuals create professional knowledge.
Scaffolded support		Temporary, structured support designed to move learners forward in their thinking.
Scientific literacy		The capacity to use scientific knowledge, to identify questions, and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity. (OECD, 1998)
Social constructivism		Theory of learning that argues the “importance of the social contexts within which the activities are embedded and that these activities are inseparable from the learning to be derived from them, leading to improved student learning when associated with teachers thinking about the students they teach as a community of learners”. (Skamp, 2004, p. 15)
Sociocultural theory		The theory advocates that “activities do not exist in isolation, but are part of broader systems of relations, social structures, in which they have meaning” (Nasir & Hand, 2006, p. 449).

Socio-scientific issues		Learning topics which motivate students to explore the nature of scientific knowledge and the interdependence between science and society (Sadler & Zeidler, 2004).
Standard deviation	SD	A measure of how spread out a set of data is. It compares the data to the mean. If all the observations are close to their mean, then the standard deviation will be small.
Student outcomes		The stated objectives for a sequence of teaching and learning. Valued student outcomes can include personal, social, and academic attributes. It is important to measure how effectively the teaching and learning programme impacts on a range of student outcomes.
Tacit knowledge		Knowledge, ideas, and beliefs that are built up over time through experience or personal training. It is internalised, routine, and difficult to communicate; in fact, the holder of the knowledge may not be aware of it. Tacit knowledge is an important part of an individual or community's knowledge base, but it can also be a barrier to change if it remains unidentified and unexamined.
Teacher outcomes		The stated objectives for participation in professional learning. Effective professional learning brings about changes in teacher's practice that impact positively on student outcomes.
Theoretical framework		A structure of concepts and theories that provide a map to guide thinking, research, and action.
Theoretical principles		A set of principles that is used to explain the links between related concepts, facts, or phenomena, especially a set that has been repeatedly tested or is widely accepted.

Theories of practice		Theories of practice comprise a teacher's personal beliefs and values, the knowledge, skills, and practices that follow from them, and on which their classroom practice is based.
Theory		A set of related concepts that have been structured to explain, interpret, and predict behaviour.
Vision		A set of goals, targets, or opportunities about how teaching might impact on student outcomes.

Chapter 1. Introduction

1.1 Introduction to the study

In 2007 the Ministry of Education released the *New Zealand Curriculum for English-medium teaching and learning in years 1 - 13 (NZC)* (Ministry of Education, 2007). The curriculum details concepts important for today's students and provides a framework for teachers outlining the characteristics of effective and engaging teaching programmes. The *NZC* is a mandated document that identifies specific elements of principles, values and key competencies that must be developed alongside each of the eight learning areas in a school's teaching and learning programme (Ministry of Education, 2007). The *NZC* document is the outcome of the revision of the curriculum documents developed under the *New Zealand Curriculum Framework (NZCF)* (Ministry of Education, 1993a). The *NZCF* document prescribed the schools' curriculum and set out directions for learning within New Zealand schools focussed on improved learning outcomes for students. The *NZCF* was not mandated, but instead led to development of individual curriculum documents for each learning area that were released progressively as a means of addressing the *NZCF* principle concepts.

The previous 1993 *Science in the New Zealand Curriculum* (Ministry of Education, 1993b) document supported the *NZCF* concepts and contained two integrating strands: Making Sense of the Nature of Science and Technology; and Developing Scientific Skills and Attitudes, as well as the same four contextual strands (Living World, Material World, Physical World, and Planet Earth and Beyond) found in the *NZC*. Although these "integrating strands were intended to be explicitly taught and to be interwoven with the contextual strands" (Ministry of Education, 1993b, p. 14), little evidence of this occurring in classrooms was evident, and they were more generally taught as "add-on to a traditional science course" (B. Bell & Baker, 1997, p. 181). Although the 1993 *Science in the New Zealand Curriculum* shared some of the

elements of the *NZC* Nature of Science (NoS) strand, the descriptors related to few internationally recognised aspects of the NoS. The revised *NZC* explicitly brings the role of the NoS to the forefront of science teaching in providing students with “a way of investigating, understanding and explaining our natural, physical world and the wider universe” (Ministry of Education, 2007, p. 28). The NoS has been introduced as the “overarching, unifying strand”, and the “required learning for all students up to year 10” and the NoS “outcomes are pursued through the ... major contexts in which scientific knowledge has developed and continues to develop” (Ministry of Education, 2007, pp. 28-29). This is a new focus for the teaching of science in New Zealand schools, and raises the issues of:

1. How well developed teachers’ NoS understanding is?
2. How to build teachers’ NoS capability through professional development programmes?
3. Whether professional development on the NoS can impact on teachers’ classroom programmes and increase both teacher and student NoS capability?

1.2 Statement of the problem

The implications of the *NZC* for science teaching programmes and teacher practice must be clearly understood, so that programmes addressing the introduction of the NoS to the science learning area in a school’s curriculum are underpinned by relevant thinking and planning. The introduction of the *NZC* exposed the need for teachers to have a clear understanding of the NoS and raised the question of what professional development approaches were required to enable teachers to implement programmes that developed the required aspects of the NoS with their students (Ministry of Education, 2007). Consequently, any professional development programme for science teachers is likely to need to challenge teachers’ existing

beliefs about science (Abd-El-Khalick & Lederman, 2000). In addition, bringing the NoS to the forefront of science learning highlights the dilemma Timperley, Wilson, Barrar, and Fung (2007) acknowledged concerning the identified chain of influence from professional development provider, to teacher, to classroom practice to enhanced student outcomes. Teachers must understand both the perspective of the *NZC* and what constitutes the NoS so that they can build the NoS capability in their students. If science teachers perceive their role only as transmitters of science knowledge consisting of established facts and techniques, then the *NZC* focus on developing students' ability in the NoS is incongruent with their beliefs (Abd-El-Khalick & Lederman, 2000; Bartholomew, Osborne, & Ratcliffe, 2003).

1.3 Background to the *New Zealand Curriculum*

Over the last thirty years there has been considerable debate internationally among science education researchers regarding both the intent and the purpose of school science and what should be taught to the students of the times. Much of that debate has centered on the “nature of science and the relationships between science, citizenship and the public understanding of science and interactions between school science and its problems with scientific literacy” (Scanlon, Murphy, Thomas, & Whitelegg, 2004, p. xiii). The outcomes from this debate have been the ongoing revision of school science curricula worldwide, commencing in the 1990's with a focus on incorporating “citizen thinking or citizen science” through incorporating socio-scientific issues into curriculum content, resulting in science course titles such as “Science, Technology and Society” and “Science for All” (E. W. Jenkins, 2004, p. 19). Such courses were introduced in Wales, England and the United States and in developing countries including India, Thailand and Bhutan (Coll & Taylor, 2012).

Alongside the recognition of the need to reform the “very traditional science curricula of the era up to the 1980s” was the incorporation of learner-centred or constructivist approaches to the evolving curricula, with an outcomes focus (Coll & Taylor, 2012, p. 773). Such

approaches to teaching and learning require a change in assessment from external, summative, highstakes examinations, which in the New Zealand situation did not occur for nearly 10 years. Internationally, the approach to professional development following the introduction of a constructivist based curriculum has been primarily through “one-off teacher professional development workshops run by government appointed officials shortly after the introduction of the new curriculum” (Coll & Taylor, 2012, p. 774). Such professional development has been shown to be inadequate comment Coll & Taylor (2012), with didactic teaching retained and some surface changes to address expected learner-centered approaches..

Accompanying the introduction of socio-scientific issues (SSI) as a major curriculum focus was the perception that through this approach to science students would become aware of local issues relating to personal health, hygiene and the need to improve and employ sustainable practices that “could improve standards of living by enhancing economic development” (Coll & Taylor, 2012, p. 773). At the time of the curriculum revisions little research on the effectiveness of the reform and impact on student learning was conducted. However more recently a number of researchers have described the results of focussed teaching using relevant SSI contexts leading to the assertion that use of such themes generates increased “student interest and motivation to learn science... compared to students engaged in more traditional approaches” (Troy D. Sadler & Dawson, 2012, p. 807). The other important finding noted by Sadler & Dawson (2012) is that use of SSI contexts increased student understanding of NOS and science as argumentation.

As a result of the focus internationally on increasing students’ scientific literacy, learning programmes were devised that incorporated activities designed to provide students with opportunities to “develop and practise scientific process skills (i.e. the “scientific method”) associated with accepted scientific knowledge...for students to engage in hands-on activities and discover the natural world for themselves” (McGinn & Roth, 2004, p. 99). Such

approaches were employed due to the conviction that through acting as real scientists, students would learn scientific concepts. However this conviction was based on the erroneous and mythical premise that scientists were special people with unique mental powers, highly competent at solving problems, and utilising advanced scientific process skills (McGinn & Roth, 2004). This misconception resulted in the need to acknowledge the limitations of the scientific method as described in many school science curricula as identified by Shemwell, Fu, Figueroa, Davis, and Shavelson (2010). The key idea emerging from this discourse was that the scientific method as such is a myth. In fact the research process follows different lines and approaches in a case by case manner dependent on the scientists, the assistants, the funding, the equipment and the physical and social resources, but most importantly the outcomes are influenced by scientists' reasoning based on social, cultural, material political and economic factors (McGinn & Roth, 2004). This led to science educators realisation that the focus needed to be on developing students understanding of the NoS and scientific inquiry as well as science as discourse. This resulted in a change in curriculum direction to embody NoS and science as argumentation as well as the a broader focus on the scientific inquiry process (McGinn & Roth, 2004; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003).

Jenkins (2004) suggested that the revision of school curricula occurring in many countries at the end of the twentieth century was a response to the existing "form and content of school science education" (p 13). As part of the review process he makes the assertion that one of the purposes of science education is to produce citizens who are scientifically literate and informed in scientific processes and scientific thinking. He also suggests that much of the scientific knowledge shared within school science curricula is unnecessarily complex and too sophisticated for the purpose of scientific literacy. Jenkins proposes that the science students experience in school needs to provide them with the wisdom that science seeks to explain and incorporate uncertainty in its explanations of the world rather than seeking to control the world. Such an approach requires open-mindedness when addressing science problems

relating to socioscientific issues and problems so students recognise that science knowledge is the result of creative, imaginative processes. In this way Jenkins (2004) identifies the need for science curricula to enable students to distinguish between “knowledge and action” and give “less attention to the minutiae of established physics, chemistry and biology in order to make way for consideration of issues where the science is less than secure or controversial” (p19). These aspects identified by Jenkins (2004) as being essential within school science curricula embody some of the NoS concepts accepted internationally as fundamental to develop within school science (Fouad Abd-El-Khalick, Bell, & Lederman, 1998). A uniform aspect in the reform of science education internationally has been the incorporation of NoS learning within the curriculum, yet Allchin (2010) suggests this focus has been poorly supported in providing science educators with “practical, culturally functional knowledge of NoS” (Kali & Linn, 2010, p. 519) and of ways to assess this NoS capability in students.

In the last ten years a growing body of science education research has focussed on ways to develop both NoS understanding and engagement in science as argument as part of the discourse of science. A series of papers in Part V11 of the *Second International Handbook of Science Education* (2012) present a summary of the research on argumentation and the NoS and conveys the key messages on the current direction of science curriculum development. Milne (2012) concludes that “an exclusive focus on (science as) argument separates science from its social and cultural dimensions...and (will) reinforce for students the exclusory nature of science” (p. 964). She advocates that scientific argument, NoS and use of narrative explanations, where students make connections between their life experiences and their science knowledge, all have a place within the science classroom along with observations and exploration of everyday phenomena. On the other hand Osborne (2012) advocates that engagement in scientific argument provides recognition for students’ thinking and reasoning and contrasts with the more readily accepted view of science as a body of knowledge that must be transferred from teacher to student. He does stress, however, the need for teachers to

develop theoretical and pedagogical knowledge of science argumentation as well as the understanding of its role within NoS before implementing argumentation in their classrooms (Osborne, 2012).

The *NZC* is the culmination of an extended period of curriculum review and design in New Zealand that essentially commenced with the *Curriculum Review of Science* in the 1980's (B. Bell & Baker, 1997). Extensive curriculum redesign, following public consultation in the 1980s, led to the release in 1993 of the *New Zealand Curriculum Framework (NZCF)* with its focus on teaching outcomes, representing a major shift from the content driven nature of previous curricula. The science curriculum for New Zealand schools has progressively focussed on process skills, "children's science" views, individual "sense making" or constructivist views of learning, to social constructivism and building scientific concepts and literacy through the NoS over the last forty years (B. Bell, 2005; B. Bell & Baker, 1997).

The foreword of the 1993 *Science in the New Zealand Curriculum* stated that learning in science should use contexts "meaningful to students and which lead to understanding of the interrelationship of science, society and technology" (Ministry of Education, 1993b, p. 5). This concept is further expanded in the Introduction (p. 7) which stated that "our dependence on science and technology demands a high level of scientific literacy for all New Zealanders and requires a comprehensive science education for all students". Thus the inclusion in the *Science in the New Zealand Curriculum* of the integrating Making Sense of the Nature of Science and its relationship to Technology Strand (Ministry of Education, 1993b) could be seen as reflective of the international emphasis on citizen science and the accompanying need to develop scientific literacy through school science.

In addition, the 1993 *Science in the New Zealand Curriculum* document (Ministry of Education, 1993b) outlined policy for teaching, learning, and assessment to cater for differing learning needs, as well as identifying essential knowledge, skills, principles, values, and

attitudes needed to enable students to become responsible citizens in society. Specific learning goals and achievement levels were defined for core learning areas of English, Mathematics, Science and Technology. This outcomes and standards-based curriculum defined the high expectations sought as outcomes to be shown by students at the end of their schooling, but it did not, however, define the teaching techniques or time allocation, which was left to teachers (Hargreaves, Earl, Moore, & Manning, 2001). Professional development was provided following the release of the *Science in the New Zealand Curriculum* in 1993 to support teachers to implement the intended constructivist approach of the *NZCF* (B. Bell & Baker, 1997). Schools focussed on developing learning programmes closely linked to the achievement objectives in the four worlds of the *Science in the New Zealand Curriculum* (Living, Physical, Material Worlds, and Planet Earth and Beyond) rather than in the two integrating or process strands identified in the curriculum statement (Making Sense of the Nature of Science and its relationship to Technology, and Developing Scientific Skills and Attitudes). Consequently, narrow, content-driven programmes of little interest to students were developed by teachers obsessed with checking off each achievement objective that was covered during the year (Rennie, 2006). This content focussed teaching was partially the result of Education Review Officers checking school programmes to ensure achievement objective coverage. Such reviews strengthened teachers' use of a behaviouristic approach, resulting in programmes with a focus on the content and facts that the teacher believed necessary for students to acquire, but of little interest to students (Aikenhead, 2006; Rennie, 2006). The behaviourist approach views students as only becoming intelligent in proportion to the volume of information supplied and learnt, with the teacher being the key for knowledge transfer to students (B. Bell, 2005). Classroom practice emphasised mastery learning, leading to highly diagnostic, prescriptive teaching, although sometimes modularised instruction was used (Bybee, 2006). The *NZCF* suited a behaviourist approach due to teacher perception that the focus was on achievement objectives within curriculum areas. English and

Wood (1997) expressed concern that “the separation of science skills and attitudes (science methodology) from science concepts may result in a restricted definition of procedural knowledge by teachers” (p. 67). In addition they perceived that the *Science in the New Zealand Curriculum* sought to integrate the processes and skills of science and concepts within the Nature of Science and technology. However, they identified that the separation of the skills and attitudes into a separate strand led to teachers creating an artificial separation that led to content and skills being taught as discrete knowledge, failing to integrate the two, and often completely ignoring the Nature of Science and technology strand. An additional observation was that experimental work was seen to emphasise conceptual knowledge without providing the procedural knowledge needed by students to carry out the practical skill. To overcome this, English and Wood (1997) suggested the need for professional development to change teacher focus and place greater emphasis on “developing both processes and concepts together so that students were able to develop their procedural knowledge of questioning ... and the multiple purpose of practical work” (p. 78). The *New Zealand Curriculum Stocktake* verified their concern within the range of considerations presented for science which needed to be addressed in the revision of the *Science in the New Zealand Curriculum* (Ministry of Education, 2002).

In contrast to the *NZCF*, the *NZC* provides a well defined account of what respondents to the consultation and review of the *NZCF* viewed as being important for twenty-first century learners. It provides a vision for students of lifelong learning through school-based curriculum encompassing the eight learning areas and responsive to students’ needs, yet based on clear outcomes for students (Ministry of Education, 2007). Essentially the *NZC* sets “the direction for student learning” and provides “guidance for schools as they design and review their curriculum” (Ministry of Education, 2007, p. 6). This function was not part of the *NZCF*. As the *NZC* is underpinned by both social-constructivist and sociocultural theories, it

prioritises the development of processes within each of the eight Learning Areas rather than the content sharing and assessment that resulted from teachers' interpretations of the *NZCF*.

The *NZC* shows the impact of six ideologies of student learning identified by Eisner (1984). These ideologies are rational humanist, religious orthodoxy, progressivism, critical theory, reconceptualisation, and cognitive pluralism, and set the scene for a student-centred curriculum design by individual schools to address the needs of their learners (Eisner, 2002). Such a design would focus “students on taking responsibility for their own learning” (p. 582) and enable the vision of lifelong learners of the *NZC* to be realised (Eisner, 2002).

Inclusion of the “Effective Pedagogy” section with its focus on “teacher actions that promote student learning” (Ministry of Education, 2007, p. 34) reflects the impact of constructionism on the development of the *NZC*. This is a new direction for curriculum in New Zealand, as it provides direction on teaching and learning practices not seen in previous curriculum documents. In addition, the *NZC* provides a “clear set of principles on which to base curriculum decision making” (Ministry of Education, 2007, p. 4) as well as values and key competencies that emphasise the importance of learning for life. All these impact on the considerations teachers need to make when designing programmes to address the science learning area and the *NZC* intent.

1.4 Purpose of the study

The purpose of this study was to examine selected science teachers' existing understanding of NoS in the Southern region of New Zealand, using an internationally accepted survey, the Nature of Science as Argument Questionnaire (NSAAQ) (Sampson & Clark, 2006), and then design a professional development programme to address any identified lack of NoS understanding. Analysis of data from this survey provided information on the NoS concepts to be included in the design of a professional development intervention. This design was

constructed and trialled with three clusters of Year 1 - 10 teachers in the Southern region of New Zealand using design-based research (DBR) methodology (Collins, Joseph, & Bielaczyc, 2004). The study drew on constructivist learning theory in producing the design of an intervention to use with the clusters. Participant feedback on the intervention was provided from their reflections in journalling and in group meetings, as well as a pre and post intervention use of the NSAAQ survey to assess any change in their NoS understanding.

The challenges of curriculum reform were identified in research on the development of collaborative curriculum decision-making with a group of New Zealand schools in the 1990s. This research emphasised the need to address key conditions around the change process to ensure success (Ramsay, Harold, Hill, Lang, & Yates, 1997). The *NZC* changes are as complex as those that occurred with the *NZCF* implementation, where the concept policy-to-practice led to the provision of teacher development alongside the curriculum introduction (B. Bell & Baker, 1997). The implementation of the changed focus of the science learning area of the *NZC* requires teachers to reflect on and reassess the processes focussed on in science teaching and learning programmes. Such reflective practice involves school management in recognising, addressing, and planning approaches to overcome teacher resistance to change, while complying with Ministry requirements around the annual charter review.

The teacher assumes a definitive role as the agent through whom the content and intent of the science learning area of the *NZC* is implemented and enacted in classroom programmes (Davis, 2007). Teachers should identify and adopt the new thinking behind the *NZC* so they can transform their practice to address this, rather than simply using the terminology while maintaining their traditional practice (Spillane & Zeuli, 1999). Only in this way will their classroom practice change. Decisions about content may change little, but their teaching should reflect the principles, values, and key competencies, as well as developing the processes outlined in the NoS in the *NZC*.

An understanding of the theoretical underpinnings of the *NZC* is important for teachers as they seek to implement its intent. The *NZC* closely aligns with constructivist or humanistic teaching approaches, while the introduction to the science learning area identifies with social constructivism and sociocultural theory (Skamp, 2004). Consequently, a teacher's ability to address the *NZC* and the intent of the science learning area will depend on the theory underpinning their teaching methods (B. Bell & Baker, 1997). If the teacher relates to the humanistic learning approach, the teacher identifies their students' interests and concerns, and uses these to help students link, develop and build on existing ideas to develop a deeper understanding of the context (B. Bell, 2005). Such a teacher provides an environment where students are supported to manage their own learning in order to become independent, self-directed, creative learners who have developed the skills that can lead to them becoming "confident, connected, actively involved and lifelong learners" (Ministry of Education, 2007, p.8). Similar approaches will be evident when a teacher follows the constructivist approach in the classroom, where experiences are provided to help students actively generate meaning and absorb new ideas (B. Bell, 2005). In providing for social constructivism, the social context of the activities is important and linked directly to the learning itself, so that the teacher provides a learning situation that enables students to move from an everyday culture to a scientific culture in their studies in science (Skamp, 2004). To build students' thinking and their scientific concepts requires effective scaffolding of student learning through the provision of a wide range of scientific experiences within the NoS (Skamp, 2004). Such approaches have been advocated in science teaching philosophy over many years, but have become lost in science teaching where the focus on sharing the facts of science has become more prevalent in schools (Charles, 1976; Rennie, 2006).

If a teacher has been using any of these humanist or constructivist approaches, the changes they will need to make to implement the *NZC* will be minor and gradual first-order change according to Marzano, Waters, & McNulty's (2005) descriptors, as the change will require

modification of previous work patterns but will fit “within existing paradigms” (p. 113). If the teacher has been using a behaviourist or teacher-directed approach, the change required will be greater and may need second-order change management which according to Marzano et al. (2005), requires totally “breaking with past practice, outside existing paradigms and conflicts with prevailing values and norms” (p.113). Therefore, priority must be given to supporting teachers through the change process as they endeavour to transform their practice to a humanist or constructivist approach in implementing the *NZC*.

Science teachers could have a challenge implementing the intent of the science learning area of the *NZC* with the focus on incorporation of the scientific processes of the NoS into teaching and learning programmes, rather than solely transmitting scientific knowledge. If a teacher is committed to positivist approaches to science teaching involving the “unity of science and a single scientific method” (Levin, 2010, p. 347) incorporating the scientific processes described in NoS will conflict with existing personal theoretical perspectives. Unless science teachers adequately engage with the intent of the *NZC*, an emphasis on school-based curriculum design to address the needs of the learners in their classrooms could show a mismatch between their pedagogy and the demands of the the science learning area and the *NZC*.

Many of the science teachers I have worked with as a Science Facilitator on the implementation of the science learning area do not appreciate the intent of these *NZC* changes. They favour behaviouristic approaches where content is prioritised through a didactic teaching model, often at the expense of pursuing scientific investigation and discussion of science ideas. This has resulted in the sharing of decontextualised content knowledge, exclusion of practical work, failure to link science to students’ lives and has led to disengaged students who see no relevance in learning science (Rennie, 2006). Such teaching supports the traditional views of a science knowledge that is proven, provides the right

answers, and is based on the truths of science that are discovered by accurate observations, experimentation, and objective data which is used to provide common sense responses to explain the world (B. Bell & Baker, 1997). To change such practice and bring about a focus on the NoS and scientific processes will require significant change in both thinking and teaching priorities or what has been described as a change from a form to a function focus (Spillane, 2000). The argument is that if science programmes are developed around themes of interest to students, contextualised and using the big ideas behind themes, then student engagement will increase alongside their capability for scientific investigation and communication. Trialling such approaches in Australia resulted in increased student motivation and interest in science, using themes developed through student input rather than predetermined by teachers (Rennie, 2006; Tytler, 2007).

Building students' competence in science processes requires a shift in teacher practice. This suggests the need for teachers to analyse their teaching style, identifying its pedagogical and theoretical underpinnings, as well as rethinking their teaching routines, increasing lesson preparation, and altering their existing values structures (Wolk, 2007). Many of the science teachers I work with require support to bring about second-order change as described by Marzano et al. (2005) in their practice. Consequently, this level of the change process would be addressed within a professional development programme that builds teachers' understanding of the underlying principles of the NoS strand. The result would be the development of contextually-based programmes to build students capability in the NoS scientific processes as described in Tytler's model (Tytler, 2007).

In my position as an in-service teacher educator (ISTE), I work with teachers and school management to assist them to implement the *NZC* with particular emphasis on science, and to build sustainable formative assessment practices. From my analysis of the issues facing schools as they implement the *NZC*, three intertwined themes emerge for schools to address as

they seek to provide a school-based curriculum addressing the requirements of the science learning area whilst satisfying the criteria for programmes of learning as set out in the *NZC* document. These aspects of curriculum are mandated so need to be addressed by the Board of Trustees through the staff for all students from year 1 - 13 (Ministry of Education, 2007).

Science programme design should address the three themes: reflecting the principles, values and key competencies; using effective pedagogy; and addressing the NoS as the required learning in science. This requires teachers to engage in identifying the concepts underpinning the *NZC* principles, values, and key competencies, so that the learning area programmes develops these (Ministry of Education, 2007). Teacher practice should incorporate the aspects of effective pedagogy which “create a supportive learning environment, encourage reflective thought and action, enhance the relevance of new learning, facilitate shared learning, make connections to prior learning and experience while providing sufficient opportunities to learn” (Ministry of Education, 2007, p. 34). Building and sustaining such teacher practices may require appropriate change management processes. Science teachers need to discuss the science learning area introduction of the *NZC* to develop a shared understanding of the intent of the focus on the NoS so they are able to address the development of scientific processes within the learning programmes developed for the school. These themes hold equal weighting for sustainable change to occur in teachers’ thinking and in school-based curriculum design.

The researcher’s role as a Science and Curriculum Adviser involved supporting school management in managing the change process required by science teachers to facilitate shifts in pedagogy and curriculum so that science teachers were able to address the *NZC* intent. This was a key to the intervention process and included ensuring Marzano et al’s (2005) change management concepts were incorporated within the intervention. Therefore, the professional development intervention had to be adaptive and responsive to differing needs of

individual schools, departments, and teachers, and required the commitment of the school management to implement the *NZC* intent in the school's Science Teaching and Learning Programme (Marzano et al., 2005).

1.5 Significance of the study

With the launch of the 1993 *Science in the New Zealand Curriculum*, professional development was planned alongside its introduction due to the existing policy-to-practice approach at that time (B. Bell, 2005). The programme provided by the Ministry of Education to support the implementation of the *NZC* from 2007 to 2010 had minimal focus on the learning areas. The current research provides evidence of the existing level of teacher understanding of the intent of the science learning area as described in the *NZC* to provide programmes that develop students' NoS understanding through the contextual strands (Ministry of Education, 2007). In addition, it provides a design for a professional development programme to support development of teacher understanding of the NoS as outlined in the *NZC*.

This research will contribute to:

1. The work of New Zealand Ministry of Education Curriculum Facilitators and School Support Services Science Advisers by providing insight into a group of New Zealand teachers' perceptions of the NoS and its place within the *NZC*.
2. New Zealand School Support Services Science Advisers by providing them with information on formats for planning professional development designed to develop teachers' ability to address science learning area requirements of teaching science contexts through the NoS strand of the *NZC*.

3. International Science Education research by adding to research on programmes and questionnaires as tools to develop the NoS capability in teachers and students from the New Zealand viewpoint.

1.6 Research questions

The overarching research question was developed as a result of reflection on the review of literature and observation of ways the science learning area was being implemented in schools through my work as a Science and Curriculum Adviser in the Southern region of New Zealand. Research of selected literature pertaining to curriculum implementation and design, professional development, the NoS and learning theories provided stimulus for refinement of the question and development of the underpinning questions.

1.6.1 Overarching question.

How does a theoretical understanding of the NoS attained through a professional development programme facilitate changes in science teaching practice?

1.6.2 Underpinning questions

1. What are teachers' existing understandings of the NoS?
2. How does a targeted in-depth professional development approach build teachers' understanding of the NoS as described in the science learning area of the *NZC*?
3. How is increased NoS understanding evidenced in teacher practice?

1.6.3 Hypotheses

1. A theoretical understanding of the NoS attained through a professional development programme should facilitate changes in science teaching practice because it is designed to challenge teachers' existing theoretical frameworks, present different theoretical models of learning, and build their NoS understanding

through exposing teachers to theoretical, pedagogical and practical activities based on the NoS.

2. Teachers' existing understandings of the NoS may be limited because little emphasis has been placed on this aspect of science in science teacher training in New Zealand prior to 2009, and tertiary science courses have a content focus.
3. A targeted in-depth professional development programme would build teachers' understanding of the NoS as described in the science learning area of the *NZC* because the design would link theoretical, pedagogical and practical activities to challenge existing teacher theoretical frameworks.
4. Increased NoS understanding would be evidenced in teacher practice as teachers increasingly build a theoretical understanding of the NoS that is supported by improved pedagogical content knowledge and ability to effectively incorporate a range of NoS focussed approaches and activities into their science programmes.

1.7 Assumptions of the study

The study pertains to the *NZC* as the *Te Marautanga o Aotearoa* (the national curriculum for Māori medium) goes beyond the scope and limitations of this study. Therefore the prime focus is on building the NoS understanding using international perspectives of the NoS, rather than developing aspects perceived as “Māori Science” (Stewart, 2005, p. 852). It is accepted that all cultures contribute to the accepted international NoS understandings, and that this knowledge and way of thinking has been built up over a long period of time as people of all cultures have sought to explain and rationalise natural phenomena observed in their daily lives.

1.8 Limitations of study

As the sample size is small, the findings are not significant from a statistical perspective, due to the professional development programme having been conducted with three groups of 10 - 12 teachers teaching Science to Year 1 - 10 students from schools in the Southern region of New Zealand. However, although the findings are not generalisable, they could be applied in a similar situation, and provide a prototype for trialling by others engaged in professional development for science teachers that is aimed to build their NoS capability to address the intent of the *NZC*.

1.9 Overview of the thesis

Chapter 2, Literature Review, summarises four themes explored in depth in recent research literature. Part 1 identifies theoretical underpinnings of the *NZC* and its science learning area statement. Part 2 explores national and international perspectives and understandings of the NoS. Part 3 investigates literature on possible professional development approaches to identify those most likely to be effective with science teachers. Part 4 links information from the previous three sections to determine possible approaches and resources to be incorporated into professional development intervention to build science teachers' capability to address the NoS effectively into school programmes.

Chapter 3, Methodology, presents the theoretical model underpinning the research, and describes the method used to collect evidence of the need for professional development on the NoS using the NSAAQ survey designed by Sampson and Clark (2006). The method used to develop the professional development programme in the design-based research approach is also outlined.

In Chapter 4, Results, the analysis of the NSAAQ survey of science teachers in Southern region of New Zealand is presented, and its implications for the professional development programme are identified and discussed. The development of the design of the professional development intervention through three iterations is outlined, together with qualitative evidence from the research participants. Data comparison before and after the professional development intervention using the NSAAQ survey with participants provides quantitative evidence of shifts in their NoS understanding. Three vignettes are used to share teacher reflections on the effectiveness of the design of the professional development on their understanding of the NoS and ability to use this in teaching and learning programmes for their students. The generic design resulting from the research is presented and discussed in comparison to the processes used by other researchers to build NoS ability.

Chapter 5, Findings and Conclusions, considers the analysed data with reference to the three underpinning research questions. Features of the design intervention are summarised and emergent theoretical perspectives from the design research are also outlined. Emerging themes are identified and discussed alongside issues identified from the research process.

Chapter 6 Recommendations, Implications and Identification of Areas for Future Research, shares aspects requiring further investigation and development are presented. In addition, the need for the intervention is clarified and the possibilities for further evolution of the intervention design are raised. Issues arising from the research are discussed and areas for further research identified.

Chapter 2. Literature Review

2.1 Introduction

The introduction of the revised *New Zealand Curriculum (NZC)* in 2007 brought the role of the Nature of Science (NoS) to the forefront of science teaching by providing students with “a way of investigating, understanding and explaining our natural, physical world and the wider universe” (Ministry of Education, 2007, p. 34). For science teachers who perceive their role as transmitters of the established facts and techniques they believe are the essential science knowledge necessary for students to become future scientists, the *NZC* focus on developing students’ ability in the NoS is incongruent with their beliefs (Abd-El-Khalick & Lederman, 2000; Bartholomew et al., 2003; B. Bell & Baker, 1997; Osborne, 2006). Consequently, any professional development programme addressing the revised *NZC* for science teachers will need to challenge their existing beliefs about science in such a way that they understand the perspective of the *NZC* and recognise the requirement to build students’ NoS ability. Given this situation, the question arises as to what professional development approaches will enable teachers to implement programmes that develop aspects of the NoS outlined in the *NZC* with their students. The response to that question is presented in this literature review and is presented in four parts.

Part 1 identifies theoretical underpinnings of both the *NZC* and the science learning area statement and their links with the NoS as described in the document.

Part 2 reviews both national and international perspectives and understandings of the NoS.

Part 3 identifies the professional development approaches accepted by educational researchers as being most effective for teachers, in particular for science teachers.

Part 4 draws together the information from the previous sections to outline professional development approaches and resources effective in developing science teachers' capability to incorporate the NoS effectively into their programmes, while recognising that any professional development will need to challenge their existing beliefs.

2.2 Methodology

This literature review explored both conceptual and empirical papers to build an understanding of the *NZC*, especially the NoS as described in the science learning area of the *NZC*, professional development approaches used in science, and the theoretical stances taken by researchers. Articles were selected from professional journals, conference papers, and Best Evidence Syntheses in Science and Professional Learning using predetermined keywords. To provide this information, a range of search strategies were used to search both New Zealand and international databases, restricting the search to articles published in electronic journals since 1995 to ensure most recent literature was accessed. The keywords and phrases were refined from keywords of articles. Keywords and phrases used were: *Nature of science, scientific processes, professional development, professional learning and science, science concepts, scientific knowledge, scientific understanding, scientific reasoning, communication in science, scientific investigation*. From use of these keywords it became apparent that a number of author names were leading the research into professional development in science or research into the NoS with teachers. This led to a follow-up search of selected authors in specific journals and their institutions to locate further papers. Books and book chapters that were widely referenced in articles were also consulted. The abstract of each electronic article was read to ascertain its relevance to the review questions and if relevant the full article was downloaded, read and assessed using a template adapted by Dr S Sandretto from Goodwyn and Stables (2004) for EdD candidates' use. The literature selected

as relevant for each of the four themes has been critically synthesised in this review to provide both a context and a justification for the study.

2.3 Part 1. Theoretical underpinning of the *New Zealand Curriculum* and Science Learning Area

Within this section, the theoretical underpinnings of the *NZC* are explored through the literature, and its implementation process is linked to the process used with an earlier version of the New Zealand curriculum in the 1990s. The implications for teacher pedagogy and programmes of the introduction of the *NZC* are then identified and discussed using experiences drawn from both New Zealand and overseas. The final section delves into the science area within the *NZC* and the links this has to constructivism and sociocultural theories, and how this might impact on existing teacher practice in science teaching when compared with the intent of the *NZC*.

2.3.1 Theoretical underpinnings of the *New Zealand Curriculum*.

The *NZC* emphasises the development of a rational mind, instilling values, principles and a vision for students for lifelong learning through the provision of programmes that are responsive to students' needs yet based on "Aristotle's three forms of knowledge – theoretical, practical and productive" (McGee, 2006, p. 2). Essentially the curriculum is underpinned by social-constructivist theory as lifelong learners engaged fully with others and modern technologies. Therefore, the *NZC* prioritises the development of processes within each of the eight learning areas rather than the content sharing and assessment that resulted from teachers' interpretations of the *NZCF* (Ministry of Education, 1993a).

In addition, the focus of the "Effective Pedagogy" section of the *NZC* on "teacher actions that promote student learning" (Ministry of Education, 2007, p. 34) reflects the impact of

constructionism through the six aspects identified as essential if school-based curriculum design is to cater for student learning needs. Those aspects identify the need for a learning environment supportive for all students that encourage reflection on their learning, while providing for sharing of learning, as well as experiencing a range of learning opportunities that link to students' prior learning and experiences through provision of relevant contexts. All of these aspects are implicit in constructionist theory as defined by Crotty (1998), for they focus on "the collective generation and transmission of meaning" (p. 58). Consequently, teachers need to review their programmes, and schools need to develop school-based curricula to implement the principles, values, and key competencies as described in the *NZC*.

2.3.2 The *New Zealand Curriculum* implementation.

As the *NZC* changes are complex, the issue for its implementation is for school management to recognise, address, and plan to overcome teacher resistance to change, while complying with Ministry requirements around the annual charter review. The *NZC* specifically stipulates that "schools are required to implement a curriculum that is underpinned by and consistent with the principles, ... the values are encouraged and modelled, ... supports students to develop the key competencies" (Ministry of Education, 2007, p. 44) while providing a learning environment that is supportive and responsive to the needs of individual students within the context of the local community. However, schools need to understand the concepts underlying the *NZC* to develop its intent; also school managers need to appreciate their responsibility in developing their school-based curriculum. Schools require support in this process of review and reflection to ensure their school vision focusses on students, rather than the school or community, also in unpacking their understandings of the principles and values to provide clear definitions and approaches for their curriculum. Similarly, the key competencies must be explored to provide students and teachers with a common language expressing their understandings to share with parents (Hipkins, 2007). Spillane and Zeuli

(1999) suggest these discussions should not take place with senior management and Board of Trustees at a strategic planning retreat, but should involve staff so that all are committed to the school's curriculum. The enormity of curriculum reform was identified in research on the development of collaborative curriculum decision-making with a group of New Zealand schools in the 1990s, emphasising the need to address key conditions around the change process to ensure success (Ramsay et al., 1997).

2.3.3 Implications for teacher pedagogy and programmes.

The implications of the *NZC* for teaching programmes and teacher practice must be clearly understood in order that a school's curriculum is underpinned by relevant thinking and planning. The teacher assumes a definitive role as the agent through whom the content and intent of the *NZC* is implemented and enacted into classroom programmes (Davis, 2007). Thus, teachers must identify and adopt the new thinking behind the *NZC* in order that they transform their practice to address this, rather than simply using the terminology while maintaining their traditional practice (Spillane & Zeuli, 1999). Only in this way will their classroom practice change. Decisions about content may change little, but their teaching must reflect the principles, values, and key competencies, as well as developing the processes outlined in the *NZC* (Carr et al., 1997).

As the *New Zealand Curriculum Stocktake* indicated, curriculum design alone does not result in quality teaching and better outcomes for students, rather, quality teaching is dependent on the interaction of curriculum, pedagogy, and assessment (Ministry of Education, 2002).

The intent of the *NZC* closely aligns with a constructivist or humanistic teaching approach, thus a teacher's ability to address these will depend on the pedagogical content knowledge underpinning their teaching methods (Carr et al., 1997). In a humanistic approach, students are seen as bringing ideas, knowledge, and concepts relevant to the context, with the teacher

facilitating the learning. The teacher identifies their students' interests and concerns, using these to help students link, develop, and build on their ideas to provide a deeper understanding of the context. Also, the teacher provides an environment where students can develop responsible attitudes towards learning, fostering their independence, creativity, and self-reliance through exposure to self-guided learning, including using inquiry and decision-making processes in the classroom (Charles, 1976). Similarly, in the constructivist approach, experiences are provided to help students actively generate meaning and absorb new ideas (B. Bell, 2005; Carr et al., 1997). However, the key focus of learning science is to help students build an understanding of the scientific communities' currently accepted understandings of natural phenomena in the world around them. Students are not simply making guesses about the phenomena from their observations, but rather endeavouring to align their understanding with the scientist's (Jenkins, 2000). This requires both student and teacher to acknowledge the importance of the scientific knowledge of experts, and promotes learning as a social activity that engages the learner, rather than an individual activity, thus recognising the links to social constructivism for the theory of learning in science (Jenkins, 2000).

If a teacher has been using either of these approaches, the changes they make to implement the *NZC* will be minor and gradual, or according to Marzano et al. (2005) descriptors, first-order change. First-order change is identified by Marzano et al. (2005) as change that "extends work engaged in previously and fits within existing paradigms", while second-order change is perceived as "breaking totally with past practice, outside existing paradigms and conflicts with prevailing values and norms" (p. 113). If a teacher has been using a behaviourist approach, the impact of the change will be greater, possibly requiring second-order change management, as they will view teaching as management of students' learning of science to ensure they "learn" the required knowledge (Marzano et al., 2005). If a teacher employs a positivist approach based on preplanned science teaching, sharing scientific concepts in a linear, mechanistic manner with students, shifting to developing a science

programme that is flexible, non-linear and requires spontaneity in addressing student needs and interests using a constructivist approach will also require second-order change (Levin, 2010). Therefore priority must be given to supporting teachers through the change process as they endeavour to transform their practice to a humanist or constructivist approach in implementing the *NZC*.

2.3.4 Science learning area within the *New Zealand Curriculum*.

There are challenges facing teachers implementing the science learning area of the *NZC* with its focus on scientific processes of the NoS rather than transmitting scientific knowledge. Unless school management and teachers adequately engage with the intent of the *NZC*, with its emphasis on school-based curriculum design, their pedagogy could show a discrepancy to the demands of science within the document. Changing views of science and its learning over the last forty years have implications for science teacher practice. The changes in the science curriculum have focussed on

- process skills in 1970s;
- the importance of ‘children’s science’ views in 1980s;
- constructivism involving individual ‘sense making’ in 1990s; and
- social constructivism to develop scientific concepts and literacy through the NoS in 2007 (B. Bell & Baker, 1997).

The focus of learning science is now on building students’ ability to solve problems and make decisions across many aspects of their lives using “scientific perspectives that take into account social and ethical considerations” (Ministry of Education, 2007, p. 28). This means there can no longer be a passive transfer of knowledge from teacher to student of the discoveries of scientists and the sharing of disembodied facts about the laws and principles of science unrelated to students’ lives (Bybee, 2006; Carr et al., 1997). Another implication of

the Science learning area statement is that students should be involved in investigation and debate of topics relevant to their lives, and important to them as twenty-first century learners (Osborne, 2006). This view is supported by researchers who advocate the value of engagement with socio-scientific issues as an essential part of science learning (Driver, Newton, & Osborne, 2000; Rennie, 2006; Sadler & Zeidler, 2005a, 2005b). Furthermore, science in the *NZC* is similar to those of other western countries, with the focus on students being able to link the processes of science to make claims about issues of biological, chemical, and physical phenomena they encounter and to argue in an informed way in decision making scenarios (Abd-El-Khalick et al., 1998; Venville & Dawson, 2010). The emphasis has shifted from the knowing of science facts to being able to use scientific principles and evidence to suggest explanations and to predict outcomes based on well-reasoned arguments about the world (Duschl & Osborne, 2002; Rennie, 2006). This change in emphasis has been reflected in the revision of both the questioning strategies and assessment approaches of the National Certificate of Educational Achievement (NCEA) used to measure student achievement in Years 11 to 13 in New Zealand schools against Achievement Standards designed to align with the *NZC*. NCEA has both internal and external assessment opportunities, with importance placed on students being able to explain and justify their responses in order to achieve Merit or Excellence grades, rather than a description of facts and details as required for an Achieved grade. The internally assessed Achievement Standards focus on the assessment of the NoS achievement objectives through the four contextual strands as detailed in the explanatory notes of internal Achievement Standards (see, for example, NZQA, 2012). Low numbers of Merit and Excellence achieved in sciences is perhaps indicative of a lack of appreciation of the change in focus which would not address Merit and Excellence requirements of students are taught in a content focussed manner. Such an approach could fail to provide students with the resources and experiences to enable them to explain and justify their responses using the concepts inherent with the NoS objectives

(English & Wood, 1997). Hipkins and Neill (2006) presented a summary of research into mathematics and science achievement in NCEA which indicated that teachers in both these learning areas had begun to perceive the need to change their teaching practice in order to teach students the “use of language conventions in science and to emphasise learning for meaning rather than coverage of content” (p. 34). Several teachers reflected that this made their science teaching:

less spontaneous, and gave a narrow focus on Achievement Standards, as the assessments needed to incorporate a narrower range of thinking as this was directly linked to assessment requirements for achieving merit and excellence, and these teachers were not happy with less content coverage aspect. (Hipkins & Neill, 2006, p. 39)

The sample size in Hipkins and Neill’s study was limited to 13 science teachers, however, it is possible other New Zealand teachers could be in a similar situation, and may be reluctant to move from a content focus for their teaching. This could result in the failure to teach for understanding of the NoS concepts as required in the *NZC* and therefore limit their students’ ability to achieve merit or excellence.

The “Effective Pedagogy” section and the introduction of the science learning area in the *NZC* both identify with social constructivism, whereas Crotty notes that the “scientist has invented concepts and theories to describe and explain...using scientific meta-language”, thus the “knowledge of the natural world is socially constructed” (Crotty, p. 56). The “Why study science?” section of the science learning area (Ministry of Education, 2007, p. 28) outlines aspects of constructivism in the ways students will develop understandings about the world through learning about currently accepted theories, and how that knowledge evolves as they engage in scientific problem solving through investigation processes that build their ability to communicate and make informed decisions. The NoS strand is identified as being both

“overarching” and “unifying” as it brings these aspects of science together as the understandings about science, the investigation processes of science, the breadth of scientific communication, and the engaging in and becoming informed about socio-scientific issues. The range of scientific processes that students need to learn and develop an awareness of through the contextual knowledge strands are also outlined (Ministry of Education, 2007, p. 28). Thus, the *NZC* provides teachers with freedom in their design of learning programmes as outlined in designing school curriculum section. By comparison, the UK science curriculum is more prescriptive, allowing teachers little flexibility in programme design (Coll & Taylor, 2012). The “Effective Pedagogy” section highlights six aspects that promote student learning, namely: the creation of an environment that supports learning (aspect 1); encouraging the use of reflection and metacognition (aspect 2); promoting learning through use of cooperative and shared learning strategies (aspect 3); enhancing the relevance of new learning through challenging students (aspect 4); linking the learning to prior experiences in a relevant manner (aspect 5); while providing a range of learning opportunities (aspect 6); (Ministry of Education, 2007, p. 34). All these aspects link well to constructivist theories of learning.

Many science teachers favour behaviouristic approaches, prioritising content in a didactic teaching model, often at the expense of pursuing scientific investigation and communication (B. Bell, 2005). Sharing decontextualised content knowledge, excluding practical work, and failing to link science to their lives has resulted in disengaged students who see no relevance in learning science (B. Bell, 2005; Rennie, 2006). Such teaching approaches are an indication that the teachers do not appreciate the intent of the *NZC* changes to the science learning area. Consequently, focussing on the NoS and scientific processes will require considerable change in both thinking and teaching priorities, or a change from a form to a function focus (Spillane, 2000). Both Spillane (2000) and Tytler (2007) argue that if science programmes are developed around themes of interest to students, contextualised and using the big ideas behind themes, then student engagement will increase alongside their capability for scientific

investigation and communication. Trialling such approaches in Australia resulted in increased student motivation and interest in science, using themes developed through student input rather than predetermined by teachers (Hoban & Nielsen, 2010; Tytler, 2007).ⁱ

The shift to building students' competence in science processes requires teachers to analyse their teaching style, identifying its pedagogical and theoretical underpinnings, as well as rethinking their teaching routines, increasing lesson preparation, and altering their existing values structures (Carr et al., 1997; Wolk, 2007). If school management and professional development support programmes do not identify the order of change required by science teachers, then progress will be slow and commitment poor, with little sustainable change in practice (Marzano et al., 2005).

As many science teachers have been identified as requiring second-order change management support, any professional development programme on building understanding of the underlying principles of the NoS in the *NZC* must address the change process described in Tytler's (2007) model so that teachers develop contextually-based programmes to build students' capability in scientific processes and therefore in the NoS.

2.4 Part 2. Nature of Science, National and International Perspectives

Nature of Science (NoS) refers to the epistemology of science, science as a way of knowing that incorporates the beliefs and values that underpin the development of scientific knowledge (R. L. Bell, Lederman, & Abd-El-Khalick, 2000; Hipkins, 2006). The NoS has been

ⁱ Tytler's model asked two questions of students to identify the science themes for the year, programmes were planned around these themes and their underlying big questions.

described in the science learning area introduction of the *NZC* as the “overarching unifying strand” (Ministry of Education, 2007, p. 28) which will be developed through the “four contextual strands – Living World, Material World, Physical World and Planet Earth and Beyond” (p. 28). The learning area introduction identifies four aspects of the NoS, understanding what science is; how scientific ideas are communicated; how scientific investigations are carried out; and how scientific ideas influence decision-making about issues and actions in the world and our lives. It also states that students should develop an understanding of the world and an awareness of how scientific knowledge is continually changing and evolving as new evidence is considered. At the same time, students will be building their scientific skills, acquiring attitudes and values that will enable them to make informed decisions on scientific issues in the future (Ministry of Education, 2007). The inclusion of the NoS as an essential component of the *NZC* Science learning area is in line with similar trends in other countries – England, Wales, United States and most recently Australia (Osborne, Erduran, & Simon, 2004).

While there has been much international research on the NoS over the last thirty years, there has been comparatively little doctoral level research in New Zealand on the NoS capability and understandings of our science teachers. Consequently, this international body of literature must be evaluated or considered for its relevance to the New Zealand context (Austin, 1997; Hipkins, 2006). It also became apparent from the literature that differing views exist on the NoS and there appears to be no single perception of the NoS. The four aspects outlined in the *NZC* do not completely align with those identified in international science research papers. For example, Lederman and Neiss (1997) describe the NoS as the tentative, subjective, and creative ways in which scientific knowledge is developed using empirical evidence to support the knowledge. They state this is often wrongly combined with the scientific method and processes and is simply described as problem solving and making

observations. McComas, Clough, and Almazroa (1998) present a consensus view of the NoS objectives extracted from eight international science standards documents as being:

- Scientific knowledge while durable, has a tentative nature.
- Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments and scepticism.
- There is no one way to do science (therefore there is no universal step-by-step scientific method).
- Science is an attempt to explain natural phenomena.
- Laws and theories serve different roles in science, therefore students should note that theories do not become laws even with additional evidence.
- People from all cultures contribute to science.
- New knowledge must be reported clearly and openly.
- Scientists require accurate record keeping, peer review, and replicability.
- Observations are theory-laden.
- Scientists are creative.
- The history of science reveals both an evolutionary and an evolutionary character.
- Science and technology impact each other.
- Science is part of social and cultural traditions.
- Scientific ideas are affected by their social and historical milieu. (McComas et al., 1998, p. 6)

In a later paper, Schwartz, Lederman and Crawford (2004) describe the NoS as referring to the “values and underlying assumptions that are intrinsic to scientific knowledge, including

the influences and limitations that result from science as a human endeavour” (p. 611). Furthermore, they state that a scientifically literate person is able to bring together an understanding of scientific inquiry, the NoS and current science content knowledge in such a way that it is useful both to the individual and to society. Science education research, on the other hand, has described six generalisations on scientific knowledge that should be understood by all students of school age (Abd-E;-Khalick et al., 1998; R. L. Bell et al., 2000). These generalisations identify scientific enterprise or the NoS as:

tentative, empirically based, subjective, partly the product of human inference, imagination and creativity, socially and culturally embedded, involving a combination of distinct observations and inferences, and also describing both the functions of and the relationship between scientific laws and theories. (Abd-El-Khalick et al., 1998; R. L. Bell et al., 2000; Skamp, 2004).

These researchers state that there is significant overlap and interaction between scientific processes and the NoS, yet each is distinct. Scientific processes are defined as “activities relating to collecting and analysing data and drawing conclusions” (Skamp, 2004, p. 132) and include data collection, collation, analysis, and interpretation in the drawing of conclusions and making inferences from the data. The NoS is defined as the “characteristics of scientific knowledge that are directly, and necessarily, derived from how knowledge is developed” (Skamp, 2004, p. 131). On the other hand, the understanding that the depth of our observations and conclusions is limited by our perceptions and knowledge of scientific theory is part of the NoS understandings (R. L. Bell et al., 2000; Skamp, 2004). Shamos (1995) suggests that the scientific method proposed early in the 20th century worked well in the type of investigation traditional in science education where a cause and effect relationship is often the norm. However, this recipe-like method of aim or question, observations, hypothesis forming, predicting outcomes, experimenting to test predictions, and rejecting or accepting of

the hypothesis does not provide solutions to many of the problems facing scientists where the issue is in accurately defining the problem and then deciding what to observe, how to experiment, and how to conduct the investigation (Skamp, 2004). If teachers formalise the scientific method as a predetermined series of steps to be carried out in a rote manner as a set of learned skills, it is likely to result in students not being introduced to the key purpose of scientific investigation process being to provide explanations for observed phenomena (Shamos, 1995; Skamp, 2004).

In contrast to the international perceptions of the NoS, there seems to be confusion between the skills and processes of science and the NoS in the *NZC*. This is most apparent in the “Investigating in science” and “Communicating in science” strands, where the emphasis is clearly on the skills and processes of science rather than the NoS. For example, the achievement objective from the Level 6 Investigating in Science criteria states:

- Develop and carry out more complex investigations, including using models.
- Show an increasing awareness of the complexity of working scientifically, including recognition of multiple variables.
- Begin to evaluate the suitability of the investigative methods chosen. (Ministry of Education, 2007, p. 53).

This places emphasis on the skills and process approach of scientific investigation, and makes no mention of the need to link, interpret, and make sense of their observations and investigations to develop answers to defined questions or problems using scientific theoretical perspectives (Skamp, 2004). In pursuing the links to the skills and processes of science from an international perspective, these more closely align with the accepted concept of scientific literacy identified independently by Aikenhead (2006), Ryder (2001) and Rennie (2006). They describe ways a science curriculum should, through building scientific literacy, provide

practical relevance for students in real life situations, rather than the NoS as applied from the internationally accepted criteria. Scientific literacy is defined as an individual's interest in the world they live in and their ability to use the big ideas of science to discuss, conjecture, and investigate questions about scientific matters to draw evidence-based conclusions, while retaining a healthy scepticism of supposedly scientific claims especially relating to world environments, health and well-being (Hipkins, 2006; Rennie, 2006).

Similarly the achievement objective for "Communicating in science" for Levels 5/6 indicates students should be able to "use a wide range of science vocabulary, symbols and conventions" (Ministry of Education, 2007, p. 53), which also illustrates a scientific skills and process focus. However, the second achievement objective for "Communicating in science" for Levels 5/6 requires students to "apply their understandings of science to evaluate both popular and scientific texts (including visual and numerical literacy)" (Ministry of Education, 2007, p. 53). This objective could be taught in a way that would align with international conceptions of the NoS by pursuing a narrative approach, using science fiction to help students think critically about the relevance of science to their lives. If students were to think more creatively about where science may take us in the future, they would be engaging a NoS view of scientific literacy (Weaver, Anijar, & Daspit, 2004; Gough, 1993, 2004). Another approach could be to use narrative to help students make links between their own cultures and worldviews and those of science in a way that would relate to R. L. Bell et al's. (2000) view of the NoS as creative, imaginative, as well as socially and culturally embedded (Aikenhead, 1996; Gilbert, 2001). If such an approach was employed it would align with Milne's (2012) assertion that use of narrative constructions can "assist students to make connections between their funds of knowledge and the science knowledge of the classroom" (p. 964) in explaining the science they experience in their lives while strengthening their understanding of NoS. However, research prior to the *NZC* indicates that most NoS teaching in New Zealand schools is implicit rather than explicit (Hipkins et al., 2002). This observation aligns with that of

Lederman and Lederman (2004) who attest that most teachers employ implicit approaches to the NoS, and only by explicitly incorporating strategies and activities to build the NoS capabilities in teachers will they in turn explicitly use such activities with their students.

Hipkins (2006) reports that “Understanding about Science” from the *NZC* NoS strand is covered by some teachers using the uncritical promotion of the importance of science for contemporary life, as these teachers believe they are addressing the NoS by relating applications of technology to science. The descriptors of this strand, shown in Figure 1 (see p. 32), most closely align with international epistemological understandings of the NoS, clearly identifying some of the seven aspects described by R. L. Bell et al. (2000). For example, the Level 1 reference to “open-mindedness” and “more than one explanation” certainly relates to the NoS ideas on the subjective and tentative nature of findings. However, the Level 5/6 and 7/8 descriptors relate to the ideas involving a combination of observations and inferences to demonstrate the relationship between scientific laws and theories, and a scientific knowledge that is socially and culturally embedded.

Level 1 and 2	Level 3 and 4	Level 5 and 6	Level 7 and 8
Students will appreciate that scientists ask questions about our world that leads to investigations, & that open mindedness is important because there is may be more than one explanation.	Students will appreciate that science is a way of explaining the world & that science knowledge changes over time. They will identify ways scientists work together and provide evidence to support their ideas.	Students will understand that scientists’ investigations are informed by current scientific theories, and aim to collect adequate evidence that will be interpreted through processes of logical argument.	Understand that scientists have an obligation to connect their new ideas to current and historical scientific knowledge and to present their findings for peer review and debate

Figure 1: Understanding about Science from *NZC* (excerpt from (Ministry of Education, 2007)).

Evidence from international and local studies indicate that both students and teachers hold naïve views of the NoS as they perceive the content of science to be the most important aspect of learning (Abd-El-Khalick & Lederman, 2000; Hipkins, 2006; van Driel et al., 1998).

Hipkins (2006) suggests that teachers may hold a working understanding of the NoS but may be unable to share this with students if they may lack the confidence to address the NoS, especially if they have not developed explicit strategies to use with students. Lederman and Lederman (2004) support this view, asserting that teachers often hold well developed NoS views, but fail to transfer this into their teaching practice, as their lessons focus on instruction in science content knowledge rather than developing students' thinking about science. Other research on teaching and learning of the NoS has indicated that unless teachers understand it themselves, they will not teach it to students, rather maintaining a consistency between their concepts "of how scientific knowledge is constructed and their beliefs about how students learn science" (Da-Silva, Mellado, Ruiz, & Porlán, 2007, p. 463). Furthermore, for students to develop an understanding of the NoS, the teaching must be explicit and incorporate constructivist approaches and strategies within the learning programme (Skamp, 2004). Research has shown that including history of science or scientific investigations in contexts without explicit focus on the NoS leads to little change in student understanding of NoS, unless the teaching included "student participation in problem solving scenarios, frequent use of inquiry oriented questioning and frequent teacher-student interactions" (Skamp, 2004, p. 136). Thus, students need to be involved in a range of hands-on activities making explicit references to the NoS to develop this understanding (Gluckman, 2011; Skamp, 2004). Evidence suggests it is easier for students to develop a better understanding of the nature of scientific knowledge rather than on the nature of scientific enterprise, possibly because the idea of science knowledge being tentative, evidence based, and empirically based is more accessible than the concept of scientific enterprise being creative (Dogan & Abd-El-Khalick, 2008; Gluckman, 2011).

A further international perspective that has been investigated by a growing number of science education researchers has been the interrelationship between NoS and science as explanation and argument. Matthews (1994) began the focus by suggesting the necessity to include NoS

aspects in teacher education programmes to help teachers incorporate conceptual change approaches into their teaching practice. Further, the critical need was identified for teachers to use guided discourse and writing practices as part of the conceptual development of NoS in inquiry situations in order to develop a functional NoS understanding (Schwartz, Lederman, & Crawford, 2004). Osborne (2012) outlines the importance of students engaging in using their explanations of observations of scientific phenomena within their world view to advance their model of the world and justify its foundations. By engaging in this process, students were demonstrating their understanding of NoS and also developing their use of science as explanation and were able to learn about science as argumentation. For as stated by Sampson (2006), “understanding the purpose and scope of scientific knowledge and why this type of knowledge is valued by scientists is critical to a view of science as a process of explanation and argument” (p. 5).

Science as explanation and argument is addressed within the NoS of *NZC*, particularly under the Participating and contributing strand with its emphasis on “gathering scientific evidence on socio-scientific issues in order to draw evidence based conclusions” (Ministry of Education, 2007, p. vi) at Level 5 and 6, and also within all the other levels. The NoS strands do not lend themselves specifically to a development of science as explanation, although it is evident within the contextual strand descriptors such as Level 6 Living World, which states “Explain the importance of variation within a changing environment” (p. vi). Similar phrases are found under some other contextual strands but not consistently across the levels or strands. It could be argued that the intent of science as explanation is reflected in the “Understanding about science” strand, but it is only clearly evident in Levels 1 – 4, while Level 5 and 6 focus on processes of logical argument, and Level 7 and 8 on peer review. The issue with this lack of clear progression is that teachers using the achievement objectives to guide development of their programmes will not get a sense of the interrelationship between NoS and science as explanation and argument.

A recent discussion in *Science Education* journal has highlighted the need to ensure NoS is not described as a skill, for it embodies a knowledge of conceptual understandings that are separate from attitudes and skills (Schwartz, Lederman, & Abd-el-Khalick, 2012). The *NZC* is in danger of confusing skills and attitudes with NoS understandings as it incorporates distinct skills foci within Investigating in Science and Communicating in Science. Consequently it will be important for development of tools alongside the *NZC* not to treat all the NoS aspects as “skills that students *do* and are assessed on, but to retain an explicit – reflective approach so that students understand what makes science *science*” (Schwartz et al., 2012, p. 686). In this way NoS will also not be equated with scientific literacy, for although NoS is part of scientific literacy, as is scientific inquiry, neither are effectively taught by direct instruction rather requiring use of multiple experiences that build and reinforce NoS aspects over time (Schwartz et al., 2012).

From my analysis of the range of understandings about the NoS, for the purpose of this research, the NoS is regarded as a critical, creative, empirically-based perspective on scientific knowledge and knowledge construction, based on a clear understanding of both the myth of the universally accepted scientific method, and the nature and assumptions that underlie the development of scientific theories. This must be combined with an understanding of the relationships between scientific concepts of hypotheses, theories and laws, and perceived realities, as well as the tentative nature of scientific reasoning.

2.5 Part 3 - Professional Development Approaches

Part 3 explores the professional development approaches identified as effective for teachers and then examines how these relate to those identified in the literature as being effective for science.

2.5.1 Professional development.

Professional development in education refers to support provided for in-service teachers and teacher educators. In this section of the literature review, professional development focuses on responding to changing educational priorities such as those inherent in the *NZC*, especially those outlined in the “Effective Pedagogy” section (Ministry of Education, 2007). Professional development is defined as being an intentional, ongoing, systemic process designed to build the pedagogical content knowledge, skills, and attitudes of educators to provide better learning outcomes for students (Guskey, 2000; OECD, 1998; Thornton, 2003). More particularly, professional development includes the processes and activities intended to increase or enhance the professional job-related knowledge, skills, or attitudes of teachers so they in turn devise programmes to bring about improved student learning (Fullan, 2001; Guskey, 2000). Professional development can take a variety of formats, but it is recognised as including individual study, attendance at workshops, conferences, participation in study groups, peer coaching and mentoring, as well as involvement in curriculum development. A broad approach to professional development is taken by many providers, as no one approach will necessarily be effective as the outcome is dependent on the level of change in practice required (Marzano et al., 2005), thus it may be in-depth with multiple-contact points and inclusive of classroom/practice observations (Abd-El-Khalick & Lederman, 2000; Guskey, 2000; Timperley et al., 2007).

In researching selected literature on professional development for teachers, it became evident that information gleaned from overseas research may not be entirely applicable in New Zealand where professional development is not mandatory but open to teacher choice. A variety of professional development opportunities are available to New Zealand teachers from attending day or half day courses to update on requirements for managing school systems, to in-school, in-depth facilitator-led school developments focussed on literacy, numeracy, ICT,

or assessment. In the latter programmes, facilitators support teachers to engage in action research or teaching as inquiry into their own practice to follow the achievement of target groups of students (Ministry of Education, 2010). The current New Zealand Satisfactory Teacher dimensions of the New Zealand Teaching Standards limit professional development requirements to the demonstration of teaching and learning knowledge developed from teacher education programmes and on-going study, research, reflection and practice, while the Teacher Code of Ethics requires teachers to demonstrate “continuous professional learning to provide the best knowledge available about curriculum content and pedagogy” (New Zealand Teachers Council, 2004). However, the Registered Teacher Criteria (New Zealand Teachers Council, 2009) emphasise on-going professional learning, development of personal professional practice through establishing professional learning goals, participation in professional learning and initiating learning opportunities to improve professional knowledge and skills. As these criteria are not in force fully until 2013, teachers are displaying reluctance to endeavour to meet these requirements, but even when in place there is no stipulation on the number of hours or specificity of the professional development requirements.

Professional development is prescribed in many educational contexts, such as in the United States and United Kingdom where teachers are required to complete specified hours of professional development each year. For example, Las Lomas District of California, USA requires 150 hours over five years; Kentucky and Nevada require four days annually and the United Kingdom requires 30 hours annually (Aikenhead, 2006; Ministry of Education, 2002).

In order to address any possible bias reaction that compulsory professional development might bring, the literature selected for inclusion in this review only deals with teachers who volunteered for professional development programmes. This is based on the assumption that

these samples will show less negative response to professional development than those who engage in professional development by conscription (Guskey, 2000).

The characteristics of effective professional development, according to Newmann, King and Young (2000) are a concentration on instruction and specified student learning outcomes directly related to the school, as well as the provision of opportunities for working with colleagues on inquiry into practice, observations, and feedback, while utilizing external expertise that recognises the teachers' prudence and creative ability. Newman et al. (2000) also support sustained, continuous professional development rather than one-off or spasmodic sessions. These ideas align with Guskey's (2000) four principles of effective professional development. First, that it is clearly focussed on both learning and learners; second, it emphasises both individual and organisational change; third, the focus is on a series of small manageable changes guided by a shared, common, overarching vision, and finally, that the professional development is an on-going activity that becomes embedded in each individuals' professional toolbox. Many researchers advocate the use of external expertise, but stress that the goals should be jointly prepared by presenters and the organising team, and that the professional development includes follow-up activities that provide coaching, observations, and feedback (Robinson, 2007; Guskey, 2003; Timperley, 2001). Guskey (2000) further elaborates on the critical nature of this collaboration, that it must include both a sound research basis and be implemented in a supportive environment where the quality is monitored through use of appropriate indicators. He also points out that a professional development programme working in one context may not work in another, due to the complex nature of relationships among teachers within schools and among groups participating in the professional development, a concept also supported by researchers in science professional development (R. L. Bell et al., 2000; Guskey, 2003; OECD, 1998). Therefore, Guskey (2003) argues that there is no definitive list of characteristics that lead to effective professional development, but rather the effectiveness is dependent on both the context and the

professional development process used. For example, Guskey (2003) suggests if sufficient time and resourcing is provided for professional development, but the focus is not on engaging learners and student learning outcomes, then the professional development is unlikely to be effective in bringing changed teacher practice, while Robinson (2007) and Zimmerman and May (2003) indicate that feedback on learning processes is more effective than that on learning outcomes.

An aspect of professional development not explicitly raised by Guskey (2003), but identified by other researchers, is the need to incorporate adult learning approaches into professional development (Darling-Hammond & McLaughlin, 1995; Lieberman & Pointer Mace, 2008). For example, adult learning proponents indicate the need to motivate teachers to analyse student data and identify goals and outcomes for their students, then identify the teachers' own learning needs and develop appropriate professional development to address these, rather than presenting information in a lecturing style (Lewis, 1999; Ingvarson, 2003). In-service teacher educators need to determine the methodology that will best facilitate the learning process of the teachers involved in professional development, regardless of considerations of time and effort involved in professional development preparation, instead focussing on the increased learning that will be achieved (Seaton & Boyd, 2008).

Guskey (2003) also emphasises the need to develop teachers' pedagogical and content knowledge so that a deeper understanding of the content being taught and the ways students learn is developed. Only then will professional development be effective. He asserts that most of the studies on pedagogical content knowledge have a science or mathematics focus which may not apply to all learning areas. However, his study provides evidence that it would be important to include activities to develop teachers' pedagogical and content knowledge in professional development for science teachers.

2.5.2 Science professional development.

Research on professional development for science teachers identified three different models of professional development: skills-based; research-supported; and apprentice models (Hemler & Repine, 2006).

Skills-based professional development concentrates on transferring scientific content in traditional labs/lecture style, which builds skills but does little to develop NoS understanding; in fact, it can enhance teachers' thinking that scientific inquiry adheres to set routines with predictable outcomes (Hemler & Repine, 2006; Schwarz et al., 2008). Research-supported professional development arose in response to the lack of progress in NoS understanding of teachers following involvement in skills-based professional development. In research-supported professional development, teachers worked in scientific research labs alongside scientists in a collaborative research programme for a set time, producing a joint report with the scientist at the end. This approach has been trialled internationally and in New Zealand with the Science Teacher Fellowships. However, reflection by those involved indicates that little change in teaching occurs as a result, but the teachers involved develop a better understanding of the tentative nature of scientific inquiry (Vosniadou et al., 2001; Hipkins, 2007).

The apprentice model provides both collaborative and apprentice situations for the teachers. First, they are instructed in necessary scientific knowledge, but then the supporting scientists act only as resource providers and do not direct the apprentice teacher-scientists as they work in groups on a research question (Hemler & Repine, 2006; Schwartz, Lederman, & Crawford, 2004). Such programmes require intensive time commitment from both teachers and scientists. Hemler and Repine's (2006) group had three weeks of direct contact, including a Geology field experience with written requirements, as well as individual journalling of teaching practice, but no direct observations of classroom practice. The outcomes describe

increased familiarity and confidence with scientific processes, a greater willingness to share the NoS with their students, and an appreciation that actually contributing to science knowledge through their research had greater impact on them than previous professional development courses the teachers had engaged in where they merely duplicated investigations (Hemler & Repine, 2006). A key difficulty of the apprentice model is the time and personnel commitment to enable teachers to gain either of these experiences, as it would require input not just from in-service teacher educators, but also scientists, making it difficult to involve a large number of New Zealand science teachers.

A weakness I perceive with both research-supported and apprentice model professional development techniques is that there was no direct observation of change in teacher classroom practice in developing the NoS understandings with their students. Thus, in the apprentice model, their espoused feedback from journalling of the impact of the research experience on their NoS understanding cannot be verified. The literature on science professional development tends to focus on development of either pedagogical content knowledge to the exclusion of NoS views (Arzi & White, 2008; Spektor-Levy, Eylon, & Scherz, 2008; Thornton, 2003; van Driel et al., 1998), or on concepts and views of the NoS with little development of pedagogical content knowledge (R. L. Bell et al., 2000; Dogan & Abd-El-Khalick, 2008; Hemler & Repine, 2006; Laugksch, 2000; Taylor & Dana, 2003). On analysis of the research into the NoS, Dogan and Abd-El-Khalick (2008) and Akerson and Hanuscin (2007) were the only studies I found that focussed on assessing both students' and teachers' conceptions of the NoS. More specifically, Akerson and Hanuscin (2007) found four key elements to be included in professional development to build the NoS capability in teachers. These were monthly, facilitator led workshops that led teachers through explicit activities that could be used in the teachers' classrooms; on-site support for individual teachers; the need for a longer term engagement in professional development; and inclusion of teacher goals or inquiry approach (Akerson & Hanuscin, 2007). Other studies focussed on changes in the

teachers' views and understanding of the NoS rather than on whether this changed view brought changes in teaching practice. More importantly, no evidence was collected on students' developing understanding of the NoS, thus Guskey's (2000) assertion that evidence of effective professional development research must be based on achievement of relevant student outcomes is vital, and should be a component of any research on effective professional development for science teachers.

2.6 Part 4. Possible Effective Professional Development Approaches for Developing Nature of Science

Drawing on the literature reviewed on professional development and the NoS, it is possible to determine a professional development approach that could be effective in developing science teachers' capability at incorporating the NoS effectively into their teaching programmes. Researchers working in both Turkey and the United States identified the need for extensive professional development when reforms that prioritised the NoS in the science curriculum occurred in their respective countries, in order that the curriculum revision intent was attained (Astor-Jack, McCallie, & Balcerzak, 2007; Dogan & Abd-El-Khalick, 2008). Recommendations from researchers developing teachers' ability to support science as inquiry also identified the need for extensive professional development. It is acknowledged that this cannot happen in isolation from students, as teachers must know how students think about the science concepts they are developing so that student misconceptions can be addressed and challenged (Carlson, Humphrey, & Reinhardt, 2003). These researchers recommend that effective professional development for science should incorporate a range of components, including using inquiry as an adult learner, long term supported professional development, reflection on teaching and learning of students, collaboration and sharing with colleagues, and daily classroom practices including gathering and using formative assessment data to advance student learning (Carlson et al., 2003).

The studies reviewed on professional development in the NoS provide ideas on approaches that could be effective in building teachers' NoS capability. They indicate the need for time, sustained professional development that addresses individual teachers' needs to build content knowledge alongside an understanding of the NoS, development of the teachers as a community of learners to build capability and collaboration, accompanied by classroom observations, and feedback opportunities (Akerson & Hanuscin, 2007; Constible, McWilliams, Soldo, Perry, & Lee, 2007; Eberle, 2008). This list is similar to that for effective generic professional development in education outlined earlier by Bell et al. (2000), Guskey (2003), and Robinson (2007), except that individual teacher need is specified as relating to scientific content knowledge and NoS understanding. Another consideration is the incorporation of aspects from the research supported, or apprentice models of science professional development. Findings indicate both have the potential to build greater teacher understanding of the NoS, but the impact on student learning outcomes for the NoS has not been researched. In addition, research on building student NoS understanding indicates the need for explicit teaching and practical activities linked with discussion that allows for reflection on the concepts from a theoretical NoS perspective (Khishfe, 2008; Yacoubian & BouJaoude, 2010). The corollary of this is that teachers themselves gain a better understanding of the NoS through explicit experiences and reflective discussion approaches as indicated in the apprentice model approach (Akerson & Hanuscin, 2007; Hemler & Repine, 2006).

Students need to learn how science works, its processes and purposes, not just "the what" of facts and figures. Both students and teachers need to be able to demonstrate understanding of how science works. A static view of science is that content such as facts and learned information is of prime importance, while a dynamic view perceives science knowledge as tentative, and achieved through an understanding of scientific ideas and establishing the relationship between the ideas gained through instruction incorporating hands-on

experiments. The NoS places reliance on the scientific investigation process of observation, obtaining scientific evidence that leads to a prediction from which a model is constructed resulting in the construction of meaning (Beckett, 2007). Knowledge of the NoS helps students and teachers build an understanding of science concepts that is integrated with their existing conceptual framework of scientific knowledge to help them make meaning of their world (Beckett, 2007). An alternative theory of this construction of scientific knowledge is postulated by Beckett (2007), where curiosity leads to theory-laden observations that result in a contestable model supported by the perceived evidence being established. This model is constructed using an individual's reasoning and must withstand criticism from others; otherwise it will lead to refinement of the concept or production of a counter model. This process differs greatly from the traditional approach to science teaching where the teacher expounds the facts, students listen and accept what is shared with them by the teacher and are passive learners of the facts as presented to them.

Another aspect of science teaching highlighted by McComas et al. (1998) is the focus on textbooks as a teaching tool, especially as the majority of science texts take an inductivist-empiricist approach, thus conveying a view of the scientific knowledge presented, as well as the process by which this knowledge was derived. In a similar way, the process of scientific investigation used in practical sessions conveys to students definite ideas about science processes and how scientific knowledge is constructed. Thus teachers need to consider the place of "cookbook verification" laboratory work providing predetermined results if they are determined to build NoS understanding in students. As early as 1991 it was suggested that a classroom resembling a research laboratory with students investigating in social groups was a better learning environment for students (Burbules, 1991). This has been described as an application of social constructivist learning to classroom practice.

Berger (2007) describes the impact of the *NZC* as creating additional demands on teachers who will now have to change not only their practice, but also their thinking. They will need to expand their minds to accommodate their role as constructors of curriculum as well as deliverers, in their schools and classrooms (Berger, 2007). She draws on Robert Kegan's constructive-developmental theory to understand the different perspectives and complexities that people use to view their world. This theory portrays our personal development as a journey passing through five different orders of the mind from a magical childlike mind that cannot understand moment by moment changes in their world, to the second stage when an awareness of other peoples' interest only becomes important if it conflicts with their own. The third stage focuses on the socialised mind, governed by external influences of society, ideals or institutions to the extent that they are unwilling to trust their own thoughts to make responses outside of societal norms due to the wish to conform. The fourth stage, the self-authored mind, reveals the ability to critically examine externally applied rules, opinions, and expectations yet consider these in a personal way so that the individual is motivated to make their own stance on issues with the confidence to be reflective and self-correcting if necessary. Berger (2007) cites Kegan's assertion that this will often only occur as we mature, while the fifth dimension of the self-transforming mind may never be achieved, and definitely not before midlife (Berger, 2007). Using this information, Berger designates many young teachers as being of the socialised mind while mostly older teachers reveal self-authored minds. If teachers are at the socialised mind level, they will need to be challenged to change their thinking. For schools to develop the school-based curriculum design described in pages 36-39 of the *NZC* (Ministry of Education, 2007), the thought capability of the self-authored mind to bring about this intent of the curriculum is required (Berger, 2007). In addition, Berger (2007) states that teachers with socialised minds are threatened by a curriculum that does not supply the answers, as is the case with the *NZC*. If a teacher is of a socialised-mind then a science programme that is not based on retrieval of facts and carrying out fair testing

for scientific inquiry exposes them to confusion, for until now they have not been required to make decisions about what to teach, what is right and what is wrong. On the other hand, mature teachers are probably more likely to accept the challenge of *NZC* as they will likely have self-authored minds. Therefore they will be able to consider the opportunities and be motivated to design flexible learning programmes that engage students, and come to terms with developing an understanding of the NoS through the contextual strands (Berger, 2007). Berger (2007) identifies that professional development must help teachers move to develop self-authored minds. She suggests that conditions for this can be created through development of journalling and critically reflective practice, while engaging teachers in questioning their underlying assumptions about teaching and learning, as well as developing and practicing active listening skills to gain an idea of others' perspectives. This concept is supported by Carlson et al. (2003) who advocate that teachers should be actively engaged in improving their science teaching by continually exploring new ideas for teaching, learning and assessing in science, as well as reflecting on their teaching and their students' learning to maintain their own professional growth as science teachers. The approach suggested by Carlson et al. (2003) closely resembles the "Teaching as Inquiry" (Ministry of Education, 2007, p. 35) approach advocated in the *NZC*. The *NZC* approach links the need to start from the knowledge of students' current abilities and needs through the use of a focussing inquiry, followed by a teaching inquiry where the teacher explores and selects strategies that may best suit the students' learning needs. This is then followed by teaching and learning, and the learning is then evaluated using an appropriate range of assessment strategies. The Teaching as Inquiry cycle will either continue with appropriate refinements or the next stage of learning will commence with another focussing inquiry.

2.7 Evaluation of Professional Development

Any professional development programme should be evaluated to gain an indication of its effectiveness in building teacher understanding. As part of the literature review it was important to identify appropriate approaches, for evaluation may be conducted with participants in various ways including gathering their reflections and/or feedback at the conclusion of the programme. The value of the evaluation will depend on the tools used to carry out the process, and only if these are deemed to be reliable, the professional development provider will be able to justify ongoing applications of the programme (Timperley et al., 2007).

If Guskey's (2000) definition of evaluation is used the "systematic investigation of merit or worth" (p. 41) then any professional development programme used will need to be evaluated by investigating and analysing the appropriate information and comparing the data to relevant standards that will provide feedback on the effectiveness of the programme. He further stipulates that the evaluation process will need to explore a range of aspects and use a range of evidence as the links between professional development and effects on teaching is often tenuous, and although the programme may build teacher knowledge and change teacher practice, it may not lead to improved student learning outcomes. It has been stated, however, that for improved student learning outcomes, high quality professional development is essential, but this must lead to ongoing changes to classroom practices for the teacher over a longer time frame (Guskey, 2000; Hill, Hawk, & Taylor, 2002; Thornton, 2003).

It is important to note Guskey's (2000) assertion that without professional development improvement in student learning outcomes is unlikely to be observed. Any marked improvement has always been associated with professional development specifically focussed on learning and learners, and has clearly stated goals of this intent. An additional statement is that the professional development must include opportunities for practice, feedback on

practice, collaborative learning and planning, and support over a period of time. Other points raised relate to the advantages of evaluation of professional development impact on student learning outcomes through raising the expectations for results from the professional development, while providing more effective standards and focussing on a wider range of factors that influence the effectiveness of professional development. In addition, it means participants view the professional development differently, providing facilitators with the knowledge that they must ensure the sessions are significant (Guskey, 2000).

To measure the effect of professional development on student learning outcomes a number of strategies need to be used. These could include: observations, standardised tests, group tasks, questionnaires and student records for cognitive information; questionnaires and interviews for affective information; observations, interviews, school records, and questionnaires for psychomotor information (Guskey, 2000). To ensure validity of the results, multiple sources of data should be used, and to select students to obtain information from either simple random sampling or stratified random sampling should be used. If the focus is on the effectiveness of the professional development comparatively for boys and girls, then the latter would be used (Guskey, 2000). However, it is important to repeat the data collection, as often the impact of professional development on teaching occurs in a spasmodic manner as a result of building or changing teacher concepts as the programme progresses (Fullan, 1996). Triangulation and repetition of data collection is also essential if change or improvement in student learning outcomes is to be assessed (Fullan, 1996).

Guskey (2000), in his summary, indicates that there are 12 steps involved in a “systemic evaluation process” (p. 272) in order that reliable, meaningful, and useful results are generated. These steps are:

1. Clarify the intended goals.

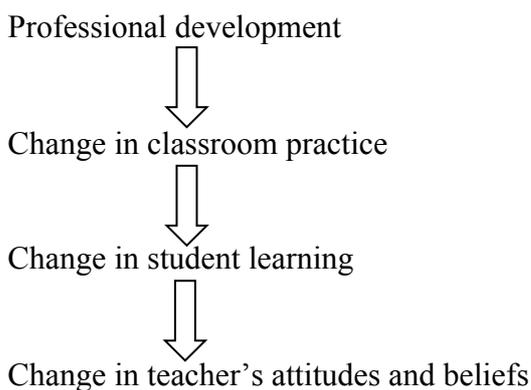
2. Assess the value of the goals.
3. Analyse the context.
4. Estimate the potential of the programme to meet the goals.
5. Determine how the goals can be assessed.
6. Outline strategies to gather the evidence.
7. Gather and analyse evidence on participants' reactions.
8. Gather and analyse evidence on participants learning.
9. Gather and analyse evidence on organization support and change.
10. Gather and analyse evidence on participants' use of new knowledge and skills.
11. Gather and analyse evidence on student learning outcomes.
12. Prepare and present evaluation reports. (p. 272)

Evaluation needs to be incorporated at appropriate times throughout the steps in the professional development. The timing of this evaluation is important and should begin at the planning stage and continue throughout each stage of the professional development as an ongoing process. The evaluation processes utilised will change with the different stages of the professional development, and be responsive to needs of participants, leading to refinement of the programme as participants' needs alter as their knowledge and understanding of concepts develops over time. This partly reflects the model of teacher change suggested by Guskey (1985) where change in teacher attitudes and beliefs only occur as a result of observed changes in student learning due to the implemented changes in teacher practice. Consequently, the evaluation of student learning must accompany any professional development programme to provide evidence of improvement, as without this there is no substantiated evidence of change. Such evidence must be gathered both prior to and post professional development, and where possible be triangulated. Similarly, Guskey (2000)

suggests that participants' use of the new knowledge and skills from the professional development programme should be evaluated using a range of strategies. He highlights the need to identify some indicators from the professional development that will provide critical evidence of application of the new knowledge and understanding into the classroom practice. This includes ensuring the professional development both engages teachers with activities and content knowledge and specific examples that can be easily transferred to the classroom; as well as providing support during the programme, both individual and collaborative, while providing theoretical underpinnings for the professional development. Guskey suggests three aspects for evaluation of teacher's use of new knowledge and skills. The first aspect is the need to monitor the stages of concern that the teachers experience as part of the professional development process of change. Secondly, the need to determine the level of use of the new knowledge into classroom practice, and thirdly, for teachers to describe the difference the professional development has

made to their teaching practice. This will require both pre- and post-professional development evidence of practice gathered from interviews with participants, Heads of Departments, and students, as well as from reflective journals, lesson plans, and portfolios. He also suggests that direct observations, questionnaires, and focus groups can help to provide triangulation of evidence (Guskey, 2000).

Guskey's (2000) Model of Teacher Change is summarised in the following sequence:



2.8 Possible Resources to Build the Nature of Science Understanding of Teachers

A wide range of practical and theoretical resources on the NoS are available both on-line and in specifically written textbooks that assert their suitability to build NoS capability with students across the year levels in science. The criteria used to select suitable resources were that the resource must provide background ideas and theoretical concepts on how it related to the NoS, as well as being a practical activity that was not simply following a recipe-like set of instructions or must not consist of a completion worksheet. The reason for this is that there are many resources that are “fill the gaps” or “follow the instructions” available to schools, but to build NoS understanding, students need to be encouraged to work like scientists and follow the principles identified as being essential for students (Khishfe, 2008; Wertsh & Tulviste, 1990).

2.9 Summary

From the synthesis of the literature reviewed, an appropriate professional development programme for developing the NoS capability of science teachers would be long-term with multiple contact points for reflection, discussion, observation, and feedback, and a

collaborative process incorporating the challenging of teachers' assumptions and beliefs about both science and teaching. Providing opportunities for participation in both practical investigations and original research to build their understanding of the NoS and of the intent of the science learning area of *NZC* would be important, together with developing understanding of the need to address the NoS through the use of constructivist approaches and strategies within learning programmes. The professional development would need to be accompanied by journalling and observation, reflection, and feedback of their specific teaching on the NoS.

The key idea to emerge is that effective professional development should bring about change in both teacher programme design and in student learning outcomes. Professional development programmes initiated to enable science teachers to implement programmes to address the NoS requirement of the *NZC* should gather evidence on its effects on developing student NoS capability. The effectiveness of the programme should be evaluated using a range of evaluation tools to collect and analyse data on both student and teacher change in understanding of the NoS in a triangulated manner.

Chapter 3. Research Methodology

3.1 Introduction

The focus of this research project was to design, facilitate, and evaluate a professional development programme that enabled teachers to understand the intent of the NoS strand of the Science Learning Area of the *NZC*, and apply their understandings to developing programmes that build student capability in the concepts and processes of the NoS through contextual approaches.

This chapter introduces the research methods underpinning this study in Part 1, followed in Part 2 with detail of the methodology employed. Part 2 contains detail on methods employed to gain a response to the research questions and underpinning questions including the participants, an outline of data collection process including the instruments used, data analysis processes used, and a description of how the results will be presented. In addition, Part 2 contains detail on the design interventions incorporated within the design-based research (DBR) methodology.

3.2 Part 1. Theoretical Perspectives - Research Methods

Design-based research (DBR) can generate both practical and theoretical outcomes as it must begin with a meaningful, practical problem that is analysed by both researchers and teachers (University of Georgia, 2006). In this study the research problem addressed was the building of teachers' NoS understanding through a professional development programme. Using a collaborative approach between researcher and teachers, a solution to the problem was developed based on an underpinning theoretical framework of teaching and learning. An intervention was developed, implemented, revised, and evaluated based on feedback from the teachers gained through observations during professional development sessions, classroom

visits, interviews, surveys, and journal entries. Further refinement of the intervention followed each workshop session, before being used with another group of teachers. The resultant programme was trialled with a group of teachers. An on-going evaluative process provided flexibility for further refinements of the intervention, and ultimately led to the construction of design theories about learning and instruction in the NoS that could be adapted to other contexts and new settings. The constructionist and socio-cultural theoretical perspectives of teaching practice make the use of DBR methodology more appropriate from the collaborative researcher/teacher perspective, as both can engage with iterations of the intervention through the DBR approach as part of the research process.

Within the NoS settings, my theoretical design conjecture was that teacher's learning is enhanced through the employment of interventions that relate to social constructionism as defined by Crotty (1998). Consequently, the theoretical activity involved engagement in exploring scientific argument in depth as a process and a structure employing constructionist principles in a social setting with other teachers; the design tools were a range of activities, readings, and scientific inquiries to provide experience in aspects of the NoS (Sandoval, 2004). Sandoval (2004) indicates that the focus of design in DBR is on the "design of interventions including designed technologies, curricular materials and participation structures" (p. 213). The main focus of this research was on the design and development of curricular materials and participation structures that could build teachers ability to effectively teach the NoS as defined in the *NZC* through increasing their understanding of the NoS.

In researching the appropriate methodology to utilise to provide responses to the research questions, participatory action research theory was explored. This theory proposes that if practice is to be transformed, then researchers and practitioners must be linked together in such a way that the collaborative research project enlightens and transforms through critical reflection, leading to practical actions (Kemmis & Wilkinson, 1998). Initially it appeared to

be a possible approach to employ, however, Fox, Martin, and Green's (2007) description of the key features of participatory action research as being the collaborative nature of the participants in the problem solving situation which is focussed on improving teaching practice, therefore to use participatory action research as the methodology, the participants would need to identify the issue and want to address this through classroom research. From my work as a facilitator working with groups of teachers on implementing the intent of the science learning area of *NZC*, I was aware that many teachers did not understand the overarching nature of the NoS, and consequently would not readily engage in a participatory action research programme focussed on an aspect they were unaware of being an issue (Ministry of Education, 2007). This resulted in an exploration of other methodologies on which to frame this research. It became apparent that DBR provided possibilities due to the fact that it is "grounded in both theory and real world context" (Sandoval, 2004, p. 214), and because it is aimed at providing flexibility. It is also responsive to the effects of the intervention so that they are continually evolving in response to the situation. I also like the concept of a collaborative approach between researchers and practitioners as this seems to fit my question where it seemed that participatory action research did not. The concept of a research design continually evolving in order to improve the process is both challenging and innovative, but must require a lot of careful analysis and reflection by the researcher and the practitioner, which would need to be addressed in the research methods developed.

Wood and Berry (2003) discuss the use of DBR as an effective research approach to use in designing professional development models and identify five reasons for its value. These reasons are:

For the researcher: the product of a professional development model

- is developed and tested and is subject to implementation, reflection and revision as it passes through a series of iterations;

- is influenced by considerations of other models and theories as it is refined;
- enables the researcher to be positioned “as a an interventionist rather than a participant observer, in a collaborative, reflective relationship with the teachers as the professional development model evolves and is tested and revised” (Wood & Berry, 2003, p. 196)

For the teacher: the product provides

- tools and strategies or mechanisms to use with their students;
- results that can be shared with others.

In addition, Wood and Berry (2003) suggest a number of professional development settings where they consider DBR would be an appropriate research approach as it can provide the opportunity to address “complexities of ... teaching as well as teacher development while allowing for teacher educator/researcher reflections and revisions of the model” (p. 196).

3.3 Part 2. Methodology

The aim of this research was to test and build an intervention for use with teachers to enable them to develop the intent of the science learning area of the *NZC* (Ministry of Education, 2007). The *NZC* is underpinned by both sociocultural and constructivist theoretical concepts, thus strategies that address these concepts had to be incorporated in the professional development programme designed to build teachers’ NoS capability. A learning environment emphasising the NoS and utilising constructivist teaching approaches was designed.

It was important, therefore, to elicit the teacher/participants assumptions, beliefs, and practices about their own teaching practice and use this knowledge to develop a professional development programme that challenged participants to construct new understandings, practices, and beliefs (Skamp, 2004) aligning with the NoS intent of the *NZC*. At the same

time, the programme devised had to diminish the role of the facilitator as the expert, instead emphasising facilitation using open-ended problem-solving contexts for each workshop with limited pre-planned activities to ensure alignment with constructivist principles.

If teacher/participants perceived their role as helping students to learn about and understand the world, they are likely to prepare hands-on activities and strategies and present these to students in a rational, logical order (Rennie, 2006). This learning process would be enhanced if the participants became a community of learners engaging in collaborative learning as they constructed and made meaning within a social setting, discussing their own interpretation of the activities, and aligned these with new ideas and concepts presented through the activities. Skamp (2004) suggests that a similar approach could be applied to teacher professional development, where engaging as a community of learners could strengthen their conceptual understanding. This concept is acknowledged in both social-constructionism and socio-cultural theory (Crotty, 1998; Skamp, 2004). Constructionism is a theory of learning, and places emphasis on developing concepts through a series of active processes that result in new ideas being incorporated within existing mental models, and by refining existing conceptual frameworks (Crotty, 1998). Skamp (2004) stresses that for this to occur, cognitive dissonance must be created so that conceptual change results, leading to the adoption of scientific conceptions in place of an individual's own conception. Socio-cultural theory also underpinned this study as my own belief systems, values, and practices and those of participant teachers influenced individual assumptions and teaching practices (Wertsch, 1990; Skamp, 2004). Thus the intervention had to ensure the development of participants as a community of learners and provided activities that created dissonance with their existing mental models.

In order to develop an effective professional development programme, as the facilitator for the intervention, reflection on my facilitation practice was needed to ensure the professional

development enabled teachers to confront the underlying philosophies, beliefs, and assumptions of their science teaching (Ovens, 2000). My approach to facilitation is underpinned by my acknowledgement of the constructivist nature of teaching and learning and by the Ovens (2000) “inquiry model of professional development” (p. 208) which identifies three elements within the inquiry. These elements are interpretation, understanding, and application. Interpretation involves reflecting on how you came to interpret your own actions and ideas of others to lead to self-development; understanding requires an appreciation of others ideas to understand and use their perspectives to build your own actions and interpretations; and application involves improvement of practice through development of ideas based on critical incorporation of own and others ideas (Ovens, 2000).

As professional development facilitator, I was involved in the research, planning, and development of appropriate activities to develop the NoS understanding. Both participants and researcher needed shared common understandings of the intended outcomes for the professional development. I had to be prepared to support the teachers throughout the cycles of the programme, through individual classroom observations, and feedback sessions. This required the establishment of an open and inclusive relationship with the teachers that enabled honest communication during the programme. However throughout the professional development intervention it was important for me to maintain objectivity and accuracy when recording and analysing information, and to ensure I did not produce constructs that were explicitly stated by participants. In addition, I maintained respect for the privileged information participants shared with me as part of their reflection and discussion, particularly relating to classroom observations, and had to ensure any confidences were not breached (Mutch, 2005). To ensure the effectiveness of my facilitation of the intervention, I personally engaged in a critically reflection process after each workshop with a colleague, and sought feedback on my facilitation from participants in their journalling and sought suggestions for improvement of the sessions.

DBR methodology provides a mechanism for developing an intervention which involves the bringing together of theory, design, and pedagogical practice as indicated by Joseph (2004) and Collins et al. (2004). The intent of my research was to enable teachers to learn more about the teaching of the NoS by designing a professional development programme that, through a series of iterations, became an effective intervention to support and activate effective teaching of the NoS. I used research on both the NoS and effective professional development in science to improve the effectiveness of the programme. This entailed improvement in my practice as a facilitator and researcher, as well as increased knowledge of the theory and design of the intervention over time. To enable this, the team included teachers as implementers of the intervention, myself as researcher, and peers as supporting facilitators. However, I was responsible for the design, research, and practice of the intervention.

This aligns with Cobb, Confrey, diSessa, Lehrer, and Schauble's (2003) DBR approach, as it addresses their suggested three main phases of the design:

- preparation for the design experiment,
- conducting/implementing the experiment, and
- retrospective analysis that includes systematically working through the data using clear criteria when making any inferences.

The four critical elements of the design experiment indicated by Cobb et al. (2003) were also addressed. First, a clear view of possible learning programmes with identified on-going support and communication among participants and facilitator; second, continuing development of relationships with the participants; third, an understanding of both adult and

student learning processes; and fourth, engagement in regular debriefing sessions (Cobb et al., 2003).

As DBR studies real-world learning environments, the researcher has to continually make choices and refine the research, so that the actual questions to follow in the research may change and evolve as the intervention is enacted (Joseph, 2004). This is the result of the way the intervention impacts on the learners, their culture, and their motivation to engage with the intervention. Thus, as part of the reflection on the first iteration, it was important to identify the aspects that motivated and engaged the learners, and any subsequent theoretical and philosophical questions that arose and impacted on the intervention. In other words, analysis of the first design experiment was critical as it identified the questions and pathways for the on-going professional development programme to address and to develop solutions for these (Joseph, 2004).

Another aspect of DBR is the overwhelming amount of both quantitative and qualitative data gathered during the implementation and refining of the design. All of this may not ultimately be used, however it needs to be collected and collated in order to identify participants' needs, and enable appropriate linked learning activities to be developed (Radnor, 2001).

To develop an initial intervention, two aspects of teacher belief needed to be identified; the teachers' understanding of the NoS, and the theoretical underpinning of their science teaching practice. These are complex, and not easily obtained through any one technique. Consequently, questionnaires and semi-structured interviews were developed in order to gain an understanding of the teachers' theoretical perspectives, reveal their approach to science teaching and the NoS, and elicit their underpinning beliefs and practices.

Both questionnaires and interviews have limitations. Initially, the participants' understanding of NoS was to be identified through the use of the VNoS questionnaire which used written

responses to ascertain perspectives on NoS aspects (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). To reduce the problems common with written questionnaires, the Nature of Science as Argument Questionnaire (NSAAQ) developed by Sampson and Clark (2006) was used to measure key aspects of participants' epistemological understanding of the nature of scientific knowledge. The NSAAQ provides information on four specific aspects of NoS: the nature of scientific knowledge; how scientific methods are used to generate that knowledge; how that knowledge is evaluated; and whether participants believe science is a socially and culturally embedded practice. The questionnaire was validated by its designers using content, translational, face, convergent, discriminant, concurrent and criterion validity, and thus provided data that allowed valid conclusions to be made relating to the four identified aspects of the NoS (Sampson & Clark, 2006). The four aspects of the NSAAQ link closely to some of the aspects of the NoS identified in *NZC*, namely understanding about science, investigating in science, and participation and contributing in science. Each question presents two contrasting views on aspects of NoS, one from a naïve perspective, the other of an informed perspective, with a five point scale separating the two statements (Sampson, 2006). In responding to each question, participants choose either 1 or 5 indicative of agreement with the specific view, or 2, 3 or 4 as a weighted response to either view. In constructing the questionnaire typical naïve responses given by students (as reported in literature (Lederman et al., 2002) were used to overcome interpretation issues with the NoS contrasting views (Sampson & Clark, 2006). As with any questionnaire that uses a bipolar semantic index, there may be inconsistencies in participant responses depending on the thinking of the individual at the time, and they may not demonstrate a totally naïve view across all the questions relating to a particular aspect of the NSAAQ survey (Halloun, 2001; Sampson, 2006). The NSAAQ survey endeavours to overcome this issue by including at least 5 questions addressing each of the identified aspects of NoS. The NSAAQ questionnaire did not cover the *NZC* aspect communicating in science as these achievement objectives are not

reflected within internationally accepted NoS concepts. Teachers' understanding of this aspect was assessed by including questions relating to Communicating in Science within the semi-structured interview and from their reflection on their teaching practice relating to the indicators of the curriculum levels of the *New Zealand Curriculum Exemplars: The Science Matrices Progress Indicators* (Ministry of Education, 2004).

The semi-structured interview prior to the intervention was used to identify consistency between participant's responses to the four aspects of the NSAAQ survey in order to reveal if their view was naïve or consistent with internationally accepted NoS views as defined by Lederman et al. (2002). The interviewer established a relationship with the teachers prior to the intervention. To overcome issues with interviews, a semi-structured approach was used with a series of ideas for the interviewer to pick up on with the participant. These ideas were raised within different sections of the interview to allow for revisiting the participants views from different perspectives (Radnor, 2001). The range of concepts covered within the interviews was broad to allow participants the opportunity to share a range of ideas relating to their understanding of science and their ability to contribute to the professional development design while personally gaining from the experience. To ensure participants were relaxed and able to commit to the professional development, initial interviews were arranged at times and locations free from interruptions to suit them (Mutch, 2005). The information gathered from the interviews prior to the workshops was analysed to identify trends among participants relating to teaching practice, understanding of science learning area as described by the NZC, as well as underpinning beliefs. The findings enabled a general but flexible framework to be generated for the first workshop to challenge individual assumptions, beliefs, and practices. Journalling responses from the first and subsequent workshops were analysed to provide guidance on the refinements required to the initial design of the intervention providing participant input into the design.

The professional development intervention adapted the seven design principles identified by Ma and Harmon (2009) as being appropriate to consider when developing a solution to a DBR problem. Applying the principles described by Ma and Harmon (2009) to the intervention design for the NoS intervention led to the consideration of the following seven principles:

- Principle 1. The tool developed should support teachers to explore a way to teach the NoS. Literature suggests that teachers will learn best when they reflect on their own teaching and on others' experiences (Guskey, 2003; Lieberman & Pointer Mace, 2008; Ma & Harmon, 2009).
- Principle 2. The intervention should include a built-in tool for teachers to “share their experiential knowledge” and “collectively construct context specific knowledge” (Ma & Harmon, 2009, p. 87) while taking into consideration the limited time teachers have available for collaboration.
- Principle 3. The tool “should provide pedagogical and technical support” (Ma & Harmon, 2009, p. 87) on how to implement strategies and activities incorporated into the tool.
- Principle 4. The tool “should provide a variety of content including subject matter content knowledge, content specific pedagogical knowledge and technical knowledge” (Ma & Harmon, 2009, p. 88), and include case studies that include learning outcomes, teaching strategies and course effectiveness to “embed pedagogical knowledge, ... content knowledge, content specific pedagogical knowledge” (p. 88).
- Principle 5. The tool “should provide multiple features” to enable participants to “access content” (Ma & Harmon, 2009, p. 88) to satisfy a range of learning styles, learning needs and information needs, such as a clear knowledge of the information to be sought when carrying out searches.

- Principle 6. The tool should use “common language to communicate” and provide “content access”, so that there is a “shared language among researcher, and participants to avoid difficulty in using keywords to conduct effective searches” (Ma & Harmon, 2009, pp. 88-89).
- Principle 7. The tool should provide support to those with both naïve and more experienced views of the NoS, and should be cognisant of the differing needs of teachers with naïve NoS capability compared to those with experienced capability. Activities, strategies, and approaches to address these differing needs should be incorporated (Ma & Harmon, 2009).

Ma and Harmon (2009) identify the need to clarify the purpose of the iterations and to generate the research issues that need to be focussed on for each iteration. They also describe four steps in developing the prototype, the first step being to decide the scope of the prototype. In this research, the prototype was an in-depth professional development programme for science teachers addressing ability to incorporate the NoS within their teaching and learning programmes as required by the *NZC*. The second step in Ma and Harmon’s process was the need to identify the tools for developing the prototype. The tools used included NSAAQ survey, workshops, personal reflection, online discussions, activities, and classroom observations for the participants. Thirdly, they describe the need “to identify a process for building the prototype” (p. 81). This was addressed by using literature on effective science professional development to provide guidance on components and approaches to consider, including suggestions on the time that needs to be allocated to bring about sustained change in teacher practice (Guskey, 2003; Hanuscin, Akerson, & Phillipson-Mower, 2006; Supovitz & Turner, 2000). The fourth step in the process was the “development of content for the prototype” and the need to include “case notes, conceptual models” (Ma & Harmon, 2009, pp. 81 - 82) and supporting materials from a range of sources and demonstrating a range of instructional methods. Guidance for possible content was

obtained from materials published by international researchers in the NoS such as Lederman and Zeidler (1987), Skamp (2004), Abd-El-Khalick and Lederman (2000), Akerson and Abd-El-Khalick (2003), and Akerson and Hanuscin (2007).

Ma and Harmon's (2009) paper highlights four questions to discuss with participants in the semi-structured interviews prior to designing the first iteration of the prototype for an intervention. Their four questions were modified to address this study as:

- How do teachers perceive a professional development programme as a tool to support their teaching of the NoS as outlined in the *NZC*?
- What do teachers perceive they would accomplish in a professional development programme that would support their teaching?
- What types of content do teachers perceive they would need in an online facility to support their teaching through the NoS?
- What major features do teachers perceive should be part of a professional development programme that supports them to develop programmes of learning that develop the NoS concepts with their students?

The questions were used in the first workshop session, and the responses were considered when redesigning the prototype and clarifying the purpose of an iteration.

To overcome difficulties with journalling, time for making entries was provided during the professional development workshop sessions in addition to the expectation of participants making regular electronic updates. The journalling was structured with a series of questions for reflection that encouraged participants to notice any emerging patterns as they engaged their students with activities. The questions assisted them to identify how the activity evolved and provided the opportunity to reflect on their own practice and beliefs. This process also

prompted them to notice any dissonance or emotional responses to the activities both from them and their students.

A concern regarding the development of the intervention tool was that teachers may perceive it as a range of tasks focussed on the NoS to be used with classes. Thus, the intervention incorporated challenges that created dissonance with teachers' existing concepts and beliefs about science so that they reflected on the basis of their beliefs and considered novel concepts and incorporated these into their schema (Supovitz & Turner, 2000).

Use of two iterations of the programme with two different clusters of teachers, following the development of the programme with the first cluster, allowed the study of science programmes in a number of schools in Southern region of New Zealand following the programme developed through DBR. The data was gathered in each teacher's school, including observations in classrooms or department meetings, secondary data from journals, lesson plans, unit plans and schemes, student activities and worksheets. Use of this range of data enabled an identified weakness of this methodology to be addressed, namely the bias and reliability of participants' evidence that can result from only using reflection and questioning. The use of three clusters allowed for comparison of the programmes developed by different teachers in response to the intervention. This provided data on the similarities and differences among the teacher participant's programmes thus tested the effectiveness of the intervention.

Kelly (2004) and Dede (2004) identified issues relating to the large and often unmanageable amounts of data collected as part of DBR, and that selection of appropriate samples in the analysis can lead to researcher bias. As the professional development programme facilitator, I needed to build secure relationships with participants so that personal interactions did not bias outcomes, or my practice create barriers to the implementation of interventions for the participants. In addition, possible bias had to be addressed to ensure validity and reliability of data analysis through data triangulation, and any mismatch between espoused and actual

practice was identified, resulting in rich data for analysis which led to a trustworthy report on the effectiveness of the professional development programme (Guskey, 2000).

To obtain credible and valid data from this (DBR) there was:

1. Triangulation of data through use of both qualitative and quantitative methods collected regularly throughout the design phases.
2. Progressive modifications of the workshops through a series of iterations together with regular contact with participants to ensure maintenance of relationships, and enable the intervention to be responsive to teachers' needs, while building individual NoS capability.
3. Gathering of a range of data over time together with careful recording of both processes and changes in a systematic and non-subjective manner so biased interpretation of the data was avoided (Collins et al., 2004).

3.3.1 Participants.

The participants in this research were three clusters of Year 1 to 10 science teachers in the Southern region of New Zealand who wished to develop their NoS capability to address the NZC intent. Teachers from this region were invited to participate in the research programme. Initial invitation was through Education Support Services school selection processes. It was important that I had not previously worked with the teachers so that any "willingness to please" response was reduced as much as possible. The teachers were grouped on a geographical basis to enable workshop meetings within their local region. Each geographic region was assigned a numeric code (1, 2, or 3) and each individual a letter related to their name giving each participant an alphanumeric code to use in the data analysis and reporting within Chapters 4 and 5.

The three groups of 12-16 teachers (two per school) from 23 schools engaged in short-term, in-depth professional development over three terms to address the implementation of *NZC* science learning area.

3.3.2 Design interventions.

The professional development programme was designed to:

- identify congruence of participants' understanding of the NoS with the intent of that of the science learning area in the *NZC*, and then develop a programme of professional learning to address the congruence or lack of it;
- initially focus on unpacking a topic such as scientific argument as a tool to focus on the NoS aspects, *Understanding Science and Communicating in Science*;
- incorporate some structured activities to develop specific NoS aspects, such as scientific investigation and scientific understanding or participating in socio-scientific issues;
- be flexible enough to allow for modification as participants' needs and interests were determined;
- be responsive to participants and allow for discussion, reflection, sharing of aspects trialled by them;
- be modified in response to findings/feedback from the first workshop session in collaboration with the participants' input from the first group (Group 1);
- be used in a modified format with the following two groups (Group 2 and Group 3);
- run in 20 to 25 week cycles, involving participants in 80 to 100 hours of activities, including five workshop sessions; up to three classroom observations and feedback sessions; in-school meetings; on-line sharing community; individual journalling, reading, activity development, and reflection;

- align the theory underpinning the approach, the design of the professional development programme, and interviews and observations of participants and professional development session practice, as well as the measurement processes engaged (Cobb et al., 2003).

The design of the professional development intervention will be reported on in Chapter 4 using the model suggested by Collins et al. (2004) with five sections: “Goals and elements of the design; Settings where implemented; Description of each phase; Outcomes found; and Lessons learned” (pp. 38-39).

3.3.3 Instruments and data collection.

The following data collection processes were used to provide evidence for the refinement of the design and the ways the professional development programme addressed the research questions.

1. A bipolar semantic differential survey using the Nature of Science as argument questionnaire (NSAAQ) (Sampson & Clark, 2006). This survey was used with primary and secondary teachers to ascertain what teachers considered to be the important aspects of science, with particular focus on the NoS (see Appendix 3). Invitations to participate were sent to 50 schools in the Southern region of New Zealand, with 32 schools responding and 86 completed NSAAQ surveys returned from the 100 forms sent out. The NSAAQ data was compared with the data from teachers participating in the intervention to provide an indication of changes in teachers’ NoS understanding with the professional development programme (Waters-Adam, 2006).
2. The NSAAQ survey (Sampson & Clark, 2006) was used with participants at the first workshop of the intervention programme and repeated at the end of the

programme to provide an understanding of the participants' NoS beliefs and any changes.

3. Individual semi-structured interviews were conducted pre and post intervention with each participant on programme to clarify their NoS views and correlate/confirm with NSAAQ findings. These were conducted either at the participant's school or alongside the workshop programme.
4. Classroom observations were used to identify congruence between participants' espoused and actual practice, and to observe and record the NoS processes in their teaching programme to identify next steps for intervention programme. These involved all participants on the intervention at the start and after 3 sessions. Time following the observations provided teacher and facilitator opportunity for reflection and feedback to identify aspects for further development or trialling.
5. Student voice was obtained using three questions: What are you learning? Why are you learning this? How does your teacher help you with your learning? These allowed the researcher to determine if there was congruence between what teachers believed/stated they are teaching and students' learning/understanding of the NoS. Responses to specific questions on learning and the NoS (see Appendix 4) identified students' common ideas on the NoS and learning concepts in each teacher's class. Sharing student voice with teachers provided an impetus for change in practice and also assisted with identification of needs to focus workshop content on.
6. Document analysis including staff meeting records, lesson plans from during professional development programme, teachers' planning and teacher archival materials were used to identify professional development in science, approaches to teaching and planning, compare espoused and actual practice.

7. Demographic data of a limited nature was collected from participating teachers to allow trends relating to gender, tertiary science level attainment, years of teaching, confidence in teaching science contexts to be identified.

3.3.4 Data analysis.

Thematic analysis of documents, classroom observations, and interviews were carried out using a qualitative data analysis programme NVIVO throughout the intervention. The interviews were transcribed and common and recurring ideas were highlighted and compared across participants. Common themes were then identified and used to guide development of the intervention and discussion within the results (Mutch, 2005). A similar process was used for the participants' journalling responses from each workshop. These were all transcribed and scanned to identify common ideas to provide both positive and negative feedback on the structure and effectiveness of the intervention design. Initial analysis occurred by comparing the responses under each journalling question, followed by grouping of responses under common themes. In this way participant responses could be quantified.

Workshops were refined as iterations of the DBR process, to lead to a programme that addressed the teachers' identified needs by building their NoS capability. At the same time, participants developed their knowledge and theory of practice to enable them to plan and implement learning programmes that effectively developed student capability in the NoS by challenging students' understanding of scientific concepts.

Quantifiable data from the NSAAQ surveys was analysed using statistical methods and SPSS. The consistency of the responses among the participants' responses to the individual NSAAQ items was calculated by using Cronbach alpha coefficient as 0.68 for the initial sampling across the Lower South Island which indicated that the questionnaire had sufficient internal consistency (Sampson, 2006).

Responses to the first underpinning question, “What are teachers’ existing understandings of the NoS?” were gained from both the bipolar semantic survey NSAAQ questionnaire and semi-structured interviews.

Both qualitative and quantitative data gathered via interviews, classroom observations, review of documentation and a repeat of the NSAAQ provided data for the second question – “How does a targeted in-depth professional development approach build teachers’ understanding of the NoS as described in the Science Learning Area of *NZC* ?”

Data on the third question, “How is increased NoS understanding evidenced in teacher practice?” included qualitative and quantitative data from classroom observations, analysis of assessment activities and planning, student voice surveys.

3.3.5 Results

The analysed data were examined with reference to the three underpinning research questions, and any emerging themes identified and reviewed.

Vignettes of three participants were constructed using these teachers’ reflections, workshop feedback, and discussions from classroom observations by the researcher. The participants whose vignettes were shared were selected as being representative across the three regional groups on their journaling and interview responses, gender balance, sector balance (with one from each of Year 1-6, 7-8 and 9-10), and participation in the in-school support component. During the writing of the vignettes, the content was read and discussed with each individual to ensure the accuracy of the transcription and summarising of their comments and their permission to share the incidents cited within the vignette.

Issues identified from the research process were identified and discussed. Features of the design intervention were summarised and issues requiring further investigation and

development were raised. Emergent theoretical perspectives from the design research were outlined. Conclusions are drawn on the effectiveness of the intervention designed as a result of the professional development programme in building participants' NoS understanding as well as consideration of subsequent changes in their teaching practices in science are reached.

The next chapter, Results, outlines the impact of professional development programme intervention designed to build teachers' NoS understanding as it is presented in the *NZC*. The impact of DBR methodology on the intervention design resulting from participants' feedback on the professional development programme will be described through the use of teacher reflections, feedback on the workshop sessions, and classroom observations. Section 4.3.2. will include facilitator reflections on the stages of development of the design intervention. The findings and their relationship to the theoretical perspectives will be outlined and conclusions to the research study will be shared in Chapter 5. Chapter 6 will then discuss the recommendations and implications of the results and suggest areas for further study.

Chapter 4. Results

4.1 Introduction

This chapter explores the results of the initial NSAAQ survey used to ascertain the depth of the NoS understanding of teachers in Southern region of New Zealand. The results from the survey were then used to assist in the design of an intervention as part of this research to develop teacher capability to deliver science teaching programmes that incorporated the aspects of the NoS described in *NZC*. Having ascertained the need to build teachers' theoretical understanding of the NoS from the initial NSAAQ survey, the purpose of this study was to design a professional development intervention that would build NoS capability and thus facilitate changes in science teaching practice to address the requirements of the *NZC*. To enable such a design to be constructed, the first approach was to identify teachers' existing understandings of NoS. As described in Chapter 3, Methodology, the NSAAQ survey was used to establish this understanding (Sampson & Clark, 2006). The analysis of the results from this survey was then used to determine the aspects of NoS that would be important to incorporate into the professional development intervention design.

The design-based research methodology (DBR) was used to create the professional development intervention. The DBR approach was outlined in the previous chapter. The intervention was developed and refined with three clusters of participating teachers from the Southern region of New Zealand. The qualitative evidence obtained from participants' journalling and reflective responses has been summarised and used to provide evidence of the intervention effectiveness. Included alongside these responses are selected reflections and statements from teachers involved in the in-school component of the design. In addition, results of the pre and post intervention NSAAQ survey are discussed. All of these are then

used to ascertain how effectively a targeted in-depth professional development approach built teachers' understanding of NoS as described in the science learning area of the *NZC*.

Section 4.6 reports on researcher observations of three participants' classroom teaching, including their reflections and anecdotal evidence, and these are collectively used to demonstrate how increased NoS understanding was evidenced in teacher practice. This information is presented as three vignettes which were developed by the researcher together with each participant, and were chosen as representative of the responses from all participants who engaged with the in-school support element of the intervention design.

Finally, the generic design that evolved as part of the design experiment within the professional development is shared, while the detailed version of the intervention, including activities and focus of each workshop is attached in the appendix 5.

4.2 Initial NSAAQ Survey of Science Teachers in the Southern region of New Zealand

The NSAAQ was selected to identify the level of understanding of NoS existing in science teachers in the Lower South Island region. It aligns with the aspects of NoS consistent with the views expressed in the science learning area of the *NZC* (Ministry of Education, 2007). Letters were sent to 50 colleges, high, area and intermediate schools in the Lower South Island region with Year 7 to 10 classes, and 32 schools in the region (63.3%) agreed to undertake the NSAAQ survey with their science teachers. These schools were teaching science to Year 7-13 students in the Lower South Island of New Zealand. This included: Year 7/8 intermediate schools, Year 7-13 colleges, Year 9- 13 high schools, and Year 1-13 area schools with designated science teachers. One hundred surveys were sent to the 32 schools, and 86 completed NSAAQ surveys were completed by teachers of Year 7-13 science from the range of schools in the Lower South Island.

4.2.1 Descriptive characteristics of respondents

The respondents completing the NSAAQ survey comprised 58% female, 42% male, and 60% of the respondents held science degrees (see Table 1 below). Of the males, 17% taught science in Year 7 and 8, and 25% of the females taught this level. The NSAAQ scores overall ranged from 55 to 111; male respondents' scores ranged from 55 to 111, and females scored from 70 to 107. It was decided not to carry out intensive analysis of the demographic data for this research as initial visual comparisons of the scores of respondents with science degrees, with those without tertiary science learning indicated limited relationships existed between level of science study and NSAAQ score, regardless of their teaching level, age, and gender. An indication of the lack of a relationship was shown where the two respondents with doctorates scored 80 and 96, while the range for those with MSc was from 80 – 107, for BSc 70 – 111, and for no tertiary level science study the range was 55 – 103.

Table 1. Summary of demographic data of NSAAQ respondents

Gender	Gender (%)	NSAAQ score	Science degree (%)	Teaching Year 7 – 8 (%)	Teaching Year 9 – 13 (%)	Age range (yrs)
Male	42.31	55 - 111	30.77	17.31	35.00	24 - 60
Female	57.69	70 - 107	28.85	25.00	32.69	25 - 61
Total	100	55 - 111	69.62	42.31	67.69	24 - 61

In scoring the responses to the NSAAQ survey, a naïve view was taken as a response of 1, 2 or 3, while an informed view was taken as a score of 4 or 5 on each of the 26 questions. This decision was based on the premise that participants who selected 3 for their response to any of the NSAAQ questions were deemed to be unable to make a distinction between a naïve view and an informed view, indicating limited understanding of the NoS as accepted from the

international perspective described in Chapter 2 (Sampson, 2006). The mean and standard deviation for each question was calculated (see Table 2 below). The range of the means for the questions was from 2.06 to 4.52, however the bipolar semantic scale used in the survey allows for whole number scores from 1 to 5, thus an average score would be 3. Effectively, a mean of 3.71 would indicate that survey participants tended towards an informed view of the NoS, and a mean of 2.75 could be taken as indicating a naïve view of the NoS. Using a mean of 3 or less to identify aspects of the NoS from the NSAAQ survey that may need addressing in an intervention, questions 1, 3, 9, 10, 14, and 22 were identified. This criteria did not allow questions with a mean of 3.06 (question 23), 3.09 (question 17), 3.15 (question 2) or 3.17 (question 5) to be selected as any mean below 4 indicates at least one respondent holds a naïve NoS view.

Table 2: Analysis NSAAQ questionnaire for naïve NoS views of science teachers from the Lower South Island.

Question Number	Question Informed viewpoint statement	M (SD)	Percentage participants responding 3, 2 or 1	Counted as Naïve view (intervention purposes)
Factor 1 What is the nature of scientific knowledge				
Qn 1 - 6				
Qn1	Scientific knowledge represents only one possible explanation or description of reality	2.75 (1.12)	67.3	Yes
Qn 2	Scientific knowledge should be considered tentative	3.15 (0.94)	59.6	Yes
Qn 3	Scientific knowledge is subjective	2.31 (1.13)	84.6	Yes
Qn 4	Scientific Knowledge usually changes over time as a result of new research and perspectives	4.52 (0.67)	9.6	
Qn 5	The concept of a species was invented by scientists as a way to describe life on earth	3.17 (1.54)	48.0	Yes
Qn 6	Scientific knowledge is best described as an attempt to describe and explain how the world works	4.38 (0.80)	15.4	
Factor 1	Responses summary	3.38 (0.53)		Question 1, 2, 3, 5
Factor 2 How is scientific knowledge generated				
Qn 7 - 12				
Qn 7	Experiments are important in science as they can be used to generate reliable evidence	3.71 (0.96)	51.9	Yes

Question Number	Question	M (SD)	Percentage participants responding 3, 2 or 1	Counted as Naïve view (intervention purposes)
	Informed viewpoint statement			
Qn 8	The methods used by scientists vary based on the purpose of the research and the discipline	4.23 (1.00)	23.0	
Qn 9	The methods used to generate scientific values are based on a set of values rather than a set of techniques	2.06 (1.06)	92.3	Yes
Qn 10	Science is best described as a process of explanation and argument	2.38 (0.89)	94.2	Yes
Qn 11	An experiment is used to test an idea	3.87 (0.91)	44.2	Yes
Qn 12	Within the scientific community debates and discussions that focus on the context, processes and products of inquiry are common	4.23 (1.08)	23.1	
Factor 2	Responses summary	3.41 (0.41)		Question 7, 9, 10, 11
Factor 3	What counts as reliable and valid scientific knowledge			
	Qn 13 - 19			
Qn 13	Scientific knowledge can only be considered trustworthy if the methods, data and interpretations of the study have been shared and critiqued	3.46 (1.13)	55.7	Yes
Qn 14	It is impossible to gather enough evidence to prove something true	2.71 (1.14)	73.1	Yes
Qn 15	The reliability and trustworthiness of data should always be questioned	4.21 (0.75)	15.4	
Qn 16	Scientists know that atoms exist because they have made observations that can only be explained by the existence of such particles	3.58 (1.18)	50.0	Yes
Qn 17	Biases and errors are unavoidable during a scientific investigation	3.09 (1.30)	55.8	Yes
Qn 18	A theory can still be useful even if one or more facts contradict that theory	3.44 (1.16)	48.0	Yes
Qn 19	Scientists can only assume that a chemical causes cancer if they discover that people who have worked with that chemical develop cancer more often than people who have never worked that chemical	4.15 (1.04)	21.2	
Factor 3	Responses summary	3.52 (0.54)		Question 13, 14, 16, 17, 18
Factor 4	What role do scientists play in generation of scientific knowledge			
Qn 20	In order to interpret data they gather, scientists rely on their prior knowledge, logic and creativity	3.85 (1.14)	26.9	
Qn 21	Scientists are influenced by social factors, their personal beliefs and past research	3.12 (1.13)	67.3	Yes
Qn 22	Successful scientists are able to persuade other members of the scientific community better than unsuccessful scientists	2.67 (1.29)	75.0	Yes
Qn 23	Two scientists (with the same expertise) reviewing the same data will often reach different conclusions	3.06 (1.11)	65.4	Yes
Qn 24	A scientist's personal beliefs and training influences what they believe counts as evidence	3.37 (1.14)	46.1	Yes
Qn 25	The observations made by two different scientists about the same phenomenon can be different	3.85 (0.89)	32.6	
Qn 26	A scientist's conclusions may be wrong even though scientists are experts	4.02 (1.04)	28.8	

Question Number	Question	M (SD)	Percentage participants responding 3, 2 or 1	Counted as Naïve view (intervention purposes)
	Informed viewpoint statement			
	in their field			
Factor 4	Responses summary	3.42 (0.66)		Question 21, 22, 23, 24
	Overall total score	88.71 (10.97)		
		3.41 (0.42)		

The decision was made to calculate the percentage of respondents who indicated 1, 2, or 3 for each question as this would provide an indication of the percentage of respondents holding naïve NoS views. The range for the percentages was found to be from 9.6 to 94.3%. However, for those questions where teachers' responses tended to the naïve view point, as they had responded with 1, 2 or 3 for a question, the percentages ranged from 44.2% to 94.3%, while those questions where respondents tended to demonstrate an informed view of NoS by responding with 4 or 5, showed percentage responses ranging from 9.6 to 32.6%. The purpose of this analysis was to identify areas where large proportions of teachers held naïve views, rather than the areas where on average teachers held naïve views, therefore frequencies were seen as being more important to use than the means. Reinforcing the prioritising of percentages over means resulted from the consideration of data from specific questions. For example, question 7 had a mean score of 3.71, while the raw scores of the NSAAQ survey showed 51.9% or 45 of the 86 participants responded with 1, 2 or 3 (or naïve view) compared to 25 who selected 5 showed a fully informed view on the bipolar semantic scale, and 16 who selected 4 on the scale. A similar observation was made for question 16 with a mean score of 3.58, where 43 participants held naïve views by scoring as 1, 2, or 3, and 17 indicated 4 on the bipolar semantic scale, and 26 indicated 5 on the scale. Consequently, it became evident that the mean alone should not be used as a determinant of the aspects to include in the intervention. Use of the dual criteria resulted in the aspects covered in questions 7, 13, 16, 18, and 24 being considered for inclusion in the intervention. In addition, questions 5, 18, and 24

were included as their percentage responses being 48.0, 48.0 and 46.1% respectively indicated the need to ensure teachers developed an understanding of these aspects as well to build their overall NoS understanding. Question 11 was also added with its 44.2% response due to the natural gap in percentage response between this question and the next percentage at 32.6% (question 25). This highlighted that there was a distinct gap between 32.6 and 44.2%, which led to the decision to place greater emphasis on the percentage rather than the mean score in identifying the aspects of NoS that would need to be addressed in an intervention to develop NoS understanding of teachers. The result was that overall, respondents were identified as holding naïve views for 17 questions, so an intervention should address the NoS aspects covered by these questions. When considering these questions for which respondents held naïve views under the four factors identified by Sampson and Clark (2006) in their development and validating of the NSAAQ tool, each factor contained at least four questions. Factors 1 and 2 both contained four of six questions; Factor 3 had five of seven questions, and Factor 4 showed four of seven questions with a naïve view. Consequently, an intervention would need to address the concepts covered in all four factors.

The mean score for the NSAAQ survey was 88.71 with a standard deviation of 10.97, thus 67% of respondents scored between 77.74 and 99.68 from the possible score of 130, while the range in the scores was from 55 to 111.

More than half the teachers completing the survey demonstrated naïve views of NoS on 17 of the 26 questions in the NSAAQ survey, and thus linked to positivist theoretical perspectives. Logical positivist approaches to teaching tend to focus on conveying knowledge as a series of key facts to be learned by students (Crotty, 1998). Thus teachers holding positivist views of science teaching will be primarily concerned with establishing facts about the world in which we live, and are likely to perceive scientific knowledge as a set of believable facts to be passed on to their students (Abd-El-Khalick & Lederman, 2000). Such a teacher will not

perceive scientific knowledge as being inclusive of and influenced by the scientists' opinions, feelings and assumptions; and consequently will present science as being value neutral (Crotty, 1998; Mutch, 2005). Considering this perception of science, it is understandable that 84.6% of the teachers responded to Question 3 by indicating that "science knowledge is objective" and 67.3% responded to Question 21 indicating that "scientists are objective, social factors and their personal beliefs do not influence their work", as these responses correlate with the positivist theoretical perspective which "embraces the epistemology of objectivism" (Mutch, 2005, p. 27).

The analysis of the NSAAQ survey indicates the need to build teachers' understanding of the NoS as the overarching strand providing the focus for learning and building capability in the processes of science where the other (contextual) strands provide the contexts for this science learning. This highlights an issue for any intervention designed to build teachers' understanding of the NoS as defined within the *NZC* (Ministry of Education, 2007), as it has deeply embedded constructivist and sociocultural pedagogy which is at the opposite end of the spectrum to positivism. Thus the intervention design needed to create dissonance with the logical positivist views and encourage critical reflection by each teacher on their practice if the stated intent of the science learning area to be taught through the NoS is to be established as teacher practice (Elmore, Peterson, & McCarthy, 1996).

The results from the NSAAQ survey carried out with 86 New Zealand teachers compare with the results cited by Cetin, Erduran, and Kaya (2010) on the use of the NSAAQ survey with 114 pre-service chemistry teachers mainly in their third or fourth year of study at Turkish universities. The mean score for the NSAAQ for this group was 84.88 with a range from 59 – 112. The results from the New Zealand teachers and the Turkish per-service teachers are also similar in that both groups show greater naïve responses in the Factor 3 – What counts as reliable and valid scientific knowledge, and Factor 4 – What role do scientists play in the

generation of scientific knowledge. Cetin et al. (2010) raise the point that to improve in argumentation skills, the Turkish teachers will need to develop a greater understanding of these dimensions of NoS. In addition, their study raises the consideration that some science domains may provide further support for the teaching and learning of NoS, as pre-service teachers who had studied Physics achieved a mean NSAAQ score of 87.82. Aspects raised for further study include the need to focus learning at the early stages of education on particular NoS aspects, especially those relating to the nature of scientific knowledge and the “processes of knowledge generation and reasoning” (Cetin et al., 2010, p. 49).

4.3 Planning the Intervention

The initial NSAAQ survey established that 67% of teachers in the region completing the survey had naïve views of NoS, indicating there was a need for a professional development intervention to build this understanding to address the *NZC* requirements (Ministry of Education, 2007). Followup of the schools who had agreed to participate in the professional development intervention in response to the letter sent to schools in 2009 led to three groups being established to develop the design for the intervention. The groups were based on geographic location. A number of schools that had completed the expression of interest in 2009 were unable to participate in the 2010 professional development due to delays in its implementation that led to the programme not commencing until the end of Term 1, as they had committed to other PLD outcomes. Consequently, the opportunity to participate was extended to all schools teaching Year 1 to 10 science in the three locations. Group 1 had 12 participants, Group 2 had 16 participants, and Group 3 had 14 participants from a total of 23 schools. Only three of these participants had completed the initial NSAAQ survey to identify the need for the NoS professional development, although other members from eight of these schools had responded to the initial questionnaire. Table 3 below summarises the demographic information for the three groups. The 18 male and 24 female participants

ranged in age from 29 – 57 years and taught across Years 1 – 13. However, the focus for the intervention was Years 1 – 10 where NoS is “required learning for all students” (Ministry of Education, 2007, p. 29) across these years of schooling, and all participants taught at least one class within this age group. Only 47.62% of the participants had a tertiary science qualification; however the NSAAQ scores showed a similar spread to the initial survey carried out to determine the need for a NoS intervention. Thus it appears that science teachers with a tertiary science qualification do not necessarily demonstrate a consistent view of NoS from the internationally accepted criteria.

Table 3: Summary of demographic data of participants (n=42)

Gender	Gender	NSAAQ score	Science degree	Teaching Year 1 - 6	Teaching Year 7 - 8	Teaching Year 9 - 13	Age range (yrs)
Male	18	71 - 103	8	4	5	9	27 - 57
Female	24	54 - 103	12	5	7	12	29 - 57
Total	42	54 - 103	20	9	12	21	27 - 57

As design-based methodology was used in developing the intervention, an introductory session was used to enable participants in the three research groups to meet, have an introduction to the science learning area of the *NZC*, and engage in discourse to begin to establish each group as a professional learning community. This initial session provided a workshop structure based on the facilitation model common to Education Support Services facilitators, with the possibility that it could provide the basic structure for the intervention design. In this model, workshop outcomes were predetermined by the facilitator, along with activities to promote these outcomes which included the use of research evidence and theoretical readings to establish a basis for workshop activities. The structure also incorporated opportunities for reflection, sharing, discussion, and evaluation of concepts, followed by time for each participant to select a concept to trial within their school

programme. This approach was based on the effective facilitation practice approach identified by Timperley et al. (2007) in the *Teacher Professional Learning and Development: Best Evidence Synthesis Iteration*. The main reason for using an initial plan was my personal lack of confidence as the facilitator in relying on the participants to devise a programme that would satisfy their learning needs. After feedback from the first cluster, the initial session plan was modified for subsequent groups.

4.3.1 Reflection on DBR and implications for intervention development.

DBR as exemplified by Ma and Harmon (2009) must address seven principles. Principle 1 requires both facilitator and participants to construct a design that supports teachers to develop and explore a way to teach NoS through the use of their own and other's teaching experiences (Ma & Harmon, 2009).

The reading in the first workshop introduced participants to the constructivist underpinnings of the *NZC* and led to the exploration of the 5E model of constructivist teaching approach of Engage, Explore, Explain, Elaborate and Evaluate phases advocated by Skamp (2004, p. 332) as a tool on which to model the design. Use of the 5E approach allowed the co-construction of a design that enabled participants to explore ways to teach the NoS, and modelled an approach they could use in their classrooms. The 5E approach also addressed Ma and Harmon's (2009) principles. Principle 2 requires the tool/design should allow for sharing of "experiential knowledge and collective construction of context specific knowledge" (p. 87), as this occurred in the Elaboration phase. Principle 3 requires the provision of "pedagogical and technical support on how to implement strategies and activities" (p. 87) which occurred within the Exploration phase in the use of theoretical readings as well as having participants carry out student activities. The 5E approach addressed Principle 4 through the inclusion of learning activities and teaching strategies that enable participants to "embed pedagogical

knowledge, content knowledge and pedagogical content knowledge” (p. 88). By including a range of both practical and theoretical activities, the design of the intervention addressed Principle 5 which suggests the need for “multiple features in the tool to address a range of learning styles, learning needs and information needs” (p. 88). This led to the inclusion of participant discussion and sharing of ideas within the Explore and Explain phases of the 5E approach. This intervention satisfied Principles 6 and 7, as the activities developed a common language for communication (Principle 6, p. 88) and provided support for both those with “naïve views and more experienced views” (p. 89) of the NoS. The emphasis placed on the links from each activity or task to the NoS was an imperative to enable the tool to lead to improved NoS understanding of teachers (Ma & Harmon, 2009).

4.3.2 Personal response as facilitator

As a facilitator used to planning and conducting workshops that provide for specific outcomes through the provision of a series of activities, engaging in DBR to develop an intervention exposed me to challenges to my usual facilitation practice. Firstly, the design was not solely my responsibility, as it was determined by the participants, commented on by each group, and modified in response to their feedback. This resulted in the third group having a slightly modified workshop session to the first group for each of the five workshops in the series. However, once the generic design was established, the fourth and fifth workshop sessions were based on it, and any differences were in the activities within the design as a result of the specific NoS aspect being developed within the session. The differences were in the types of approaches and activities used, particularly in the Engagement phase of the sessions. Secondly, I had to recognise the importance of responding to the needs of participants, and had to allow time for sufficient discussion and sharing to build their understanding of the concepts relating to NoS (Ma & Harmon, 2009). In some sessions I had to accept that the theoretical understandings developed by participants did not attain the depth I had hoped

might have occurred, however this was partly because I had made assumptions about their existing understanding of the NoS aspect.

4.3.3 NSAAQ questionnaire at beginning of intervention (BoY).

To provide baseline quantitative data, all teachers participating in the workshops completed the NSAAQ questionnaire at the start of the first workshop to provide an indication of their understanding of the NoS. The analysis was carried out using the same protocols as for the initial survey where both the mean and the percentage responding with 1, 2, or 3 were considered to determine if the participant demonstrated a naïve view of the NoS. As shown in Table 4 (see p. 83), participants indicated naïve NoS understanding for questions 1, 2, 3, 5, 7, 9, 10, 13, 14, 16, 17, 18, 21, 22, 23, and 24. These were the same questions as identified in the initial NSAAQ survey of the wider sample of teachers (refer Table 1). Since both samples of teachers held naïve views for 16 of the 26 questions in the NSAAQ survey in the Lower South Island region, it is possible that such naïve views could be found among science teachers elsewhere in New Zealand. This could be taken as indicative that an intervention to build teachers understanding of the NoS could be applicable in other regions of New Zealand as teacher education programmes throughout New Zealand follow similar approaches. In general, the secondary teacher training consists of a one year course following completion of a science degree course, while primary teacher training consists of a three year programme including one or two semester courses in science during that time.

Table 4: Summary of Time 1 NSAAQ survey responses data analysis by group and overall.

Question Number	Question Informed view statement	Mean				Percentage 1, 2 or 3 response	View of NoS Naïve
		Group 1	Group 2	Group 3	Overall		
Factor 1	What is the nature of scientific knowledge?						
Qn 1-6							
Qn1	Scientific knowledge represents only one possible explanation or description of reality	2.9	2.6	2.4	2.6	80.56	Yes
Qn 2	Scientific knowledge should be considered tentative	3.7	3.0	2.7	3.2	55.56	Yes
Qn 3	Scientific knowledge is subjective	2.3	2.3	1.9	2.2	88.89	Yes
Qn 4	Scientific Knowledge usually changes over time as a result of new research and perspectives	4.6	4.7	4.6	4.6	0.00	
Qn 5	The concept of a species was invented by scientists as a way to describe life on earth	2.8	2.9	3.2	3.0	55.56	Yes
Qn 6	Scientific knowledge is best described as an attempt to describe and explain how the world works	4.5	4.1	4.2	4.3	0.08	
Factor 1	Responses summary	21.0/30 (70.0%)	20.2/30 (67.3%)	19.2/30 (64.0%)	20.1/30 (67.0%)	67.00	Question 1, 2, 3, 5
Factor 2	How is scientific knowledge generated?						
Qn 7 - 12							
Qn 7	Experiments are important in science as they can be used to generate reliable evidence	3.5	2.8	3.8	3.4	86.12	Yes
Qn 8	The methods used by scientists vary based on the purpose of the research and the discipline	4.5	3.4	3.3	3.7	27.78	
Qn 9	The methods used to generate scientific values are based on a set of values rather than a set of techniques	2.7	2.1	2.3	2.4	94.45	Yes
Qn 10	Science is best described as a process of explanation and argument	2.5	2.7	2.7	2.6	91.68	Yes
Qn 11	An experiment is used to test an idea	3.3	4.0	3.9	3.8	44.45	
Qn 12	Within the scientific community debates and discussions that focus on the context, processes and products of inquiry are common	4.5	3.5	4.5	4.2	19.45	
Factor 2	Responses summary	21.1/30 (70.3%)	18.4/30 (61.3%)	20.5/30 (68.3%)	20.0/30 (66.7%)	66.67	Question 7,9,10,11
Factor 3	What counts as reliable and valid scientific knowledge						
Qn 13-19							
Qn 13	Scientific knowledge can only be considered trustworthy if the methods, data and interpretations of the study have been shared and critiqued	3.1	3.3	3.7	3.4	58.34	Yes

Qn 14	It is impossible to gather enough evidence to prove something true	2.3	2.8	2.8	2.7	75.01	Yes
Qn 15	The reliability and trustworthiness of data should always be questioned	4.0	4.1	4.5	4.2	16.68	
Qn 16	Scientists know that atoms exist because they have made observations that can only be explained by the existence of such particles	3.1	3.2	3.2	3.2	52.78	Yes
Qn 17	Biases and errors are unavoidable during a scientific investigation	2.2	2.7	2.9	2.6	66.67	Yes
Qn 18	A theory can still be useful even if one or more facts contradict that theory	3.1	3.1	3.4	3.2	50.00	Yes
Qn 19	Scientists can only assume that a chemical causes cancer if they discover that people who have worked with that chemical develop cancer more often than people who have never worked that chemical	4.1	4.4	4.3	4.3	13.89	
Factor 3	Responses summary	22.1/35 (63.1%)	23.6/35 (67.4%)	25.1/35 (71.7%)	23.6/35 (67.4%)	67.40	Question 13,14,16,17, 18
Factor 4	What role do scientists play in generation of scientific knowledge						
Qn20- 26							
Qn 20	In order to interpret data they gather, scientists rely on their prior knowledge, logic and creativity	3.9	2.9	4.1	3.6	44.45	
Qn 21	Scientists are influenced by social factors, their personal beliefs and past research	2.1	3.0	3.2	2.8	66.67	Yes
Qn 22	Successful scientists are able to persuade other members of the scientific community better than unsuccessful scientists	3.0	2.3	2.2	2.5	75.00	Yes
Qn 23	Two scientists (with the same expertise) reviewing the same data will often reach different conclusions	3.1	2.9	3.2	3.1	66.67	Yes
Qn 24	A scientist's personal beliefs and training influences what they believe counts as evidence	3.1	2.9	3.3	3.1	52.78	Yes
Qn 25	The observations made by two different scientists about the same phenomenon can be different	3.9	3.6	4.0	3.8	30.56	
Qn 26	A scientists conclusions may be wrong even though scientists are experts in their field	3.4	4.0	3.9	3.8	30.56	
Factor 4	Responses summary	22.5/35 (64.3%)	21.6/35 (61.7%)	23.8/35 (68.0%)	22.7/35 (64.9%)	63.00	Question 21,22,23,24
All Factors	Overall total score	86.7/130 (66.7%)	83.1/130 (63.9%)	88.9/130 (68.4%)	86.2/130 (66.3%)	66.3	

The summary of the NSAAQ questionnaire indicates that at all three workshop locations, the participating teachers held naïve views of the NoS for four questions in each of Factors 1 and 4, five questions of Factor 3, and three questions of Factor 2. For each of the four factors defined in the NSAAQ survey, between 63 and 67 percent of participants held a naïve view of the NoS. This confirmed a definite need for the intervention to build participants' NoS understanding. There was little difference between the numbers showing naïve views in the different clusters, therefore it was deemed that a similar intervention could be applicable to each.

The factors of NSAAQ align with the NoS strands within the *NZC*: Factors 1 and 4 align with Understanding about Science; Factor 2 aligns with Investigating in Science; Factor 3 aligns more with Participating and Contributing, although also addressing elements of Understanding about Science. Understanding about Science as described within *NZC* is addressed by the NSAAQ Factor 1 “Nature of Scientific Knowledge”, identified by Sampson (2006) where the informed view statements used to base the NSAAQ on were:

“Scientific knowledge is a attempt to explain how things happen and why they happen; Scientific knowledge is revisable; Scientific knowledge varies in scope and purpose; Scientific knowledge varies in degree of certainty; Scientific knowledge is constructed by people; Scientific knowledge is theory-laden” (p. 11)

These statements align with the progressively developed Understanding about Science statements within *NZC* from Level 1 to Level 8 (Ministry of Education, 2007) and also with internationally accepted views of NoS (Lederman et al., 2002).

Factor 2, Methods that can used to generate scientific knowledge, is in the same manner based on the following accepted understandings of NoS:

“The methods used by scientists vary depending on the phenomenon being studied; Scientists use methods that are valued by the scientific community; Experiments are used to generate evidence or to test an idea; Science is a process of explanation and argument.” (p. 11)

These statements are similar to the concepts developed within Investigating in Science achievement objectives in the progression from Level 1 to 8 of the *NZC* apart from the statement “science is a process of explanation and argument”, which is referred to in Level 6 of Understanding about Science as “through processes of logical argument” (Ministry of Education, 2007, p. v) and in Level 3 and 4 Understanding about Science in “appreciate that science is a way of explaining the world” (p. iv).

Factor 3 “What counts as reliable and valid scientific knowledge” addresses the NoS concepts:

“Valid and reliable scientific knowledge is reproducible; Valid and reliable scientific knowledge is consistent with other scientific knowledge; Valid and reliable scientific knowledge is determined by consensus; Valid and reliable scientific knowledge has predictive power” (p. 11).

Not all these concepts are addressed within *NZC* NoS descriptors, however at Level 5 and 6 of Investigating in Science students are to “begin to evaluate the suitability of the investigative methods chosen” and in Level 7 and 8 of Understanding about Science, students are to “understand that scientists have an obligation to connect their ideas to current and historical scientific knowledge and present their findings for peer review and debate” (Ministry of Education, 2007, pp. v, vi). Thus two of the four concepts of “What counts as reliable evidence” NSAAQ subscale are addressed through the NoS achievement objectives of *NZC*.

The fourth NSAAQ subscale, “The social and cultural embedded nature of scientific practice” develops the NoS concepts: “Scientists decide what counts as evidence; Scientists decide what evidence to use to justify an explanation; Observer bias is a threat to interpretations; Science includes collaboration, cooperation and competition; Observations are theory-laden” (Sampson, 2006, p. 11). These concepts are not readily identified within the achievement objectives of the NoS in the *NZC* apart from the reference in Level 3 and 4 Understanding about Science statement that “Students will identify ways in which scientists work together and provide evidence to support their ideas” (Ministry of Education, 2007, p. iv).

The NSAAQ subscales were developed to address the internationally accepted concepts of NoS, and to provide a tool that could be used to discriminate between the views of NoS held by survey participants. In addition to identifying participants’ NoS understanding under the subscales, the individual questions provide a tool to highlight the specific NoS concepts to explore within the workshops in order to enhance each individual’s NoS understanding. The other value of the NSAAQ survey is that it was developed to learn “more about how students’ ideas about science (or their epistemological beliefs) influence how they engage in scientific argumentation” (Sampson, 2006, p. 2). The importance of “science as explanation and argumentation” is stressed rather than the view of science as “exploration and experiment” within both US and UK science curriculum policy in order to enable students to “develop a more sophisticated understanding of how knowledge is developed, justified, and evaluated in science” (Sampson, 2006, p. 1).

The implications of the NSAAQ analysis for the focus of the workshop sessions were that the intervention needed to provide more opportunities for participants to develop understanding of concepts within Understanding about Science and Participating and Contributing than on Investigating in Science (Ministry of Education, 2007). However, it was important to include details on the diversity of scientific methods used to generate scientific knowledge within

Investigating in Science, as the NSAAQ indicated this was not well understood by most teachers participating in the intervention (Question 9, $M = 2.4$, Question 10, $M = 2.6$). The data indicated the only aspect with an accepted scientific view was “understanding of the purpose of experiment” shown by the mean score of question 11 ($M = 3.8$).

4.4 The Intervention as it Evolved

The first workshop session as described under Section 4 - Planning the Intervention, was based on the model used by Education Support Services facilitators engaged in in-service teacher education (ISTE).

A reading on constructivism was used to focus participants on the intent of the *NZC* and the requirements of the science learning area statement. Participants’ reflection on their current teaching practice led to my sharing of the 5E constructivist approach (Skamp, 2004) at the initial session. Seventy percent of participants requested further ideas on ways to incorporate models such as Skamp’s (2004) 5E approach to science learning into classroom practice. In the light of this feedback, the design of the intervention was modified to enable these elements to be addressed. As a result, future workshop sessions modelled and utilised the fairly rigid design of the 5E approach as for them it “provided a structure that could help them be less teacher directed, and help them see how to use the constructivist approach in their science lessons” (Participant 3S – all participants were assigned an alphanumeric code to help ensure confidentiality).

4.4.1 5E approach .

The feedback precipitated a redesign of the workshop structure to incorporate Skamp’s (2004) 5E approach. In subsequent workshops the initial Engage activity set the context for the session and elicited participants’ views, existing beliefs, and questions. This was followed up by the Exploration phase, where NoS concepts were explored using further activities and

practical investigations to build knowledge, incorporating theoretical readings to enable participants to discuss their findings and relate them to an aspect of NoS. In the Explanation phase, development of explanations of the relevance of the activities to the NoS built participant awareness of the intent of particular aspects and allowed concepts to be socially constructed (Skamp, 2004). The fourth Elaboration phase used group brainstorming to develop ideas on how the concept could be incorporated into the different topics participants were currently engaged in within their schools, as well as providing a time for sharing and applying the concept to new situations. The final phase was Evaluation of the learning from the session and how their ideas compared with those they had held at the start of the session, followed by identification of the concepts that participants perceived were important for the next session. Use of this approach aligns with adult learning principles described by Merriam and Cafferella (1999) in *Ki te Aoturoa* (as cited in Dreaver & Chiaroni, 2008).

The teachers stated that the 5E approach provided a mechanism that enabled a better focus for their science lessons, as it “made them focus on the learning they wanted for students”. The use of the engaging activity enabled them to elicit their students understanding of the concepts to be covered in the lesson. Teacher 3S indicated that initially she was scared to “let the students go” as she had been used to a very formal lesson structure where content was “broken down and pre-digested into isolated fragmentary facts and procedures that are then practiced” (Boylan, 2009, p. 64). Teacher 3S recognised that students were engaged in recipe-like practical investigations to verify the concepts taught, and were assessed on their ability to recall the facts and the procedures (McComas et al., 1998). She noted that student engagement was poor, behaviour bad, and achievement low on the recall tests used across the school. Several of the participants also identified that the 5E approach could be applied to a range of outcomes from lesson, to unit, to scheme planning.

4.4.2 Key aspects of intervention design.

The intervention was developed to build teachers' understanding of the NoS so that they would develop teaching and learning programmes focussed on developing the NoS processes for students. As it utilised Skamp's (2004) 5E approach to the workshop structure, it presented the design from a constructivist perspective which supports the use of a student-centred approach, placing the teacher in a role of facilitator and guide in the learning process (Symington & Kirkwood, 1995). In addition to workshops, the design aimed to support teachers to implement the NoS into their teaching by providing in-school support and on-line support and discussion options.

The approach used in the intervention aligned with the professional development approach used by Doppelt, Schunn, Silk, Mehalik, Reynolds, and Ward (2009) in that it consisted of five 4 hour workshops with the purpose of building teachers' knowledge and understanding of a revised curriculum that they had to implement in their teaching and learning programmes. The similarity goes further in utilising a collaborative approach among the teachers to build understanding of the curriculum and develop and create solutions to teaching problems. The objective of the research by Doppelt et al. (2009) was to provide evidence of the need for professional development alongside the introduction of revised curriculum so that teacher participation in professional development could be directly linked to enhanced conceptual achievement by their students-. The approach used in Doppelt et al.'s (2009) research has some elements that align with those of the 5E approach as the workshops had six key elements to address. These are: administration issues; knowledge – both pedagogical content and basic content; discussion on ways to engage students in active learning; teacher reflections on classroom experiences; team trialling of activities before use with classes; and presentations of the teams' adaptations of the activities. The key finding from their research was that the percentage of time spent in the workshops on each of these elements was

reflected similarly in participant's classrooms in the time they allowed students to engage in each element during a lesson (Doppelt et al., 2009). This leads to a question as to whether a similar trait may have occurred in participants' classrooms in the NoS professional development.

4.4.3 Use of theoretical readings in workshops.

Theoretical readings provided an opportunity for participants to share and reflect on theoretical perspectives underpinning science teaching, and allowed for the generation of ideas on ways to bring about changes to their teaching practice.

Workshop 1 used readings on constructivism from Jenkins (2000) and from Wilson and Liepolt (2004) to expose some participants to the difference between teacher-centred and student-centred learning, which led to discussion of management issues for science. One of the ideas that most challenged the workshop participants was the statement from Jenkins (2000) reading:

constructivists have a commitment to the idea that the development of understanding requires active engagement on the part of the learner. Put another way, knowledge cannot be 'given' or handed over and received in the same way as a parent might give a child a book, a toy or a tool. (Jenkins, 2000, p. 601).

This revealed the conflict between the participants' belief that their role was to share content with students, while the readings were directing them to engage their students in exploring and investigating to actively build understanding of scientific concepts. To support the building of participants' understanding about constructivist pedagogy, a follow up reading from Skamp (2004) was used to both unpack constructivism as a theory of learning for science teachers, and to provide a model of a way constructivist approaches can be used in the science classroom. Such was the impact of these readings that feedback from the participants

indicated that they would like this approach modelled and followed in subsequent workshops. One of the younger teachers also reflected “since this has been around since 1997, how come we didn’t learn about it at [teacher training] college as it would have helped us with our teaching?” Such a statement could indicate that this teacher was at Berger’s (2007) socialised mind stage, and could feel threatened by the NoS where the answers are not focussed on recall of content but understanding of scientific processes as in the *NZC*.

Workshop 2 focussed on developing participants’ understanding of Investigating in Science and used readings on “cookbook science” (McComas et al., 1998, p. 363) to unpack thinking on how they carried out investigations with their students. Most reflected that they had thought the use of “recipe like investigations” was helping students learn about science and investigation approaches, so this reading exposed them to new thinking about the strategies to use in the classroom. A follow up reading, “Sometimes it’s not fair” (Goldsworthy, Watson, & Wood-Robinson, 1998) was shared by one of the participants and led to online and on-going face-to-face discussion as it provoked thinking on the irrationality of always applying “fair testing” in school science. Discussion included the influence of assessment requirements of NCEA on creating a focus on fair testing as the only way to investigate in science, as well as the influence of science fairs where judging focussed on the use of a fair test format. Teacher 3Y commented that the “reading from Goldsworthy was dated 1998 and yet it was the first time she had any idea that scientists did not actually apply fair testing as their practice in research”. Teacher 2J commented that he now understood why a parent, whose child’s science fair project was not accepted for the local fair, was upset. The teacher had responded that it did not use the right template, and the parent had replied that science research could be presented in different ways that were just as appropriate.

As a result of the readings and accompanying practical activities, all participants followed up the use of different approaches to practical activities and reported on them at the subsequent

workshops. A range of feedback was shared, including Teacher 3L who reported that some year 9 and 10 students were reluctant to approach an investigation “without instructions to follow”. The teacher reflected that students had become dependent on these and were concerned about getting the right answer rather than using their own ideas, and had a strong “fear of failure”. This teacher persevered with the approach, and began to use more starter activities to build student confidence at exploring situations. In addition, he emphasised that it had provided “key ideas to share and build with other science teachers back at school”.

The focus of Workshop 3 was on the “Participating and Contributing” strand of the *NZC* and the theoretical concepts of “science as argument” were developed. This used Bereiter and Scardamalia’s (2008) article, “Teaching how science really works” to unpack the concept and focus discussion. Few participants had encountered the concept of science as argument, but could perceive the relevance of this concept to the *NZC* focus on “socio scientific issues” (Ministry of Education, 2007, p. 29). The reading did, however, introduce another issue in that all the teachers had no prior experience of developing the argumentation process with students. This led to inclusion of a range of activities and strategies in Workshop 5 to further support teachers in developing this process, as Workshop 3 contained introductory ideas and strategies, but did not fully develop the process. As facilitator, I had made the assumption that all the participants had similar background experiences to mine, and had been engaging students in making a case for and against a proposed situation based on factual evidence. Perhaps this skill was gained through teaching both agriculture and biology to senior students.

One teacher (3H) commented that the argumentation process was great as it was “about making connections, finding evidence relating to an issue, and students could work with others to share their ideas, and it overcame the idea of science being right or wrong.”

Teacher 3M used the argumentation approach with a disengaged class of Year 10 boys and found that they were really challenged and excited by the process. As a result, they worked

really hard to research scientific evidence for and against the issues involved in alternative fuels for use on farms in the locality and produced excellent evidence backed scientific arguments to support their chosen stance. The teacher commented that he felt it gave focus to the research process and that the boys learned more through use of this approach than they would have in traditional ways he used in teaching them. He began to incorporate socio-scientific issues into each topic to continue to develop this capability with the class.

The reading used to build “Understanding about Science” in Workshop 4 was an adaptation by McComas titled “Dispelling the Myths” (McComas et al., 1998). The reading was accompanied by a task where participants worked in pairs to précis the McComas’ ideas about the two different myths they were given. Their précis and interpretations were shared and discussed with the rest of the group. This led to some very intriguing observations as one pair misread their myth so that it fitted with their own acceptance of the myth that science models represent reality, and could not be moved in their interpretation of the reading despite others reframing it and providing additional examples. In the other two groups this did not occur, and participants reflections indicated that it had provided a valid method for unpacking their misconceptions, had raised their awareness of these, and provided them with a tool to use with students to identify student misconceptions.

Workshop 5 focussed on building understanding of “Communicating in Science” through reading about scientific literacy from “Why educate ‘little scientists?’: Examining the potential of practice-based scientific literacy” (O'Neill & Polman, 2004) and the concept of “science as explanation” (Scotchmoor & Scott, 2006). The key observation from these readings was that several participants had not previously known the difference between literacy in science and scientific literacy. On discussion, it was identified that many of their schools had undertaken a focus of literacy across the curriculum in previous years and thus teachers thought they were addressing scientific literacy by engaging a focus on vocabulary

use and reading strategies. This response can be justified from one perspective as the *NZC* focus of “Communicating in Science” clearly emphasises use of vocabulary and texts within the achievement objectives from Level 1-6 (Ministry of Education, 2007). The curriculum itself makes only passing reference to the concept of scientific literacy, although some of the underpinning elements are identified within “Understanding about Science” and “Investigating in Science”. However, the focus of “Communicating in Science” does not address the accepted scientific literacy aspect of a person’s ability to understand science and in turn communicate this understanding of science (Skamp, 2004).

Most participants accepted the concept that science sought to explain the world, but for some the perception was of a strong link to students being able to write explanations in science. On discussion this was identified as attributable to two factors. Firstly, due to the wording of NCEA assessment tasks where students are required to describe, explain, or justify their responses. Participants indicated that it had made them focus on teaching students the difference between describing a scientific observation compared to explaining the science behind the observation. For Teacher 3G, this was new learning as she had not known that was required to produce an explanation, saying “ I have only been teaching students to write descriptions, now I will have to show them how to link to the science behind the description”. Secondly, the primary teachers felt the links to explanation were strongly about writing, as they would develop explanation writing as a writing process with Year 5 to 8 students, but would not put emphasis on relating to the science behind the explanation. The reading helped these participants to see that in using science as a basis for writing development, they had to ensure incorporation of accurate scientific concepts. This implication for science teaching has been identified by Joyce, Bull, Hipkins and MacIntyre (2008) in their research into how the *NZC* NoS aspect of “Communicating in Science” is being understood by students.

The consensus from participants was that the theoretical readings provided a basis to build their understanding of NoS and gave them evidence and ideas to think about and discuss. Some participants found the readings a challenging part of the sessions, although they said they gained from the discussion and sharing of ideas. Teacher 3A admitted to being threatened initially by the faster readers who seemed to respond with their ideas before she had finished reading. However, when she got more confident she asked them to note their ideas down and give her a bit more time, and then joined in the discussion. This appeared to be more of an issue for participants from a primary teaching background.

Although readings were emailed to participants as part of the reflection process through the on-line component, only three individuals read and posted online comments prior to the workshops. However, all participants from all three groups contributed to the face-to-face discussion.

4.4.4 Resources used to develop activities.

A range of engaging activities were developed to provide a mechanism to address each of the key elements of NoS inclusive of both internationally accepted concepts and New Zealand Curriculum concepts more closely aligned to the international concepts of scientific literacy. Similar approaches were used to develop Exploring, Explaining, and Extending activities.

Activities for developing explanations linking to NoS and scientific literacy included developing the concept of “science as explanation” through writing of cause and effect statements to suggest scientific explanations for observations in science investigations. This was then extended to writing scientific explanations initially supported by the use of writing templates, and led to use of scaffolding approaches to assist the development of students’ writing ability. This was supported by the use of three specific rubrics “suggesting explanations, using scientific vocabulary and writing scientific explanations” (Ministry of

Education, 2004, p. 3-6), derived from the *New Zealand Curriculum Exemplars: The Science Matrices Progress Indicators* to identify next steps for teaching and to support student learning.

Group discussion was the main approach used to provide support activities on Extending ideas and applying ideas relating to the NoS to plan new situations for use with participants' students. This discussion was often structured and facilitator-led or based on reflection questions. The importance of these approaches to discussion was that it provided modelling of approaches, useful for engagement in scientific discourse. For example, participants were required to paraphrase the previous speaker's comments before adding their own reflections and ideas.

Processes for Evaluating learning focussed on developing reflective practice in teachers, and modelled activities for the NoS processes that could be used to develop self and peer assessment with students, and included the use of rubrics and identification of developmental sequences.

Activities to build teachers, and ultimately students, understanding of the NoS, were developed from the Lederman and Neiss (1997) resource which provided initial ideas, such as "Tricky Tracks", designed to demonstrate that science is subjective, tentative, creative and based on empirical evidence.

4.4.5 Participant reflections and involvement.

Initially, the main emphases of participants' reflections were on the understanding of science in *NZC* and the role of the NoS within it, as well the need to be provided with more ideas on how to focus on the NoS in their teaching. As the workshop sessions continued, their reflections placed increased importance on the value of engaging in practical activities, the need to develop assessment resources that enabled a focus on elements of the NoS rather than

content of the strands, and the ways they were individually developing an understanding of the NoS aspects. All participants became involved in sharing during the reflection times. As the intervention proceeded, the reflections moved from a more basic technical level to reflexive in nature (Haigh, 2000) with participants' reflections including not just what they did, but what they would do differently in the future and why, as well as ways they may have impacted on student learning and engagement. For example, Participant 3Y reflected that instead of just using a glossary, which had been usual practice, she now had students making their own study cards where they put their own question, not one she provided, and left them to find their own answers and share and check these with other students to get a consensus on the answers. Only then would she check in with them. This had resulted in much higher level of student participation, and it helped students learn the terms and reinforced the concepts they were learning more, and students were keeping their cards in their portfolios. To support them in this, the teacher was going to incorporate this activity in future using different coloured card for each topic. She also reflected that it was helping students have more confidence in their ability to answer questions, and their questions were not simply recall types.

In addition to the increased depth in the reflections shared during workshops, the depth and detail included in the written responses increased. This could be attributed to the use of open-ended questions in the Journalling Responses resource following the suggestions on effective evaluation from Guskey (2000). A sample of participants responses to the journalling questions is provided in Table 5 (see p. 97) to demonstrate the change in the nature of their reflections, and provides further evidence of the increase in their confidence in their knowledge of the NoS as well as in their ability to include the NoS in their lessons and teach through it as required by *NZC* (Ministry of Education, 2007). The role of discussion with others during the workshops in building participants' understanding is also evident from these responses, as well as the reflections on how to assess student understanding of the NoS rather

than the recall of facts. Timperley (2008) indicates that for effective professional development, teachers need to be able to “monitor and reflect on the effectiveness of the changes they make to their practice” and that they “need sophisticated assessment skills to identify what their students know and what further learning they themselves need if they are to assist their students in learning” (p. 13). The participant reflections indicated that the intervention has provided opportunities for them to address both these aspects identified by Timperley (2008). This is shown especially by responses of participants 1A, 2Y and 3S after workshop 5 where they clearly identify changes made in their individual teaching of science and the use of assessment tools to identify student needs and provide feedback to students. All participants identify an increased understanding of NoS after Workshop 5, and the impact this has had on the change of emphasis in their teaching, for example 1E, 1W, 2B, 2Y reflections details this.

Table 5: Sample of Participants’ reflections after Workshop 1 and Workshop 5.

Participant	After Workshop 1	After Workshop 5
1A	I understand more about the science in the NZC. I need more ideas for practical activities.	Sharing ideas, planning and thinking has helped me gain confidence in including NoS and ways that simple activities and investigations can build understanding and playing with ideas and discussing with others has helped me see ways to know what students need, and their level of understanding. Also we can now assess NoS in a way that gives students feedback and helps them know what they need to work on. I am not scared of doing science any more.
1E	I need more ideas on how to we do this in secondary classes. Going to talk to HOD about the NoS and how we assess and report.	Now have a better understanding of NoS and the importance of the process versus the knowledge of facts (of science). We are now starting to put emphasis on different things with our classes. We want to change our reporting to give more of a focus on NoS.
1T	I had no idea this was what science is about. We have just set our teacher trainees up to take a science focus for the next 3 weeks and we have got it all wrong in what we are asking them to teach. We are getting the students to do a recipe like approach to science and then do a fair test for science fair. How can the students do this when we have not even had them exploring their ideas?	I was like wandering around in the dark with science, my level of understanding has increased and the light is on, I know about the what, how, why, where, and when of NoS, am doing lots more experiments and use correct terminology.

Participant	After Workshop 1	After Workshop 5
1W	I can see that I have not really understood what is changed with Science, but now I am starting to see it is more than “recipes” or “fair tests”.	Using the hands-on, easy to do activities has helped challenge children's understanding, while helping both me and them to understand the NoS focus. It has also given us good ideas on how to apply this in our own classrooms. The focus of our assessment has changed from assessing content and what kids recall to using rubrics that help us plan next steps for their learning – this is very good.
2B	Did not know what science was about in NZC -Need to put NoS as a goal for year and the focus for planning – need to motivate staff to think more sciency – integrate.	Now doing more science, bringing it in as part of reading and writing, giving it a focus. Still hard to get other teachers to do the same – they just want “themes”. Now really understand NoS and how it makes science lots more fun for kids – and me too. I have more confidence and am using more hands on and more resources and ideas. I’ve got more understanding of scientific concepts.
2L	Practical exercises [helped] to reinforce our understanding.	I realise that when I started I had not opened [NZC] or understood what NoS was, it [the professional development] exposed me to lots of challenges and has resulted in more understanding and enjoyment in what I’m teaching; and now I am risk taking and doing things differently – not just the students taking notes, more focus on doing and on practical activities. Still lots to learn, but now it’s like the lights been switched on, and I can discuss and work with colleague 92Y, and Kate’s support has been great..
2Y	Made links to NoS clearer	When we started I knew what NoS was, but had difficulty in seeing much beyond communicating and investigating. I was challenged to re-evaluate traditional approaches [I used in my teaching] and my own thinking to enable me to alter my expectations within the classroom. I could now explain to someone else something of what they [NoS aspects] mean and link more confidently to classroom activities. I am much clearer about the links to Understanding and Participating and Contributing. The workshops have enabled specific practical activities that clearly hook into NoS. My next steps/ongoing challenge is to develop junior programmes that are more flexible and creative and to continue to move away from a content focus to a NoS and skills focus.
3H	I liked discussing practicals and different types of investigations and the thinking activities	I am now thinking differently in my teaching, not giving as many instructions, trying to make students find out for themselves, and then helping students make sense of what they have found out. I’m thinking more about the needs of my students, how to engage them and relating everything to the NoS, I’m also incorporating more text and vocab into my lessons and breaking tasks down into smaller pieces. I still need support to keep extending ways to build NoS ideas in.
3S	We have been trying to bring NoS into	My thinking has changed so much, I now think about

Participant	After Workshop 1	After Workshop 5
	our planning, now I see why we have to do it.	how to engage students and the different levels the students are at and I relate everything to NoS, so understanding text and breaking down tasks into smaller pieces is important. I'm not giving as many instructions, and...trying to let students find out themselves and then helping them make sense of what they have found out.

4.4.6 Impact of teacher feedback from journals on intervention design.

Journal responses from the initial workshop indicated participants valued opportunities to participate in simple practical activities that encouraged reflection on the science explanations and would be manageable in the classroom. Key elements identified as important for inclusion by most participants in future sessions were:

- ways to build questioning and observation skills of students and develop effective use of models in investigating in Science; 1V response: “ways to question students in science”; 3S response: “how to question”.
- suggestions of ways to develop understanding of socio-scientific issues (SSI) other than in conservation contexts relating to the Living World; 3Y response: “we don’t address Participating and Contributing, explore ways we can?”; 2S response: “ways to build science as argument into programmes that aren’t LW”.
- clarification of what “Understanding about Science” really means for teaching (Ministry of Education, 2007); 3Y, 1V, 2S: all asked Helping us understand what “Understanding about Science” is about.
- ways to extend communication in science beyond use of language, symbols and diagrams to helping students explore and assess the validity of the science ideas within different types of texts from advertisements to popular and newspaper texts; 3S response: “how to question, how to incorporate reading skills into Science”.

- sharing ideas on ways to assess the NoS using rubrics so that students receive feedback that supports them to identify their next steps and engage in self-assessment of their ability to engage with the NoS processes. 3J response: “ideas on Assessment options - Recording/Tracking”; 2J response: “Link to NZC & assessment possibilities”.

Although the participants did not have the results of the NSAAQ when they completed the first journal entry after the initial workshop, the requests for support aligned with the needs identified from the survey, apart from the prioritising of Investigating in Science through a focus on questioning. Participants indicated that discussions clarifying the place of the NoS within the *NZC* document and the sharing of a possible assessment process were valuable.

1W reflected:

Discussing the NoS focus and how to apply this in our own classrooms, and using the matrix linking KC & NoS. The assessment is also v.g. Theory/practical balance is about right. It is good to look at the theory behind what we are doing.

This assessment process aimed to support the monitoring of students’ NoS capability within relevant aspects of the NoS over time using the *New Zealand Curriculum Exemplars: The Science Matrices Progress Indicators*. Another aspect of the introductory workshop that had a strong impact on participants was the inclusion of readings on social constructivism and constructivist approaches to the teaching of science. These were included as the *NZC* is partially based on these and sociocultural approaches to teaching and learning.

The ongoing requests coming from each workshop session were for continuation of practical strategies to support them in developing their ability to address the NoS in their teaching and learning programmes, as well as the discussion of theoretical perspectives relating to both science and pedagogy. For example, in journalling responses on Workshop 1, 38 of the 42

participants commented on the hands-on or practical activities and requested these be included in the design for the next session. Once the design of sessions was established, participants felt the structure supported their learning, provided opportunity for “collegial sharing and support” (1L) and fostered their learning as a group. This was so much so that the primary teachers felt they were “learning from the secondary teachers” (3M), while the secondary teachers were adamant that their “needs were being met” (2V), and they were gaining from their primary counterparts “ideas and suggestions” (1J). Even when discussion focussed on external assessments, the primary participants felt it “helped them understand the pressures” (3A) on their secondary colleagues and they could empathise with this and their similar perceptions of the effect that national standards could have on their teaching if they allowed them to.

Overall, the consensus was that as a group they all had a lot to learn about the NoS and the implications of the prioritising of this in the science learning area for their individual teaching and learning programmes, thus they were all learning together. In a similar way to the professional development approach used by Wolfensberger, Piniel, Canella, and Kyburz-Graber (2010), the design framework used in the intervention allowed both the facilitator and the “teachers to search for and try out new solutions to the questions they had at the beginning of the research” (p.721). This was achieved by the facilitator assisting them with practical ideas and advice relating to both teaching of specific NoS aspects and on their reflection on the trialling of the strategies with their students. The inclusion of several cycles of reflection and action in the intervention possibly provided positive effects for participants as it gave them “multiple opportunities” (Wolfensberger et al., 2010, p. 721) to reflect, and allowed them to identify and put changes in place for their teaching approaches. This was identified in their narrative reflections at the end of the fifth workshop.

The approach used in this professional development was a departure from the norm for those who were secondary teacher participants, as the main professional development emphasis for secondary teachers had been on building summative assessment practices to address NCEA achievement standards since their introduction in 2001. As identified by Supovitz and Turner (2000), the design-based approach used in this professional development provided teachers “with a more coherent series of ... content rich activities framed within helpful procedures and linked to larger science concepts ... that encourage inquiry and investigative culture” (p. 976). The teachers expressed that they valued this approach, as they saw it as important that they were carrying out and experiencing learning through the activities themselves, so that they were better able to modify or adapt activities for use with their students. Thus they were experiencing the “uncertainty and taking risks” (Teacher 3A), just as they expected of their students.

It became apparent that some participants, particularly the secondary teachers, needed to be up-skilled in their pedagogical knowledge, referring to their understanding of the science of teaching, and their need to have a wide range of strategies and approaches to draw upon relating to organisation, teacher talk, and learning talk, to enable effective learning outcomes for students (Alexander, 2005). Consequently, a range of approaches to activities was incorporated within the sessions, and included discussion on ways of modifying the activities for differing abilities and needs of students. This was probably best illustrated in the first session where participants carried out a similar investigation from three different approaches - a teacher-directed recipe approach, a challenge approach and an inquiry approach. Following this experience, all participants successfully incorporated different approaches to investigation into their teaching and learning programmes in science by modifying existing practical activities to incorporate either challenge or inquiry approaches.

Teacher 3M began by showing the Year 1 and 2 students that an egg could float in salty water and sink in tap water, and challenged them to find out how much salt needed to be added to tap water to make the egg begin to float. The activity was used as an introduction to a teaching unit on matter, to which the students responded with total engagement in measuring and observing the eggs as they decided how to carry out the challenge in small groups. This concentration in finding out more about matter continued over the next two weeks as they explored matter in different ways, including role playing, to model how particles behaved differently in solids, liquids, and gases. Not only did they learn a lot about matter, but together they built and used a more extensive language to describe their observations of the materials they were exploring. This came from the teacher modelling the use of scientific language to describe their observations as part of her use of pedagogical knowledge of building learning talk for her students (Alexander, 2005). For Teacher 3M this was an overwhelming experience, and a confirmation for her that “small children could do science in a scientific way like scientists”. Her request for support from the facilitator for ideas on additional practical ways to investigate matter further with her students helped build both her confidence in carrying out practical science activities with them, as well as building her pedagogical content knowledge and her knowledge of science.

Most participants needed support to develop both their pedagogical content knowledge and their ability to transform content knowledge, especially relating to the NoS concepts, so that they could effectively communicate this to their students. Thus the participants adopted the role of learners in the intervention, and their responses were therefore similar to those of students in the classroom (van Driel et al., 1998). This added a further dimension to the intervention which was addressed through the deliberate inclusion of theoretical readings addressing elements of the NoS such as the nature of investigation in science, as well as readings developing content knowledge of science, for example, on what causes surface tension. These were included within the exploration/experimentation stage of the sessions as

the emphasis here was that use of texts was a relevant skill to develop as part of the investigation process that develops understanding of concepts (Unsworth, 2001).

4.4.7 On-line component.

Online feedback and discussions were intended as part of the intervention design. Following the first session, a reading was emailed to all participants, and they were invited to share their responses to three questions via a wiki link provided. Participants were also asked to provide me with feedback and reflections on the session in response to the email, in addition to their completed workshop reflection sheet. Only three of the 42 participants did this, although 13 participants did visit the wikispace. When the reflection sheet was provided as an alternative means of providing feedback at the end of the second session, all participants responded in depth to each question. The opportunity for on-line reflection continued to be available, but only one availed herself of this.

Questioning participants on their reluctance to engage in on-line opportunities led to responses in Table 6.

Table 6: Participant responses to use of wiki/on-line resources/email.

Reason	Number of participants responding with reason
I regularly contribute to on-line communities	6
Lack of time to use/access on-line resources	10
Self-conscious of others reading my opinion	15
I might show that my science knowledge is not good	8
Don't use internet/wikis etc	6

The low response rate as an on-line community contributor indicates that the science teachers in the groups were not regular participants in on-line communities. For the participants in this

study, participation in an on-line community required them to develop confidence in submitting responses in a content area where they were aware of their individual lack of knowledge. Such commitment would require a more obligatory reason for engagement and exposure than was required in this intervention (Lieberman & Pointer Mace, 2008).

4.5 The End of Year (EoY) NSAAQ and Comparison with BoY

The NSAAQ questionnaire provided feedback on teachers' beliefs about the aspects of the NoS as described in Table 7 (see p. 105). Visual comparison of the percentages of participants with naïve views from the start to the end of the intervention showed a decrease in the percentage of participants holding naïve views of the NoS for all questions. At the start (T1) of the professional development intervention, participants indicated naïve views for 16 questions while at the end (T2) they held naïve views for six questions. As in the initial NSAAQ survey, a score of 1, 2, or 3 was used to indicate a naïve view. For example, at T1 on question 2, the naïve view was held by 59.6% scientific knowledge, while at the end of the intervention, 30.0% still held a naïve view, thus 13 participants had not changed their understanding to the accepted view that scientific knowledge is tentative. The only question where few participants changed their view of the NoS to a more informed view was Question 13. This showed a decrease of only 5.7% from 55.7% to 50.0% which indicated only two more participants had accepted the understanding that "Scientific knowledge can only be considered trustworthy if the methods, data and interpretations of the study have been shared and critiqued" (Sampson & Clark, 2006, p. xi). In all other questions, the percentage shifts to the informed view, indicating that at least 10 participants had developed a greater understanding of the accepted informed view of NoS. Questions addressing Factor 2 - How is scientific knowledge generated (Sampson & Clark, 2006) indicate that for questions 9 and 10 more participants had developed a better understanding of the diverse methods used, with a reduction from 92.3 to 65.0 for Question 9, and 94.2 to 70.0 for Question 10. However, at the

end of the intervention, 27 of the 42 participants had retained naïve views for question 9, and 29 for question 10. The need for placing greater emphasis on this factor in on-going refinement of the design was indicated by the retention of naïve views for these two questions, to enable participants to have more opportunities to engage and reflect on the concept of what constitutes the scientific method. This could indicate the need for participants to embrace conceptual changes on the diversity of the scientific method compared to the emphasis that was placed on the fair test and recipe-like approach to scientific investigations during the twentieth century as described by Lederman & Lederman (2004).

Table 7: Comparison of percentage participants holding naïve NoS views for Factors 1 – 4 pre (T1) and post (T2) intervention.

Factor	NoS focus	Question number	T1 questions Naïve view	T1 % Naïve view	T2 questions Naïve view	T2 % Naïve view	Shift in % T1 to T2
One	What is the nature of scientific knowledge	1-6	1	67.3		40.0	27.3
			2	59.6		30.0	29.6
			3	84.6	3	55.0	34.6
			5	48.0		45.0	3.0
Two	How is scientific knowledge generated	7 - 12	7	51.9		35.0	26.9
			9	92.3	9	65.0	27.3
			10	94.2	10	70.0	24.2
			11	44.2		35.0	9.2
Three	What counts as reliable and valid scientific knowledge	13 - 19	13	55.7	13	50.0	5.7
			14	73.1	14	55.0	18.1
			16	50.0	16	50.0	0.0
			17	55.8		40.0	15.8
			18	48.0		35.0	13.0
Four	What role do scientists play in generation of scientific knowledge	20 - 26	21	67.3		40.0	27.3
			22	75.0	22	65.0	10.0
			23	65.4		35.0	30.4
			24	46.1		25.0	21.1

Paired sample t-tests were conducted on the participants' NSAAQ questionnaire responses recorded pre (T1) and post (T2) intervention to determine whether there were significant differences in the mean scores for each question. A significant difference ($p < .05$) was found for nine of the 26 questions in the survey as indicated in Table 8 (see p. 107). In seven of these questions, the mean score indicated a move from a naïve view of the particular aspect of the NoS to an informed view more consistent with accepted NoS understandings. The changes in means confirm the observed differences in the number of participants changing viewpoints. Without the percentage shifts to compare with the mean scores, the assumption could be made that those who were scoring 4 in the pre intervention NSAAQ are now scoring 5. However, the shifts in the percentages indicate more participants have shifted from a naïve view, scoring 1, 2, or 3, to an informed view, scoring 4 or 5.

The intervention was designed to shift teachers' views on questions where high proportions originally held naïve views (questions 1, 2, 3, 5, 7, 9, 10, 11, 13, 14, 16, 17, 18, 21, 22, 23, 24). For 10 out of 17 questions (questions 1, 2, 5, 7, 11, 17, 18, 21, 23, 24), it appeared that the intervention had worked. In addition, teachers had shown significant changes in their understanding on questions 3, 9, 10, and 14, which were not directly addressed in the intervention, but were related. It is interesting to note that for seven of the questions, the p values and the percentage change both indicate a shift from naïve views at the start of the intervention to a more informed view after the intervention. These were questions 2, 3, 5, 14, 17, 23 and 24. Two other questions showed significant difference in the p value – questions 8 and 26. In these questions, participants demonstrated a shift in their understanding of the informed view of the NoS, as the means shifted between T1 and T2; for question 8 from 3.4 to 4.6 and for question 26 from 3.8 to 4.3. This implies that although these questions were not identified as essential to focus on in the intervention, participants had gained in their understanding of the NoS concept underlying these during the intervention.

Table 8: Paired sample t-test summary for NSAAQ survey questions pre (*M1*, *SD1*) and post (*M2*, *SD2*) intervention.

Question	Informed view of NoS of Question	t value	p value	<i>M1</i> (<i>SD1</i>)	<i>M2</i> (<i>SD2</i>)
1	Scientific knowledge represents only one possible explanation or description of reality	-.941	.359	2.9 (1.0)	3.1 (1.3)
2	Scientific knowledge should be considered tentative	-2.998	.007	2.9 (1.2)	3.8 (1.0)
3	Scientific knowledge is subjective	-3.284	.004	2.3 (1.1)	3.8 (0.9)
4	Scientific knowledge usually changes over time as a result of new research and perspectives	.900	.379	4.5 (0.5)	4.4 (0.8)
5	The concept of a species was invented by scientists as a way to describe life on earth	-2.557	.019	3.1 (1.2)	3.7 (1.1)
6	Scientific knowledge is best described as an attempt to describe and explain how the world works	-.900	.379	4.0 (0.9)	4.2 (1.1)
7	Experiments are important in science as they can be used to generate reliable evidence	-.411	.685	3.4 (1.0)	3.6 (1.2)
8	The methods used by scientists vary based on the purpose of the research and the discipline	-3.286	.004	3.4 (1.5)	4.6 (0.7)
9	The methods used to generate scientific values are based on a set of values rather than a set of techniques	-.252	.804	2.5 (0.8)	2.6 (1.0)
10	Science is best described as a process of explanation and argument	-.940	.359	2.8 (0.9)	3.0 (0.9)
11	An experiment is used to test an idea	.462	.649	3.7 (0.9)	3.6 (0.8)
12	Within the scientific community, debates and discussions that focus on the context, processes, and products of inquiry are common	-.462	.649	4.2 (0.8)	4.3 (0.8)
13	Scientific knowledge can only be considered trustworthy if the methods, data, and interpretations of the study have been shared and critiqued	.203	.841	3.4 (0.9)	3.4 (1.1)
14	It is impossible to gather enough evidence to prove something true	-3.199	.005	2.7 (1.2)	3.4 (1.2)
15	The reliability and trustworthiness of data should always be questioned	.000	1.000	4.3 (0.8)	4.3 (0.9)
16	Scientists know that atoms exist because they have made observations that can only be explained by the existence of such particles	-.657	.519	2.9 (1.0)	3.1 (1.4)
17	Biases and errors are unavoidable during a scientific investigation	-2.538	.020	2.5 (1.3)	3.4 (1.2)
18	A theory can still be useful even if one or more facts contradict that theory	-.922	.368	3.2 (1.2)	3.5 (1.3)

Question	Informed view of NoS of Question	t value	p value	M1 (SD1)	M2 (SD2)
19	Scientists can only assume that a chemical causes cancer if they discover that people who have worked with that chemical develop cancer more often than people who have never worked that chemical	-.490	.629	4.2 (0.8)	4.3 (0.7)
20	In order to interpret data they gather, scientists rely on their prior knowledge, logic and creativity	-.623	.541	3.7 (1.2)	3.9 (1.3)
21	Scientists are influenced by social factors, their personal beliefs and past research	-1.116	.278	3.1 (1.2)	3.5 (1.2)
22	Successful scientists are able to persuade other members of the scientific community better than unsuccessful scientists	-1.366	.189	2.4 (1.3)	2.9 (1.1)
23	Two scientists (with the same expertise) reviewing the same data will often reach different conclusions	-3.327	.004	2.9 (0.9)	3.8 (1.1)
24	A scientist's personal beliefs and training influences what they believe counts as evidence	-3.111	.006	2.9 (1.2)	3.8 (1.0)
25	The observations made by two different scientists about the same phenomenon can be different	0.160	.874	4.0 (0.7)	3.9 (1.1)
26	A scientists conclusions may be wrong even though scientists are experts in their field	-2.236	.038	3.8 (0.9)	4.3 (0.6)

The implication of these results is that the intervention needed to place further emphasis across all three groups on developing four of the epistemological aspects of the NoS within the four factors as described in Sampson and Clark's (2006) NSAAQ survey "Diversity of scientific methods used to generate scientific knowledge, What counts as reliable scientific evidence, Tentativeness of scientific knowledge, Beliefs about characteristics of scientists" (p.xi).

Paired sample t-tests were also conducted on the participant responses to each factor of the NSAAQ survey. Significant differences were found for each factor as well as for the total score (Table 9 see p. 109). A comparison of the means showed that the participants' scores had increased for all factors between the pre-test score and the post test. In addition, the mean overall score had shown a statistically significant increase from $M = 85.0$ ($SD = 6.8$) at the

start of the intervention to $M = 94.3$ ($SD = 10.5$) after the series of 5 workshops of the intervention.

Table 9: Paired sample t-test summary for Factors of NSAAQ survey pre ($M1$, $SD1$) and post ($M2$, $SD2$) intervention.

Factor	NoS aspect	t value	p value	$M1$ ($SD1$)	$M2$ ($SD2$)
Factor 1	What is the nature of scientific knowledge	-2.970	.008	19.6 (3.0)	22.4 (3.5)
Factor 2	How is scientific knowledge generated	-2.491	.022	19.8 (2.4)	21.4 (1.8)
Factor 3	What counts as reliable and valid scientific knowledge	-2.611	.017	23.1 (3.4)	25.2 (3.2)
Factor 4	What role do scientists play in generation of scientific knowledge	-3.129	.006	22.5 (3.5)	25.9 (4.5)
	Overall total score	-4.138	.001	85.0 (6.8)	94.3 (10.5)

The comparison of the factor scores analysis indicates the intervention has raised participants' understanding of all the NoS aspects assessed within the NSAAQ survey. The significance of these shifts is triangulated by the teachers' reflections and sharing of the impact of their learning on changed teaching approaches and classroom practice as outlined in the previous sections.

4.6 Three Vignettes Presenting the Responses from Participants

All participants were offered the opportunity to have support with their teaching to help build their capability to develop NoS understanding and strategies with their students. Only 23 of the 42 participants availed themselves of the support. All showed changes in their teaching practice over the three visits during the 25 to 30 weeks of the intervention. Vignettes of three teachers provide evidence of the changes to their practice over the time of the intervention. These are representative of the stories of all the teachers who were supported in their practice

during this time and provide evidence on the third research question: How is increased Nature of Science understanding evidenced in teacher practice?

4.6.1 Teacher Sue: letting go. Moving from teacher-centred to student-centred approaches to build NoS ability in students.

Sue had seven years previous teaching experience, a Bachelor of Science degree, and was teaching Year 7 – 13 students. Her score in NSAAQ 89/130 with 16/30 in Factor 1, What is the Nature of Scientific knowledge?

My first observation of Sue made me aware that she had a very formal lesson structure where content was “broken down and pre-digested into isolated fragmentary facts and procedures that are then practiced” (Boylan, 2009, p. 64). Students were then directed into recipe-like practical investigations to verify the concepts taught, and were assessed on their ability to recall the facts and procedures. Sue had noted on the first visit that student engagement was poor, behaviour bad, and achievement low on the recall tests used across the school. Trialling a different approach to teaching was viewed by Sue as a necessity if she was going to engage these students and enjoy teaching again. She reflected that the ideas seemed good from the workshops, but was worried that she still needed to make sure she gave the students the facts they needed to know to “pass the tests”. Sue indicated that she would like me to support her on the second visit as she was “scared to let the students go”.

Initial planning was carried out with my support as the facilitator, and a series of lessons was planned for a topic on light. I was to assist Sue in the first two lessons where she was trialling the use of the 5E constructivist approach to provide support if she needed it, and to work with small groups around the class as required. In the first lesson, Sue had reneged on her ability to carry out the planned approach and was preparing to share, via power point, the facts she wanted all the students to “learn” and for them to write them down at the start of the lesson.

With my support, this was rejected, and the original engagement task was carried out using a range of mirrors, including spoons and makeup mirrors. Sue was amazed at the ideas the students came up with, the range of discussion, the links to situations where the different types of mirrors were used, and the ideas the students had about light that she would not have uncovered if she had begun with them copy/writing down notes. The students, with support, proceeded to design their own investigations relating to mirrors – with some prompting about images and size and transfer of light energy for the rest of the lesson, and were very engaged in the process, all coming up with suggested explanations for their observations. These were followed up in subsequent lessons, and as time progressed, the class engaged fully in the different approach, and all worked well together in small group investigation and fact finding.

Achievement has improved, behaviour is rarely an issue, and the students are enthusiastic about their science and how it relates to their lives. This has had such an impact on Sue that in 2011 when the Year 10 were to sit Cambridge assessments, she was not prepared to compromise the use of the 5E approach. Instead she worked with another teacher to prepare notebooks for students to use for checking content knowledge, but her classroom teaching continued its focus on student engagement using science issues of relevance to them.

Throughout the workshop series, Sue consistently trialled aspects of the NoS with her classes, particularly valuing “learning about different ways of investigating in science” so that it was no longer just “using a recipe”. All aspects of the NoS were used with her classes as she was keen to keep the students learning new ways, to “work together to find out more about science in their lives”. Building students’ scientific literacy was seen as an important element for part of her teaching, with a specific focus on getting students to think and write using scientific ideas. The reflection process Sue engaged in demonstrated that she had moved beyond technical rationality as identified by Argyris and Schön (1978) towards reflective rationality as she had begun to ask her own questions related to her teaching practice and reflect on her

“theory in practice and her constructions on teaching and learning within her own school context”. This approach to reflection by Sue demonstrated open-mindedness, responsibility, and interaction with others alongside intuitive actions in line with Lee’s (2005) consideration of characteristics of a reflective practitioner. Sue experienced some initial difficulty engaging with the new approach to teaching, as it required “unlearning of her deep seated theories in use” (Schön, 1983, p. 255), and she was reliant on support from both the myself as facilitator and a colleague at the same school, also participating in the professional development, who was also trialling using more student-centred approaches to teaching in his classroom. Once Sue had become committed to changing her practice, the two worked on ideas together and prepared and shared resources which enabled them to share experiences and compare the response of students to the changed teaching approaches. This aligns with Zeichner and Noffke’s (2001) assertion that reflective action is a “process that involves more than logical and rational problem-solving processes” (p. 9), as it requires teachers to discuss their differing experiences to build a professional language that enables them to communicate readily about their teaching and learning experiences (Wolfensberger et al., 2010).

4.6.2 Teacher Maria: Building confidence in ability to teach science processes on NoS with young students.

Maria had twenty years teaching experience, her tertiary qualification was a Trained Teaching Certificate, and she was teaching Year 1 – 2 students. Her score in NSAAQ was 91/130 and 17/30 in Factor 1, What is the Nature of Scientific knowledge?

In the first session, Maria demonstrated hesitancy about participating as she felt she had a lack of science knowledge compared to the secondary teachers. The NSAAQ score of 87 revealed a lack of truth in this, although her scores were low in both the “Understanding of the NoS” and “How science works” compared with the others in the group. During the first session she indicated the value of learning to do science investigations through inquiry and creating

challenges were new concepts for her. She trialled these approaches with the Year 1 and 2 class, instead of the very directed and prescribed approach she had always used. Throughout the year, Maria continued to trial approaches on all aspects of the NoS with her class and used science as a context for reading and writing, something she had not done before. Her reflections indicated that the students were excited at finding out about science and that many of the simple experiments the students did at school were repeated by the students at home for their parents. This was something new and exciting for Maria and her students, and included making an egg float in water by adding salt, and making observations of the ways different types of candles burned. She engaged students in role playing motion of particles to build their understanding about particles, and developed their writing of “cause and effect” sentences to explain their observations in their science experiences. Maria brought samples of some of the students’ cause and effect statements to the third session to share with the other participants. The sentences were written by the five and six year old students about heating effects, and incorporated accurate scientific ideas about particles. A year 10 teacher (3Y) from a secondary school was amazed at the students’ writing and stated, “If my Year 10 students could write sentences like this I would be over the moon, I can’t believe these students are only six years old”.

Support from the other teachers participating in the professional development empowered Maria to continue to build science into her lessons, and also to seek additional support for both herself and her school. This support was in using more process focus for designing science themes in the Junior syndicate (Years 1 to 3). The others in the syndicate found it hard to move from the sharing of science knowledge with students, mainly involving sharing of facts to a focus on scientific processes of observation, asking questions, and exploring science ideas to suggest explanations. Through my support as facilitator with the design of some initial tasks, and my on-going support by modelling and engaging the teachers

themselves in some of the practical activities at a staff meeting, Maria began to get all the other teachers in her school trialling the approaches.

Her highlight was the end of year science field trip to the Rocky Shore where she had all the students and teachers exploring and sharing what they had found out about the animals and algae in the rock pools. She had insisted that the usual task for assessment was not appropriate – a cut and paste activity where animals were glued to the area they were found. Instead, she insisted that after some discussion as a group on what they had seen on their initial look in the rock pools, each student was to choose an animal and go back to watch it in the rock pool, record as much as they could about it and how they thought it fitted into the rock pool conditions. All the teachers expressed surprise at how much the students noticed and how well they recorded their observations. Back at school students wrote “cause and effect” statements such as “I think crabs ... because....” but had to check their ideas with the books available to them. The other teachers recognised that they had been limiting their expectations of their students’ learning due to their own lack of confidence in the science topics, and that through working with Maria they had trialled an approach that would be adopted by the syndicate. On-going planning as a syndicate had enabled this to happen, and included time for teachers to explore and investigate before commencing activities with their classes.

Sharing with her peers enabled Maria to establish an assessment approach across the syndicate focussed on building the NoS processes in students instead of recall of facts, which led to the development of a new approach to the theme selected as the focus for 2011. The school selects a theme to base the teaching and learning inquiry programmes around for the year and unpacks the theme for the different learning areas with the students. Maria is adamant that the capability for doing this came from the NoS professional development as it built her confidence and her ability to share science experiences with her students through

providing practical ideas that she adapted for younger students. The discussions at the workshop sessions gave Maria confidence when she realised that her experiences with her students could be compared and discussed with secondary teachers, and that she “could contribute suggestions as well”. The sessions also gave her “some theory” so that she had “more theory in my understanding” and readings to follow up with so that she “could share with other teachers”. It also helped her “understand the NoS was about doing things the science way through easy activities that made students think and ask questions”. The use of the exemplar matrix for assessment was good because it “made us focus on the NoS and ways to identify where students were at and their next steps to develop in our next topics”.

The key aspect Maria identified that she needed to develop was science content knowledge, as she believed she already demonstrated pedagogical content knowledge in her teaching of young students. However, an additional element she had to come to terms with was that science required building of science processes and not just sharing of the facts of science. She initially described herself as lacking the confidence to share and participate in discussion of science ideas with others at the workshops. However, as she reflected on the trialling of some small practical activities with her students, she became excited by both their enthusiasm and their ability to talk about their observations using the science ideas she shared with them. This gave Maria confidence to take the ideas further and take science into the reading and writing programmes she used with the class. Sharing the outcomes of this with a colleague on the professional development programme inspired the other teacher to also trial some activities with her older students. As a result, both teachers were prepared to share their experiences with the whole group and brought examples of student work to show.

The reflections shared by Maria indicated that she had moved from continually reflecting on her lack of knowledge to reflecting on the processes she was using in the classroom, to reflecting on the impact of the change in her teaching practices on the students’ understanding

of science processes. She did not limit the students' ability to develop their scientific literacy, as she continued to share new approaches to investigation and inquiry in science with them. To advance their scientific literacy, Maria worked with the students to identify the next steps in their learning process, making use of effective feedback so that these young students were excited about the science concepts they were exploring.

Maria benefited from the approaches used in the workshop programme as the sessions allowed time for reflection, sharing, and discussion, as well as building up scientific knowledge which she acknowledged was a key element for her. However, as the sessions progressed she also enjoyed the opportunities to engage with a range of science activities that could be used with students to develop their understanding of different aspects of the NoS. These provided her with an opportunity to demonstrate that even young students can begin to understand the nature of scientific study and processes. It also gave her confidence to share her findings with the others in the group, even though they may have had greater science knowledge. She expressed the opinion that she learnt a lot from listening to them talking about how they would use the activities with older students. Such a concept aligns with Wolfensberger et al's (2010) research, where the use of specific reflective processes built teachers ability to analyse and manage classroom discussions to meet teaching goals and criteria. Some participants highlighted the exchange among teachers as the most valuable part of the process. Wolfensberger et al. (2010) redefined reflective teaching in a narrower sense as a process of description of teaching actions subsequently accompanied by reframing and then building a different focus on the reflection that led to refined and better informed teaching actions. Such a redefinition parallels what was observed by Maria as her reflection over the time of the professional development programme. This led to changes in her teaching actions so that she became confident to share her new ideas with her colleagues to bring about changes not only in her classroom, but also within her syndicate, in how the

teaching, assessment, and learning of science was conducted from a fact focussed approach to a NoS driven approach.

4.6.3 Teacher Warren: How to challenge student thinking to lead to understanding of NoS and build ability in processes of science.

Warren had 30 years teaching experience, a Bachelor of Horticulture and a Trained Teacher Certificate, and was teaching Year 6 to 8. His NSAAQ score was 81/130 with 20/30 in Factor 1, What is the Nature of Scientific knowledge?

At the first session, Warren demonstrated confidence in content knowledge of science and of the need to lead the school towards a greater focus on science. He was unsure how to build the confidence of the four female teachers at the school who provided little opportunity for practical work for their students as they were “scared of the questions their students might come up with”. After the first session he confided to me, as facilitator, that because he was confident in his science knowledge, he had not really looked at the science learning area statements or the achievement objectives, other than to see that they were little changed in the focus for the “four worlds”. The change in emphasis came through reading the directive of the Science learning area introduction (Ministry of Education, 2007, p. 28). This had a huge impact on his thinking about the focus for science at the school. Warren reflected that without the theory/practical balance of the first workshop session, he might not have realised that he needed to change the way he was carrying out science activities with his children, as well as how he introduced science topics to them and built their understanding of the concepts of science. He recognised that he was coming from a content driven perspective, using the approach of sharing his extensive knowledge of science with students and staff, and that this could have been a barrier to science teaching and learning within the school.

The initial approach to building his own understanding of the NoS was to carry out an observation task with his class, with limited teacher input. Students were required to record their observations of a burning candle using drawings or written comments, suggest explanations for their observations, and record any questions they had about the burning candle. As the class had looked at burning and combustion in previous learning topics, the teacher was confident that students had the knowledge to make and record reasonable observations and construct appropriate questions. The resulting student observations were disappointing to the teacher, as they were very generalised and non-specific, demonstrating little evidence of any prior science learning about combustion. The impact of this task for Warren was the realisation that there was truth in the readings relating to constructivism and science learning, leading him to begin to re-evaluate his approach to science teaching.

The first step in the process was identifying the need to specifically identify and provide opportunities for students to develop the processes and skills needed to carry out tasks designed to build specific science concepts. Warren acknowledged that the students had never been helped to make observations or use measurements as part of the observing and exploring about a phenomenon, nor had they been given opportunities to share their ideas prior to exploring. Instead the approach had been teacher-directed, expository, and recipe-like, with little valuing of student existing ideas or knowledge, but group work had been regularly used (Symington & Kirkwood, 1995). The relevance of a constructivist view of learning and the need to employ strategies to address this approach in science became apparent to the teacher due to his reflection on the observation task. Although some of these strategies were part of his practice in other learning areas, Warren initially found it difficult to stop himself from moving into “expository mode” (Symington & Kirkwood, 1995, p. 194) during science lessons.

Assistance was sought from me, as the facilitator, to model both whole class and small group approaches to questioning, to elicit student ideas about the science concepts relating to balls and their “bounceability”. The purpose of this was to support students to develop testable questions and to find answers associated with different balls or situations. Students then, with support, devised and carried out small group investigations to test their ideas/predictions using a “predict, observe and explain” approach (Gunstone, 1995, p. 13). Warren reflected that as the facilitator, I used a different style of questioning that led students to air their understanding rather than just repeat information Warren had provided. In addition, he saw how a mix of individual, small group, and larger group work led to better discussions and more development of a range of ideas with students confidently defending their own ideas from their observations. This recognition of processes the teacher needed to learn reflects some of the list of skills identified by Hand and Prain (1995) as being essential for teachers to acquire if they are to adapt to student-centred learning approaches. These were: the need to develop better questioning skills; how to conduct group work successfully; and how to carry out class discussion and sharing times so that all students remain engaged (Hand & Prain, 1995).

Two further elements were identified by Warren in later workshops as necessary to fully develop a focus on developing student understanding of science concepts. The first element identified was a way to more effectively assess student understanding of the concepts and processes of science. Specific rubrics from the *New Zealand Curriculum Exemplars: The Science Matrices Progress Indicators* were selected as they were perceived as being a suitable tool to use with students as part of their self-assessment practice. The initial rubrics used by both the teacher and the students related to “exploring a situation” and “asking questions” (Ministry of Education, 2004) provided a “very good reflection tool for me, as I became more involved in the tasks I was encouraging students to carry out, and found I did not always have all the answers”.

The second element identified arose from Warren's observation that there was greater engagement of all the students in his class, regardless of gender or ability. It was this that convinced him that the science programme needed to change in its delivery and intent across all the school to building more focus on the NoS and a more "concept oriented curriculum" (Hand & Prain, 1995, p. xi). Warren also realised that it was not just providing hands-on activities, as had been his practice. Instead, it was about planning the type of practical activities, having a clear purpose for using each, and using the activities to elicit student ideas, knowledge, and conceptions or misconceptions, as well as to engage them in asking questions and exploring situations to develop scientific explanations. This progression in his understanding indicated his growing understanding of constructivist approaches.

As a result of Warren's engagement and sharing of his students' response to the science they were doing, the other teachers began to trial small activities and invest time into preparing and trialling activities to use with their classes. Warren continued to support them, but as he and two other staff members were part of the professional development, all three teachers began to use more science and even trial simple activities with their classes to challenge their thinking and expose their students to more science. Through this increased exposure, Warren became aware of the need to improve the older students' scientific literacy and to particularly address the communicating in science strand of the NoS of the *NZC* (Ministry of Education, 2007). He viewed scientific literacy in the internationally accepted sense, but perceived the starting point needed to be in supporting students to use their observations and their growing knowledge of scientific concepts to write explanations as part of their predict-observe-explain process. He used modelling and scaffolding approaches to support the students to write "cause and effect statements" such as "I think the ...", "because we noticed that ...", and "I know that ... from.....".

At the end of the year, Warren reflected that both teachers and students were excited and more confident about “doing science”, so much so that the school had a science week where students worked in whānau groups to explore something of concern or interest to them. Teachers worked closely with these groups and were prepared to provide suggestions or activities focussed on a NoS aspect that could be used to refocus the group on a more useful avenue of exploration. This was a big change from previous years, when this week had been the only science for most classes for the year, and had been a series of teacher directed recipe-like activities. Parents and caregivers were impressed with the excitement and enthusiasm their children were showing for the activities they were doing and exploring during the week, so much so that quite a number of them found reasons to come and take part.

Both students and teachers reported that they had “new interest, new understandings about science, and new way of thinking that helped them in more than just science”. The Principal reported that the science focus had led to an improvement in writing, more science being done, and more science being integrated within reading, writing, and mathematics. In addition, teachers were sharing ideas and planning together regularly, and were not afraid to ask Warren to help with explaining the science concepts behind some of the observations and questions of students. Using the rubrics from the *New Zealand Curriculum Exemplars: The Science Matrices Progress Indicators* provided a new way of thinking about science that enabled science to become an essential part of the school programme. The children now enjoyed and were confident to take part in science, this had not been so prior to introducing the focus on the NoS. The levels of the rubrics provided the teachers with a formative assessment approach that helped them identify the next steps for students, and provided knowledge of processes to develop further in lessons and experiences.

Warren also reflected that as a team they had come a long way, but he was not yet confident that he had sufficient understanding of a range of ideas needed to fully build student

understanding of the NoS without on-going support and access to suitable resources. As a consequence, a request for additional and on-going support for the school was made the following year. This aligns with Hand and Prain's (1995) assertion that the change to using constructivist approaches to science requires a "balance of theoretical knowledge with the practice of the classroom, where each needs to inform the other" so that "development of students' understanding of conceptual knowledge becomes the main focus" (Hand & Prain, 1995, p. xi).

4.7 The Final Form of the Intervention

The intervention created an intervention design shown in Figure 2 (see p. 123). An essential element in this design was the generic approach to each workshop, which incorporated elements of the 5E approach with variations in the activities and strategies used depending on the aspect of the NoS from the *NZC* being developed. This is shown in Generic Structure for Workshops in Figure 3 (see p. 125). The 5E approach drew on elements from both the BSCS model and the Skamp model designed to address constructivist approaches to learning (Bybee, 2006). The intervention was comprised of five workshops, with workshop 1 being introductory providing an overview of the requirements of Science in *NZC*, while Workshops 2 to 5 each addressed an aspect of the NoS from *NZC* (Ministry of Education, 2007). Alongside the workshops, and an essential part of the design, were the in-school support and the on-line learning components devised to build sustainable practices with the participants, as well as building their pedagogical and content knowledge. These were incorporated to "maintain momentum" (Timperley, 2008, p.20) and to ensure participants trialled their new learning with students, monitored this achievement to identify the effectiveness of the teaching, as well as consolidating theory with practice with the possibility of "external expertise" (Timperley, 2008, p.24) (refer to Intervention Design, Figure 2). The design reflects the features of DBR as it was the result of input from participants and facilitator (Ma

& Harmon, 2009). A summary of the design including examples of the activities used in the workshops is provided in Appendix 5.

Intervention design

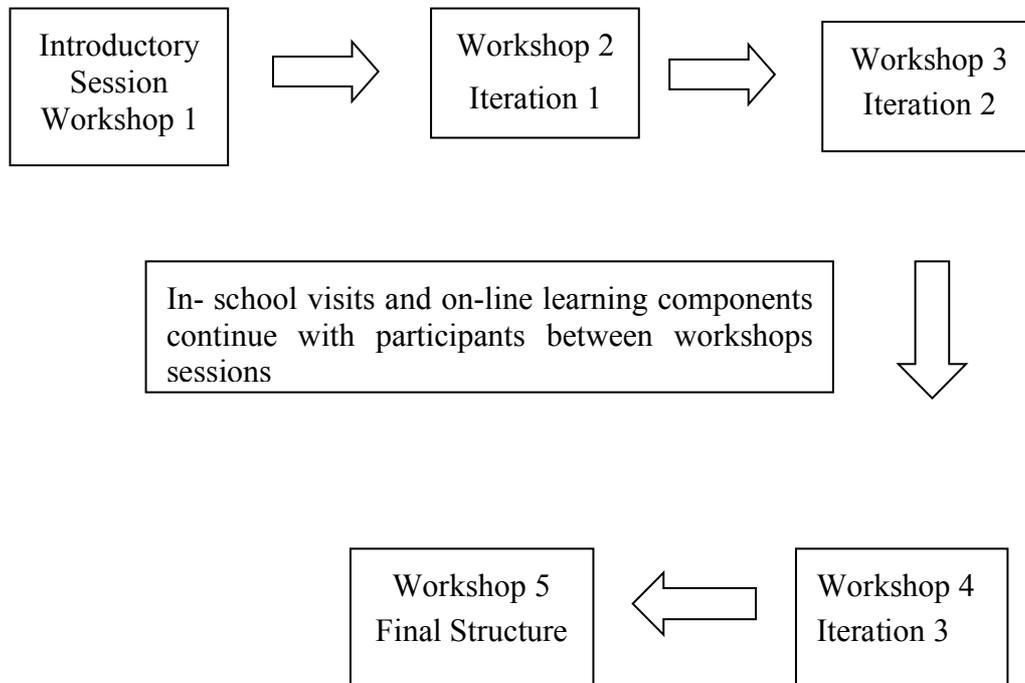


Figure 2: Final design of intervention to develop a theoretical understanding of NoS leading to increased NoS learning for students

Generic Structure for Workshops

Workshop component	Outcome for participants	Activities
Engage/Elicit	Focus for session established and prior knowledge and ideas shared	Hands – on minds – on activities as a small group to brainstorm questions and prioritise ideas to find out more about in session
Explore	Building of evidence to form theoretical and practical knowledge relating to focus	Selected readings, resources, modelling and investigations
Explain	Use valid and relevant pedagogical and scientific information to suggest an explanation/process relating to the focus	Use both qualitative and quantitative evidence to develop a response in small groups; discuss appropriateness of explanation as a whole group
Extend	Adapt and develop explanation to participant’s own teaching situation resulting in extension and integration of each participants’ learning	Individuals or small groups plan/develop another way of using ideas to build student understanding of the NoS aspect with students in the context of their class/school
Evaluate	Reflection on concepts developed in session and relevance of these to individual teaching situation	Individual reflection using questions- How has my understanding of how science works changed in relation to NoS? How will my teaching change as a result of this understanding?

Figure 3: Generic structure for workshops.

4.8 Summary

In this chapter, the results of the phases of the research have been described, data analyses have been presented, participant voice, and reflections have been shared to triangulate with the survey results and to provide evidence of the effectiveness of the intervention design as part of the research.

Chapter 5, Findings and Conclusions, will provide a summary of the research study, and a report on the design research. This report uses the five sections of reporting design experiments “Design goals and elements; Settings where implemented; Description of each

phase; Outcomes found; Lessons learned” suggested by Collins et al. (2004, pp. 38-39) to convey the evolution of the generic design for a professional development intervention that could build teacher NoS capability. A review of the findings relating to the research questions is followed by a discussion of key concepts leading to conclusions based on the research questions.

Finally in Chapter 6, the recommendations for addressing issues raised will be suggested and areas for future research will be identified.

Chapter 5. Findings and Conclusions

5.1 Introduction

This chapter, Findings and Conclusions provides a

- summary of the research study, the problem the study sought to address, the information collected to answer the research questions including the report on the design research, and a summary of the key points relating to these from the literature review,
- review of the findings from both the statistical analyses of the NSAAQ survey used to identify the NoS understanding, and from the qualitative data, and a
- statement and discussion of conclusions based on the research questions.

5.2 Summary of the Study

The research carried out in the three phases of the study sought to provide a response to the overarching question: How does a theoretical understanding of the Nature of Science (NoS) attained through a professional development programme facilitate changes in science teaching practice? During the research both quantitative and qualitative evidence was collected. The data analyses of the NSAAQ survey responses provided evidence of the need for an intervention to build teacher theoretical understanding of the NoS. This information enabled an initial approach to an intervention to be designed. The NSAAQ survey was used with participants in the intervention at the first workshop to provide baseline data on their NoS understanding; it was repeated at the final workshop session to provide comparative quantitative evidence of any change in their NoS understanding. This data was analysed and triangulated with participant voice and reflections to provide evidence of the effectiveness of the intervention designed as part of the study. The information was used to explore how

effectively the professional development intervention designed in this study developed teacher capability to deliver science teaching programmes incorporating aspects of NoS described in the *NZC* (Ministry of Education, 2007).

To enable such a design to be constructed, the first phase established an understanding of teachers' existing NoS knowledge using the NSAAQ survey designed by Sampson and Clark (2006). The analysis of the results from this survey was used to determine the aspects of the NoS to incorporate into the professional development intervention design. The NSAAQ survey contributed evidence towards a response to the research question, What are teachers' existing understandings of the NoS?

The evolution of the design of the professional development intervention with three clusters of participating teachers from the Lower South Island of New Zealand was the second phase of the research. This process has been described in Chapter 4, and included consideration of components of the design, from use of theoretical readings, to effectiveness of strategies and activities used to build participant understanding. Summaries of qualitative evidence obtained from participants' journaling and reflective responses provided evidence of the intervention effectiveness, together with the statistical analysis of results of the pre and post intervention NSAAQ survey. All of these were used to ascertain a response to the research question, How effectively does a targeted in-depth professional development approach build teachers' understanding of NoS as described in the science learning area of the *NZC*.

The third phase of the research assessed the effectiveness of the in-school and on-line components of the design supported participants to transfer their increased theoretical NoS understanding into their teaching practice. The in-school support enabled the facilitator-researcher to observe participants' teaching and their students' learning and engagement, and provided an opportunity to assess the match between participants' espoused and actual practice. As well as observing participants' teaching, opportunities were provided for

additional support to assist them to translate theory into practice. Observations of three participants' classroom teaching, together with their reflections and anecdotal evidence, was presented in Chapter 4 as three vignettes developed jointly by the researcher and each participant to provide evidence for the research question, How is increased Nature of Science understanding evidenced in teacher practice?

Finally the intervention design for a professional development intervention that could build teacher NoS capability was shared.

5.3 Report on the Design Experiment

This report is based on the reporting structure recommended by Collins et al. (2004) for design experiments. The design produced as part of this research was trialled with three groups in the Lower South Island of New Zealand, comprised of teachers from a range of urban and rural schools, primary, intermediate, and secondary. This allowed the intervention developed as to meet Collins et al. requirements so that the design could be “summatively evaluated” (p. 39).

5.3.1 Goals and elements of the design.

The goals to be achieved within the design of the intervention to develop NoS understanding through a professional development programme were established using Ma and Harmon's (2009) guidelines. The goals were to:

- develop a professional development programme that built teachers understanding of the NoS,
- support teachers to explore ways to teach the NoS,
- allow teachers to share their own experiences and knowledge together with collectively constructing content knowledge specific to the NoS,

- provide the NoS content knowledge, science specific pedagogical knowledge and technical knowledge, and to
- incorporate a range of activities, strategies and approaches to address differing needs and NoS understanding of participants.

From these initial goals it became apparent that the design had to be flexible enough to allow for modification, as participants' needs and interests were determined during workshop sessions. The design also needed to provide opportunities for discussion, reflection, and sharing of aspects trialled by participants, thus it could not be rigidly programmed.

In addition, participant feedback was an important element of the design. Therefore, modifications had to be made in response to observations of participants' engagement, interest, and participation during the workshops, and to their reflections and feedback from the each workshop. This led to the content for each session other than the first workshop being selected in collaboration with the participants, so that each incorporated some structured activities to develop NoS aspects, such as scientific investigation and scientific understanding or participating in socio-scientific issues, as well as theoretical readings. This aligned with the suggestion by Khishfe (2008) and Yacoubian and BouJaoude (2010) that to be effective, teachers needed to experience explicit teaching that combined practical activities, discussion, and theoretical perspectives that allowed them to reflect on NoS concepts. One such structured activity was a scientific argument, "Should we have wind farms in the local area?" as a tool to focus on how teaching can develop the process of science as argument to address aspects of NoS Understanding Science and Communicating in Science (Ministry of Education, 2007).

5.3.2 Settings where implemented

The design was implemented in three different locations, however, the variables within the physical environment of each location were similar, as the professional development was off site for each. The workshops were held from 12.30 to 5pm, with refreshments provided. Each location had a similar mix of participants from primary, intermediate, and secondary schools, although at one location the intermediate school participants did not attend the final session or accept the in-school support. The range of participants' ages, qualifications, and years of teaching did not appear to alter the level of engagement in the professional development, nor their willingness to engage or accept in-school support. Participants in each location came from urban and rural schools; however one location differed in having participants from four different integrated schools of differing Christian denominations, which led to some discussion of elements of the *NZC* that did not occur in the other two groups.

In the evolution of the design, the activities incorporated were selected specifically because of the ease of obtaining equipment and materials to enable participants to carry out the activities themselves back at school. This ensured cost would not be a limiting factor to implementing NoS approaches in lessons. Follow-up feedback from participants indicated that every teacher did actually do this on at least one occasion, adapting the NoS activity to their situation. Only two of the 42 participants indicated they simply trialled the NoS activities as provided, and did not adapt the activities for use with their own students. Any resources that required copying or adapting were supplied electronically or in hard copy ready for use.

Although all participants did not make use of the opportunity for in-school support, this was a key element of the design that would ensure its success in other settings. In considering using the design in future professional development settings to build teachers' NoS capability, the cost of the provision of the in-school support element is a key consideration. Without this support, several participants would not have had the self-confidence to lead their syndicate or

department to address the NoS as required in *NZC* (Ministry of Education, 2007). Having the facilitator support as they led staff meetings, or developed school programmes, or incorporated specific NoS activities into lessons helped give the confidence to continue to promote the NoS as the required learning in their schools.

5.3.3 Description of each phase.

The development of the design progressed through a series of phases, each progressed the development of the design, while addressing different aspects of it. These are outlined and described in this section.

5.3.3.1 Phase One: Identifying the NoS understanding of science teachers.

The NSAAQ survey enabled the cognitive level of teachers of science in the region to be identified before the design of the professional development intervention commenced (Sampson & Clark, 2006). The analysis of responses to the NSAAQ allowed aspects of the NoS for which respondents held naïve views to be identified. The analysis and detail of these naïve aspects were fully described in Chapter 4, section 2. This enabled the facilitator to make the generalisation that if approximately 66% of the 87 survey respondents held these views, it is likely that similar views would be held by participants in the professional development intervention. As a result, an indication of possible NoS content to be incorporated within the professional development programme was obtained.

5.3.3.2 Phase Two: Refining workshop structure

After Workshop One, the design evolved as participant feedback led to incorporation of the constructivist 5E approach (Skamp, 2004) to provide a professional development approach rather than a teaching approach. The key elements for this design were developed for the second workshop session, and refined with each iteration on feedback from each group.

However, the actual 5E structure changed little; rather, the activities were refined. This evolution is described in detail in Chapter 4, section 4.5.

5.3.3.2 Phase Three: Determining the design of the in-school support component.

In determining the in-school support appropriate to the design, it became evident that both individual classroom observation and modelling approaches to teaching the NoS were important considerations in building participants' confidence and pedagogical content knowledge. This was affirmed by participants' feedback and reflections as outlined in Chapter 4, sections 4.5 and 4.6, and aligns with Timperley's (2008) assertion that to be effective "professional development needs to support teachers as they develop the theoretical understandings and tools that will enable them to take a self-regulated, inquiry approach to their everyday practice" (p. 20). As part of the design, the need was identified to support each participant individually in their school, because the needs of one teacher may not be the same as those of the other from the same school. However, the collegial nature of the support was also important, as it enabled the two from each school to more readily share ideas with their department or syndicate, while providing opportunities to discuss their new learning and the impact of these on their students (Timperley, 2008). The three teacher vignettes provide evidence of the value of the in-school support as an essential component of the design from different perspectives, and of the different ways that the support was provided by the facilitator. This will be discussed in Section 5.6. An additional purpose of in-school support within the design was to enable any mismatch between espoused and actual practice to be identified so that individual support could lead to pedagogically sound teaching practice (B. Bell, 2005).

5.3.3.4 Phase Four: Developing the generic design.

This phase focussed on assessing the effectiveness of the design through comparison of NSAAQ results at the beginning and end of the professional development intervention (Sampson & Clark, 2006). This comparative data was triangulated with summary interviews with participants to identify any changes in their understanding of the NoS and in-school observation data. As a result of trialling the design within the workshop sessions, together with the accompanying in-school support, the generic design of the professional development programme to build teacher understanding of the NoS was developed. The combination of the workshop structure based around constructivist 5E teaching model that incorporated a range of different activities and readings, and individual in-school support tailored to teachers' needs via the in-school component, proved key elements to the success of the design. The generic design could evolve and be modified depending on the needs of participants as required for other professional development settings.

5.3.4 Outcomes found

In analysing the qualitative and quantitative data collected to provide evidence of the effectiveness of the design of the intervention to build participants' NoS theoretical understanding, several themes emerged. These are described in detail in Chapter 4, section 4.4, and selections from this information are used to discuss the outcomes found as the professional development programme evolved within the design research experiment (Collins et al., 2004).

5.3.4.1 Climate variables.

Throughout the intervention, participants exhibited a high level of engagement in the workshops with each of the three groups having only one participant absent at workshops 3 and 4, no one was absent from workshops 1 or 3, but two were absent from Group 3 for workshop 5. Data gathered over time by my organisation (Education Support Services)

indicates that when a professional development initiative runs over a series of workshops, on average 30 to 40 % of participants complete the series. For the effective pedagogy series of four workshops held in 2010, only 40% completed the series. Comparing attendance at the NoS professional development intervention with this information, there was a commitment to the NoS-intervention by the participants. Timperley (2008) suggests under “principle 2” that teachers need to be “learning worthwhile knowledge and skills” (p. 28) for effective professional development, and those likely to be most effective will have been “subject to wide research and debate” (p. 28). It can be suggested that participants viewed this intervention in this way, and valued the use of readings that highlighted the internationally accepted views of the NoS provided by authors such as Lederman and Lederman (2004), McComas et al. (1998) and Aikenhead (2006).

Within the workshops, as the participants established trust and a working relationship as a group of learners, there was a readiness to engage in the range of activities within the session, whether it was carrying out a challenge, investigation, discussion, or reflection on a reading. This aligns with the assertion by Timperley (2008) that “environments that offer trust and challenge as part of the professional development” (p. 15) will assist teachers to change their practice.

On only one occasion did a participant work independently rather than collaboratively and not complete a challenge. Participant 3J believed he knew how to complete the challenge but when he undertook it, he did not succeed. He would not join with one of the other groups to try to find a different solution because he believed his theory was correct and the way he did it should have worked. Participant 3J also did not seek in-school support, but watched and listened to the support being provided for his fellow teacher, but he did trial and report back on some of the approaches. Teacher 3J was very shy, but did share ideas with the whole group and supported the other teacher in sharing ideas with the rest of the science staff. In

addition, 3J's classroom practice changed over the intervention, with increased use of student led investigation, and less teacher directed learning.

Participants were willing to engage in reflections and sharing of their successes or problems in the implementation of their chosen NoS approaches with students in a collaborative manner. These were not just reporting back times; rather, participants took risks, acknowledging when they needed support, and actively sought ideas and solutions from others for their issues. They also challenged each other to think more strategically when limitations were suggested, especially where those related to time or content coverage restraints. For example, when teacher 2E thought it would be good to use the ice balloons but it was difficult and it would take too long to make them. Teacher 2J asked why she did not take the ones left from their engaging component and use them, or else just freeze the water in margarine pottles – that it did not have to be balloons. Teacher 2J followed up by using the activity with his year 5/6 class and used ice frozen in yoghurt pottles. In another instance, Teacher 1B described the constraints from the school's rigid planning approach, where science was only to be delivered in its turn with the other six non-essential learning areas on a Friday afternoon, and sought ideas from other participants on ways to address this. Suggestions ranged from initiating staff discussions to informing the principal that Teacher 1B should just teach science when it was appropriate for her students. The approach the two teachers (1B and 1A) from the school took was to weave science throughout their day, using Engage activities to provide stimulus for writing which was the required focus for the start of each day in the school programme. The reading and the mathematics slots were imbued with the science focus that emerged from the Engage activity of the morning. These two teachers took a risk, and as a consequence of this approach both they and their students became engaged in science and both 1A and 1B were excited by the revitalising of their teaching that this provided for them. This response by the participants aligns with the model of teacher change advocated by Guskey (2000), where change in teacher practice results in change in

student learning as a result of change in teacher beliefs and attitudes as described in Chapter 2.

Similarly, in the Extend component of the workshops, planning how to incorporate ideas and modify the NoS activities from the session to trial with participants' differing theme was co-operative both within and across schools. Journalling responses indicated that within each workshop the content challenged participants at some point, and they felt they were taking risks. The most frequent risk taking reported was in sharing their thoughts and reflections on readings. This suggests that many teachers were not engaged in developing content knowledge and pedagogical content knowledge through reading some of the more academic articles available in journals such as *Science Teacher*, published by NZASE.

Although participants in the intervention varied in their level of study in science, it appeared to make little difference to the cooperation and engagement with the concepts developed within workshops. When asked if they wanted to split into primary and secondary groups in discussions in the second workshop, the primary participants asserted that this was not necessary as they were learning from the secondary, and similarly the secondary agreed they were learning from their primary colleagues. This may have been a result of the NSAAQ results showing that background of tertiary science attainment had limited effect on the overall score (see Chapter 4 section 4.2), and that the focus on building the NoS understanding was new for all.

5.3.4.2 *Learning variables*

The NSAAQ survey (Sampson & Clark, 2006) showed that initially 63 to 67% of participants held naïve views for the four NoS factors of the survey as detailed in Chapter 4 Section 4.2. This indicated that their theoretical knowledge and understanding of NoS was limited, and as

a consequence, it was unlikely their teaching and learning programmes were addressing this in a way that would increase students' NoS capability.

The content knowledge of participants relating to the NoS increased during the intervention, as indicated by the NSAAQ scores at the end of the intervention, where participants retained naïve views for only six questions compared to the 16 of 26 at the beginning of the intervention, as shown in Chapter 4, section 4.8, Table 7. The mean overall score in the NSAAQ increased from 85.0 (SD = 6.8) at the start of the intervention to 94.3 (SD = 10.5), a statistically significant increase in NoS understanding, demonstrating the intervention had been effective. However, two aspects of the NoS required further development within the intervention to build participant understanding, both relate to concepts covered in *NZC* under Understanding about Science although also having links with Investigating in Science (Ministry of Education, 2007). The two aspects were:

- The methods used to generate scientific values are based on a set of values rather than a set of techniques, and
- Scientific knowledge can only be considered trustworthy if the methods, data and interpretations of the study have been shared and critiqued (Sampson & Clark, 2006).

The in-school learning component did reveal some differences in skill and content knowledge needs of participants. Although both primary and secondary participants sought support in incorporating the new pedagogical content knowledge into their teaching and learning, the specific support needed by primary was less on effective pedagogy, and more on ways to develop science skills or science specific content knowledge for the topic. On the other hand, secondary participants sought help with effective pedagogy as they had fewer strategies for addressing the change to using constructivist approaches to teaching and learning from a more

teacher directed content driven approach (Carr et al., 1997). This observation aligns with Carr et al.'s (1997) assertion that in switching to employing constructivist approaches, teachers need to provide a wider range of experiences for students to help them generate and absorb new ideas and concepts (Chapter 2, section 2.3.4). Upskilling in strategies became a focus in my facilitation approach so that any different strategy used was unpacked for the background idea being developed, how it supported student learning, and the intended learning outcome as well as how it linked explicitly to the NoS (Hipkins et al., 2002).

The use of the constructivist 5E model to provide the design for the workshops structure enabled a range of learning opportunities to be provided for participants to address their various needs. The Engage/Elicit component assisted the facilitator to identify specific needs for each session so that participants' learning needs were met with regard to content and pedagogical content knowledge. This led to differences between the readings used with each group, and variation in the activities used to develop the NoS concept, but the design components remained constant with the constructivist 5E model. Allowing this flexibility within the design was important, as it recognises the individuality of each group and its participants, and was responsive to their needs and could provide "multiple opportunities to learn and understand the implications for practice" (Timperley, 2008, p. 15) where required.

The design incorporated journalling and opportunities for critically reflective practice, as participants considered the effectiveness of the NoS tasks they developed and trialled with their students between workshops. This was an important component as it provided opportunities for participants to develop the "self-authored mind" (Berger, 2007, p. 27). The discussion sessions within the Explore component engaged participants in questioning their underlying assumptions about teaching and learning, as well as providing opportunities for developing participants' active listening skills to gain an idea of others' perspectives, another key element in the development of the self-authored mind. The development of the quality of

participants' journaling and reflections on their teaching trials over the five workshops, as demonstrated in Table 6, provides evidence that they were becoming more critically reflective and moving towards the self-authored mind. In addition, the engagement in the discussion and the supporting of each other in the refining and adaptation of specific NoS activities for individual programmes was evidence of participants "expanding their minds to become constructors of curriculum and not just deliverers" (Berger, 2007, p. 26).

5.3.4.3 Systemic variables.

As follow up to the intervention, contact has continued with research participants due to the relationships established with them during the professional development. The contact has been initiated by them, as they seek ideas for ways to maintain a focus on the NoS with their classes as part of a continuing science emphasis, or in sharing ideas or successes from their teaching. Three schools have sought specific school-wide support to enable them to build capacity across all the staff. In terms of sustainability, these responses indicate the design did not provide all participants with sufficient knowledge or confidence to sustain the NoS concepts developed through the professional development intervention over time. However, in view of the ideas that effective interventions require "one to two years for teachers to understand how existing beliefs and practices are different from those being promoted, to build pedagogical content knowledge and change practice" (Timperley, 2008, p. 15), this intervention could be further developed to address this. It is likely that further workshops would revisit ideas already introduced, but allow more time for challenging beliefs and trialling and feedback of implementing the NoS concepts with students. Another key element would be the incorporation of inquiry into teaching practice using an evidence-based approach with target groups of students as described in the "Effective Pedagogy" section of the NZC (Ministry of Education, 2007).

Costs relating to the design of this intervention could be perceived as an issue. However, the effectiveness of the design in building capability of two participants from a school supports both sustainability and scalability, as costs of releasing two teachers for a half day session can be accepted within most school budgets, while upskilling two teachers leads to a greater chance of sharing concepts with the rest of the staff. In addition, where teachers are less confident they can work together, sharing and developing ideas prior to working with the rest of the staff which can then allow for scalability through use of the intervention. A determined effort was made to keep all equipment and materials used in the intervention activities to those readily available in all schools to ensure costs did not become a barrier to schools developing their teaching and learning programmes to address the NoS focus required by the NZC (Ministry of Education, 2007). Consequently, the design could easily be adopted by other schools and across departments, resulting in development of pedagogical content knowledge of teachers to build the NoS capability of their students (Skamp, 2004).

5.3.5 Lessons learned.

Within each group, the workshops were adapted to the needs of the participants. However, once the 5E structure was established in Workshop 2, it was maintained. The variations came within the time spent on the individual elements of the 5E, which was influenced by the engagement or otherwise of the participants. The key findings relating to the implementation of the design are outlined under the key components of the workshops.

5.3.5.1 Engage/Elicit component.

In developing and planning activities to use as part of the Engaging component of the generic design, the need to model a range of strategies became evident. In some workshops, the engaging activity was a practical activity where participants worked together or in small groups to explore a situation, make observations, develop questions, and then use these questions in the Exploration phase. Other workshops introduced a more structured approach

to the Engage component by using well known NoS activities such as Tricky Tracks (McComas et al., 1998) to engage participants in exploring another aspect of the NoS. Yet another began by using an activity on an interactive science site to engage participants in using sound as a theme through which to learn more about Understanding about Science aspect of NoS (Ministry of Education, 2007). The strength in varying the type of activity used in the Engage component within the design was that it enabled participants to recognise that it was not essential to always use open-ended tasks, but that the key element in engaging was to “set the context, raise questions and elicit existing beliefs (Skamp, 2004, p. 507).

To build participants’ ability to elicit their existing beliefs, a range of techniques were built into the engaging activities. Sometimes the challenge approach was used by setting an activity that allowed them to use their existing knowledge of science. For example, one workshop began with the challenge for participants to produce a traffic light drink from the supplies of salt, sugar, water and food colouring. Another session began with an activity, and some structured questions were provided for participants to find answers from their observations. Another approach was for the facilitator to simply ask, “Why do you think that is happening?”, or “Could you do something differently that might give you a different result?”, or “Can you suggest a reason for your observation?”, or “I wonder why that is happening?” The strength of using the different approaches was that participants were exposed to different ways they could use with students to finding out their existing ideas. Initially as the facilitator, I did not think this stage would be necessary, but on one of the in-school first support visits, Teacher 1A asked for modelling of the Engage element and simply wrote down all the questions I used with students to elicit their ideas. She then stated she did not use that type of question and mainly asked the students “What is happening” so got very limited responses from them. At the next workshop she shared that by using a range of questions with the students they had begun to look much more closely at the activities and were trying to explain what they were observing. Both she and the students were really

absorbed in an investigation the next time I visited, and were making accurate and quantitative and qualitative observations, as well as coming up with investigable questions (Ministry of Education, 2004). This highlighted the importance of being explicit about why I had chosen the particular activities and why particular strategies were used in unpacking or extending the activities, as this was important in engaging the participants in the learning process and allowed for discussion on differences between these ideas or approaches and those they used (Timperley, 2008).

5.3.5.2 Explore component.

The purpose of the Explore component was the building of evidence to form theoretical and practical knowledge relating to focus for participants. This involved both investigations and readings to experience the different ways of exploring a NoS concept. The importance of using the two approaches was that it enabled participants to explore their own ideas and scientists' ideas about the NoS in a range of contexts. This aligns with the *NZC* assertion that NoS needs to be developed within a context which may come from one, or a combination of the four contextual strands (Ministry of Education, 2007). For some participants, the readings were initially a part of the workshop sessions they did not engage with. However, by carefully selecting readings appropriate to the aspect of the NoS being covered, and not requiring individuals to contribute ideas from the reading, instead using group discussion and reflection, this became an accepted part of the design. The strength of using this approach was that the use of group processing time allowed for the processing of new learning as well as building "collegial interactions...that can help teachers integrate new learning into existing practices" (Timperley, 2008, p. 19). One of the activities that was most effective in building participants' understanding of the scientific method was making foam, where some used a recipe-like method, others used an inquiry approach to find what made the best foam, while a third group used a challenge approach to build the highest pile of foam possible. The value in this activity was the participants were exposed to the different approaches and experienced

frustrations within each one, just as their students might in class if always given recipe-like investigations or always having challenges without the knowledge to understand the process. Two readings were used to support this investigation: “Sometimes it’s not fair” (Goldsworthy et al., 1998) and a McComas et al. (1998) excerpt on recipe-like science investigations which provoked a lot of discussion and were subsequently referred to in following workshops by participants. This provides evidence of the effectiveness of combining theory and investigation in the explore component, and that it could also be an important approach to use in the classroom.

5.3.5.3 Explain component.

The Explain component was designed to enable participants to use valid and relevant pedagogical and scientific information to suggest an explanation/process relating to the NoS focus. As the key element of this component was to aid the integration of skills and processes through the use of evidence gathered in the Engage/Elicit and Explore components, engaging in small group discussions was important. The sharing of the consensus reached on the NoS aspect in small groups with the whole group led to further distillation of the ideas and provided a valuable tool for clarifying ideas where misconceptions were evident. For me as the facilitator, this was an important element of the component as it gave me insight into where participants’ thinking was and whether there would be a need for further development of the aspect for participants. The length of time that was allowed for this component was not fixed, as some groups took much longer and engaged in wide ranging discussions than others. A key consideration was the timing and the makeup of the groups to ensure all participants had the opportunity to share. This was more evident at the first two sessions, but as people developed trust and established relationships within the groups, the sharing of ideas increased and individuals were more open with each other (Guskey, 1991).

5.3.5.4 *Extend component: Developing class activities.*

The key outcome for this component of the workshop was the application of the NoS aspect developed in the session to participant's own teaching situation. By discussing ideas with others, concepts were further clarified, new ways of adapting the learning were discovered, and participants were able to adapt and develop their explanations which helped participants extend and integrate their learning into a new situation (Skamp, 2004). The value of this component of the workshop was evident from the way the two teachers from each school elected to work together during this time, even if they had been working with others previously. Together they planned ways they would trial the idea back at school, and as they gained confidence in working with others, they also discussed how they would share the NoS aspect when they returned to school. The facilitator's role during this time was, as Timperley (2008) describes the "knowledgeable expert" (p. 20) in suggesting different perspective to the activity being designed, challenging participants to think about what learning they wanted their students to achieve, and how their approach was going to achieve that outcome. A risk in this approach is that if the facilitator does not have expert content knowledge and excellent pedagogical content knowledge, they may be unable to support participants as they seek to connect the theory learnt in the activities and readings during the session with the classroom practice in a wide range of contexts (Timperley, 2008). This component of the workshop was essentially unstructured and led by participants in the direction that was needed to enable them to adapt the NoS learning to their own situation. The only expected outcome was that each participant developed an activity or approach and a means of assessing student achievement to trial with their class and report back on at the next session. As facilitator, my role was supporting and challenging, or providing pedagogical and or content knowledge suggestions as needed to stimulate the extension of their ideas. During this component of the workshop, participants were more likely to seek specific help on an individual basis including seeking in-school support to trial a specific strategy or change in teaching practice. This is

not surprising given Timperley's (2008) assertion that "in improving scientific reasoning teachers need extended time to learn and change...to build the required pedagogical content knowledge and to change practice" (p. 15).

5.3.5.5 Evaluate component.

Reflection on the NoS concepts developed in the session, and relating these to individual teaching situations to determine their relevance, was the intended outcome of this component. An agreed set of questions was used at every workshop session to enable participants to reflect on their learning as a group. The "think, pair, share" technique was used for this to provide an opportunity for all to engage, and responses were recorded. These questions were:

- How has my understanding of how science works changed in relation to the NoS?
- How will my teaching change as a result of this understanding?

In addition, participants completed the set of Journalling questions either at the end of the session or on-line to provide feedback and to use to modify the design before using it with the next group. For a list of Journalling Questions see Appendix 4. As mentioned previously, participants' preference was for completing the journalling responses at the end of the workshop rather than on-line, although in one group, three participants did complete them as the session proceeded. The open-ended questions used in the journalling reflect the advice of Guskey (2000) to provide opportunities for participants to "have great latitude in recording their responses, and are highly effective in detecting unanticipated reactions" (p. 115). However, he also indicates that lack of detail provided by participants can limit their usefulness. Many participants provided detail in their responses that was useful, especially the responses that addressed the questions about what they might use, and how they might use the ideas, and any additional support they might require. These questions were incorporated to follow Guskey's (2000) suggestion that such questions take participants "beyond the

context of the particular experience and compel them to extend their thinking. Information from these questions is useful for planning future professional development experiences” (p. 115). The questions were:

- How might I use ideas from this session with other teachers?
- How might I incorporate ideas from this session into my teaching and learning programmes?
- What actions am I going to take as a result of this session? When? With what class?
- What support might I need to carry this action out?

One issue with using open-ended questions was that the responses were more difficult to analyse. However, once themes were decided on to use to summarise participants’ ideas, they provided valuable information for reviewing the design of the programme. It would have been ideal to have a greater number of on-line respondents, as the responses may have exhibited greater depth and allowed for a more critical element to emerge in the reflections.

5.3.5.6 *On-line component.*

The purpose of this component was to build a community of practice that could provide opportunities for participants to share ideas and activities among themselves, to engage in on-line discussions, and to share their reflections on readings. Theoretically this should have been a successful element of the design, as most of the primary teacher participants had been in ICT professional development and engaged in the process previously. However, there was limited uptake on the various elements of the on-line component, as detailed previously in the Results Section, 4.5.7. There did not appear to be any specific reason, just a reluctance to participate in an on-line community. The most likely reason could be that expressed by Lieberman and Pointer Mace (2008) that unless there is an obligation to participate, as it will lead to failure in achieving a qualification or course completion, often teachers are reluctant to

network on-line. Although this approach was unsuccessful for these specific groups of participants, it need not be excluded from the design as it is an appropriate means for building a self-sustaining community. However, the value of the on-line component needs to be addressed to ensure future participants comprehend and experience the benefits of participation.

5.3.5.7 *In-school component.*

The in-school programme was designed to address the need for individualised support of adult learners to ensure their success in integrating theory and practice. This was particularly necessary as the majority of participants were not returning from the workshop sessions to colleagues who could support them in implementing the NoS approaches. In-school visits provided the opportunity to identify specific issues that participants might be experiencing, and enable the facilitator to guide them through the identification of why the issue might be occurring and together identify ways to solve this (Timperley, 2008). The key to the success of in-school visits is the establishment of trust between the facilitator and the participant, but the facilitator must also be prepared to challenge the participant to reflect on their practice and try activities and strategies that extend them and help the process of integration of theory and practice (Skamp, 2004; Timperley, 2008).

5.3.6 Evolution of the design.

Establishing the three main components led to a design that was effective in building teacher's theoretical understanding of the NoS and supporting them to implement approaches in their teaching and learning programmes, that in turn built student NoS understanding and capability. The workshop design based on the constructivist 5E model would not have been developed without input from participants, for as the facilitator-researcher, I would have retained the format I was used to as it had been effective in my formative assessment workshops. The use of the 5E format for a workshop structure was initially challenging,

however, once I had used it for Workshop 2, I realised it provided a much better focus for the engagement of participants and assisted their learning process. In addition, it helped me be more focussed in the planning of each session, but more responsive to participants in the delivery, allowing me to assume a facilitation role in the participants' learning process rather than being considered the expert (Timperley, 2008).

Once the structure for the workshop was established, the incorporation of the other components of in-school and on-line learning followed. The in-school component was readily accepted by 67% of participants, and their reflections and feedback provided evidence of its success. For those who did not engage with the in-school support, in some situations it was partly due to lack of commitment from school management to the professional development. As one participant stated, "The management team just want us to produce the necessary documentation for the school curriculum, they really do not want to know about what Science in *NZC* is about". The two teachers from this school did not feel they could engage in the in-school support, but planned a programme for the school once a year, using a science theme that incorporated the NoS and used assessments that recorded students' NoS ability for baseline data. The issue in this situation would be that without the in-school support these teachers were less likely to make lasting changes in their practice unless they closely continued to collaborate and engage in critical reflection on the effectiveness of their NoS teaching and identified next steps for their learning (Timperley, 2008). A consideration would be for the in-school component to be included as a compulsory part of the professional development programme and be written into a memorandum of understanding with school management.

The third component of the design to evolve was the on-line component. This included a wiki for sharing resources, with a forum for discussion, posting readings and participants' reflections on the readings, as well as emailing of reflections to the facilitator in response to

the reflection questions being sent to participants. This component was not successfully adopted by participants, as described in Chapter 4, section 4.7, Table 7. The non-participation could be attributed to lack of participants' confidence in sharing science ideas and concepts if they perceived their content knowledge or pedagogical content knowledge was poor. The other reason could be that trust had not been established among the group before the first discussion commenced, resulting in only the two more confident individuals posting a response, and a third who was a member of another on-line community and felt an obligation to post. As Lieberman and Pointer Mace (2008) suggest, the on-line component may need to be made obligatory to ensure participants engage actively with the on-line learning. This could be achieved by placing more emphasis on this component by putting all resources onto the wiki and not providing individual hard copies at workshops, and by having a requirement of participation in a specific number of on-line discussions to achieve completion of the professional development programme. The appropriateness of such actions would need to be considered and discussed with participants before implementing.

5.4 “What are Teachers’ Existing Understandings of Nature of Science?”

Data analyses of the NSAAQ survey for both the wider group of teachers in Lower South Island region of New Zealand and the research participants provided evidence of the need to provide professional development to build understanding of the NoS so that teachers were better able to address the requirements of the *NZC*. The survey required participants to choose between a naïve view and an informed view of NoS that had been based on evidence Sampson and Clark (2006), collated from reported student views of the NoS. The strength of a bipolar semantic survey is that respondents were able to compare the two viewpoints to identify their own perspective, thus providing a greater degree of reliability to their selected response (Sampson & Clark, 2006). By using the identified subscales determined by

Sampson and Clark (2006) for the NSAAQ survey, I was able to both quantify and comment on the consistency of respondents' views to accepted NoS views for the four factors of the survey.

Table 2 in Chapter 4 showed that for all four factors of the survey, at least 67% of respondents held naïve views of the NoS, which indicates the need to provide professional development to build science teachers' NoS understanding. The mean score of 88.71 and standard deviation of 10.97 is comparable with Sampson and Clark's (2006) mean score of 89.4 and standard deviation of 10.1, where their respondents showed an overall score range of 56 to 111 out of the possible 130, comparing with the range for my sample of 55 to 111 (Sampson & Clark, 2006). The similarities of the mean score and standard deviation between my participants' responses compared to Sampson and Clark's respondents justified the use of the NSAAQ survey as a tool to evaluate the effectiveness of the intervention designed to build teachers understanding of the NoS. Further justification for the use of the NSAAQ survey comes from the alignment of the four factors of the survey, with the interpretations of the NoS provided in *NZC* in both the introduction to the science learning area and in the Achievement Objectives (Ministry of Education, 2007). Consequently, incorporating activities and theoretical readings into the intervention strategies that built teacher capability in each of the four aspects of the NoS from the *NZC* would be expected to have a positive impact on scores in the NSAAQ survey carried out with participants at the end of the professional development if the intervention design was effective.

5.5 How Does a Targeted In-Depth Professional Development Approach Build Teachers' Understanding of Nature of Science as Described in the Science Learning Area of NZC?

Evidence from the NSAAQ scores of participants at the end of the professional development intervention compared with the scores at the beginning indicated that all had an increased NoS understanding. The mean overall score showed a statistically significant increase from $M = 85.0$ ($SD = 6.8$) at the start of the intervention to $M = 94.3$ ($SD = 10.5$) after the series of five workshops of the intervention. This shift indicated the intervention had raised participants' understanding of all the NoS aspects assessed within the NSAAQ survey. The significance of these shifts was triangulated with participants' reflections on the impact of their NoS learning on their teaching approaches and classroom practice.

Evidence from participants' responses indicated they were employing increased NoS activities in their lessons as a result of their increased understanding of what constitutes the NoS achieved through the in-depth professional development programme. This increased understanding was evident in the practice of the 23 participants who participated in classroom observations sessions, as their lessons incorporated activities designed to build the NoS understanding and capability specifically adapted for their class science focus. This would not have occurred if the intervention had merely provided a set of predetermined activities designed to be delivered to their students, irrespective of individual needs or science learning focus, as the adaptation of ideas to the specific class science focus required understanding of the NoS beyond the naïve level (Timperley et al., 2007).

An additional outcome was that through exposing teachers to constructivist approaches to teaching and learning, most of the teachers also either fully or partially adopted these approaches into their own teaching and learning programmes. Therefore, the design not only

built participants' pedagogical content knowledge, but also their pedagogical knowledge, enabling them to develop "strong theoretical frameworks that provide them with a basis for making principled changes to practice" (Timperley, 2008, p. 24). Timperley (2008) further states that when teachers are confronted with challenges within their teaching and learning programmes, they then have the theoretical ideas they can revisit which enables them to adjust their programme appropriately to address the new situation. Where an intervention has involved training teachers in specific teaching techniques which are to be implemented in a predetermined manner, the result has been limited. Such intervention can fail to identify student need, therefore does not incorporate effective inquiry into practice approaches (Timperley et al., 2007). The intervention design developed as part of this study did not seek to offer participants the "handy hints" but rather engaged them at "both theoretical and practical levels" to build their understanding of the NoS and student learning processes as referred to by Timperley et al. (2007).

5.6 How is Increased Nature of Science Understanding Evidenced in Teacher Practice?

The vignettes in Chapter 4 provide evidence of some of the participants changed practice and greater engagement with NoS, both in their thinking and in their planning of teaching and learning programmes. This aligns with evidence from Lederman and Lederman (2004) that teachers are more likely to incorporate the NoS into learning when they understand the need to focus on explicit use of observations and more effective reflective questioning of students. Engaging teachers in modifying activities they have used as part of their existing practice to incorporate such foci can result in increased the NoS content in their learning programmes. The participants all provided evidence in their reflections, both at the workshops and in interviews of those supported in classroom observations, of the value of the strategies used to develop their understanding of both the nature and the processes of science. They observed

that the approaches used in the extending part of the workshops enabled them to incorporate more NoS activities into their learning programmes. They valued the time spent trialling the activities themselves as it built their understanding of the NoS. This reflection links well with Lederman and Zeidler's (1987) suggestion that to improve teaching of the NoS, teachers should be presented with a range of strategies designed to specifically teach them about aspects of the NoS and develop their understanding of the processes of science. The intervention design specifically addressed these ideas, and progressively exposed the participants to different aspects of the NoS over the workshop series from both theoretical and practical perspectives. This enabled participants to reflect on, build an understanding of, and incorporate NoS activities into their teaching progressively, providing the opportunity for trialling and modification of practice between workshops.

Only 23 of the 42 participants were involved in the classroom observation process. All those observed identified two key approaches to their building of the NoS capability with their students regardless of the teaching level. These were firstly, an emphasis on developing students' ability to make scientific observations that were more exact and incorporated both quantitative and qualitative ideas; and secondly, the need to make investigations more open-ended, not recipe-like, with opportunities for student designed investigations based on questions arising from their observations.

Participants described the need to teach the observation process and provide multiple opportunities to build students' observation skills. All stated that they had assumed students could do this, but use of the observation matrix from the *New Zealand Science Curriculum Exemplars* (Ministry of Education, 2004) with students had revealed students' lack of understanding of the observation process. The key role of observation is highlighted as one of the seven aspects of the NoS essential for school students to understand, thus participants' recognition of the need to develop could be interpreted as indicative of their growing

understanding of NoS (R. L. Bell et al., 2000; Lederman & Lederman, 2004). The intervention had stressed the importance of observation as each session's introductory Engaging Activity had an emphasis on observation and questioning.

Using a less teacher directed approach to investigations was reported and observed as being easier for participants teaching Year 1 to 8 than for those teaching Year 9 and 10. Two participants teaching Year 9 and 10 students reflected that they felt restrained by the time required to build a more investigative approach with students, especially considering the school expectations for content coverage in a year. However, the ten Year 9 and 10 participants I observed all reflected that their students became more engaged when exploring and designing their own follow-up investigations based on their own questions arising from observations than they were when following recipe type activities with expected outcomes. As a result, all those teaching Year 9 and 10 maintained at least one open-ended investigation by students in each topic or theme covered, in spite of reported time pressures. The thirteen participants I observed with Year 1 to 8 classes began to use open-ended investigation approaches as the norm, with reported increase in engagement of all students. This was so much so that in one rural school "Nature Tables" became a key part of each classroom, and students were observed exploring objects closely, some using magnifying glasses, during their morning break and lunchtime. Their teachers shared that this had become the norm for a high number of students – both boys and girls. The observed change in participants' practice during this intervention was consistent with the literature suggestion that effective professional development over a period of time must be linked to observation of accompanying change in teacher practice (Guskey, 2000; Hill et al., 2002; Thornton, 2003).

An additional observation I made during the classroom observation process was that all the participants observed had adapted their science programmes by the third observation session, and were incorporating aspects of the 5E teaching and learning approach. Two participants

had begun to use the 5E model to design teaching units for their syndicates that addressed the NoS elements through the 5E design. This had not been a specific focus of the workshops. Follow up questioning of six participants revealed that as the 5E workshop approach had helped them build their understanding of NoS, so might the approach help students, and as 3S responded “it seemed only natural to use it with my classes”. The additional feedback from participants was that using the 5E approach led to greater student engagement, as they actually placed greater importance on using an Engaging activity to find out their students existing ideas at the beginning of lessons or a science topic. Their reflections indicated that their students were also more actively involved in the learning process and had begun to suggest explanations for their observations based on their growing understandings of the science ideas. Thus the teachers had begun to use constructivist approaches to learning and teaching more effectively with their classes that reflected a greater “balance between teacher and student-directed learning, with teachers taking an active role in the learning process that included some formal teaching” (Gordon, 2009, p. 739) when the teachers identified the need for this.

5.7 Review of the Findings

The problem that this study sought to answer could be appropriately addressed by design-based research methodology. The analysis of the initial NSAAQ survey provided evidence that the teachers’ existing understanding of the NoS is not just a local problem confined to a few schools, but that an intervention to build the NoS capability could be of relevance to science teaching communities throughout New Zealand (Ma & Harmon, 2009). Other science advisers in New Zealand have indicated they consider the NoS understanding of teachers is also an issue in their regions. Evidence from research literature on the NoS understanding of teachers indicates that this problem is an issue in European and American schools where the NoS is part of required learning programmes (Abd-El-Khalick, Waters & Lee, 2008; Akerson

& Abd-El-Khalick, 2003; Lederman & Lederman, 2004). Thus, the literature provided a further basis for using design-based methodology as the evidence aligns with Reeves (2000) direction that it is an appropriate approach for researching solutions to widespread and difficult problems.

The design of the intervention was critical to the effectiveness of the professional development in building participants' understanding of NoS and enabling them to incorporate appropriate teaching strategies within their learning programmes to support the development of students' NoS ability. Using Ma and Harmon's (2009) research findings as guidelines in planning the intervention, and incorporating ideas from the application of constructivist theories in science teaching, led to the construction of an intervention design that was effective for participants in this study (Bybee, 2006; Skamp, 2004). Key features of the design were that it was framed around the teaching approaches for science developed to address constructivist theories of learning (Bybee, 2006; Skamp, 2004), while it also reflects the design principles described by Ma and Harmon (2009) as being key elements of design-based research. Although Ma and Harmon's principles were developed to support the development of an Online Teaching Case Library (OTCL), they provided guidance for the design of an intervention to build NoS ability. The focus in both studies was on the design of a tool to support participants to learn to teach from their own and others' experiences, while also building teaching knowledge and pedagogical content knowledge (Ma & Harmon, 2009). As in Ma and Harmon's (2009) study, this was achieved through provision of a variety of content presented in different ways, using a common language that would be effective for both novice and experienced participants. The participants' positive response to the constructivist 5E structure for the workshops provided a solution for shaping each session around the five stages of Engage/Elicit; Explore/Experiment; Explain; Extend/Elaborate; and Evaluate their learning that gave a theoretical framework for the design and a prototype to refine with three iterations across the clusters. This allowed for evaluation and testing of the

solution for the NoS intervention of the 5E structured workshops, together with the other two components of in-school support and an on-line learning community with each of the three clusters. This ensured the essential features for professional development in science identified through the review of literature were incorporated within the design (Guskey, 2003; Khishfe, 2008; Lederman & Lederman, 2004).

The use of a design tool based on a constructivist model provided a strong emphasis on the need to maintain the balance between teacher-directed and student-directed learning, inclusion of social activities, and theoretical readings to construct participant understanding during the intervention (Gordon, 2009). Thus, the model employed approaches that developed the participants as a professional learning community (Bybee, 2006; Skamp, 2004). The range of strategies experienced by participants in the intervention sessions ensured they were consistently engaged with constructivist learning approaches, thus, providing a model for them to apply in their own teaching. This aligns with Ma and Harmon's (2009) assertion that in the "development of a solution to an identified problem within a theoretical framework using design-based research" (p. 79) there is a complex series of steps to process. By using the 5E constructivist tool, the solution addressed their first step of "conceptualizing a solution within a theoretical framework" (p. 79). In applying Ma and Harmon's (2009) second step of "determining the role of research in determining the solution" (p. 79), research on effective professional development for science teachers and on approaches to build NoS capability provided strategies to incorporate within the framework.

The prototype intervention was developed and refined over three iterations which allowed the design to be evaluated and tested in practice, which addressed the third of the four steps in the process of developing a solution in design-based methodology (Ma & Harmon, 2009; Reeves, 2000). The use of the NSAAQ survey pre- and post-intervention provided quantitative evidence, while participants' reflections and classroom observations of teaching practice from

the in-school component allowed triangulation with the quantitative NSAAQ data to provide evidence of the effectiveness of the intervention design.

The use of a constructivist tool in the design of the intervention workshops was upheld as an appropriate application for the 5E model as it provided a framework that could be applied to each aspect of NoS within the science learning area of the *NZC*. The 5E intervention structure of workshops enabled participants to build NoS understanding within the parameters deemed by Beckett (2007) and Berger (2007) to be essential for building science capability of teachers, while satisfying the requirements for evaluation Guskey (2003) indicated as necessary for professional development to be effective.

5.8 Generic Design.

The new approach this study has utilised is the application of the 5E model of learning to an adult learning situation, the difference being that the learners were teacher participants and the researcher was the teacher/researcher. The generic design clearly builds on key aspects of constructivist approaches to learning where there is a balance between the facilitator and participant directed learning, requiring the facilitator “to have an active role in the learning process, including formal teaching” (Gordon, 2009, p. 739). This required the facilitator to have a thorough knowledge and understanding of the NoS in order to address participant misconceptions that arose from the exploration phase through provision of readings and leading theoretical discussions that enabled participants to reconstruct their understandings to align with internationally accepted NoS principles (Timperley, 2008). Provision of appropriate readings, practical activities and experiences to elicit participants existing understanding was a key part of the Engage, Explore component of the design. This aligns with Gordon’s (2009) conjecture that for constructivist teaching and learning to be effective, it must “be active, not passive, and ... requires construction of student’s own interpretations of the subject matter, through understanding and applying concepts, constructing meaning and

thinking about ideas” (p. 743). The construction of participants’ understandings occurred within both the Explanation and Extend sections of the design, and as facilitator, I had to demonstrate flexibility in that I had to identify the exact needs of different participants rather than making assumptions of their needs. As a result, preparations for the workshop sessions were extensive, and all materials prepared were not necessarily used at the planned session; however they were used in a different way in another session to address an identified participant need. These observations concur with Gordon’s (2009) ideas on effective constructivist teaching and learning, where the expectation would be that teachers would be constantly reflecting on the ways students are responding to the approaches used, monitoring the effectiveness of the learning, refining and adjusting the approaches to enhance the learning. The other key elements of the design were the incorporation of in-school and on-line support for participants alongside the workshop series. The importance of the in-school component as an element of the intervention design was clearly identified from participants’ feedback and reflections as it enabled them to trial ideas and approaches with the support of facilitator expertise (Timperley, 2008).

5.9 Conclusions

The study has shown that for the teachers in Lower South Island of New Zealand participating in the NSAAQ survey, there were clearly defined areas where there was a mismatch between their responses and the accepted international understanding of the NoS. Data collected indicated that this mismatch is equally evident in both teachers with tertiary science qualifications and those with no tertiary science learning. Thus, it is reasonable to assume that this lack of understanding of the internationally accepted view of the NoS is likely to be similar for science teachers in other regions of New Zealand, given the similarity of teacher education programmes throughout the country.

The intervention designed to address this lack of NoS understanding incorporated strategies to build understanding of internationally accepted NoS views increased participant understanding of the NoS in the small sample used in the intervention study. The particular design incorporating the constructivist 5E approach provided a useful tool to build the NoS understanding in teachers, and led to enhanced NoS teaching practice that was more likely to effectively employ constructivist teaching and learning approaches to the teaching of science. Thus, a theoretical understanding of the NoS attained through participation in a professional development programme that incorporated constructivist approaches to teaching and learning facilitated changes in science teaching practice through exposing teachers to both increased pedagogical content knowledge and increased pedagogical knowledge.

It is probable that the strength of the professional development design lay in its key components of building knowledge through workshops, supporting application of concepts learned in classrooms through in-school support, and on-line support. The workshops provided theoretical bases for the activities, required participants to engage and elicit their existing ideas, thus placing them into a role as learners who then developed explanations that incorporated knowledge gained from theory and practical activities. An additional feature of the design was its provision of opportunities to socially construct these explanations and then use them to develop specific learning experiences to use with their students in learning programmes. Furthermore, the design allowed for evaluation of both participants' learning about the NoS, as well as raising awareness of the importance of providing evaluation opportunities for their students, as required in the "Effective Pedagogy" section of *NZC* (Ministry of Education, 2007, p. 34).

In conclusion, the design provides a sound theoretical platform for building teachers' understanding of the NoS as required by *NZC* while presenting an approach to teaching

science that models constructivist approaches to learning, providing the opportunity for a more student directed focus to science learning programmes.

5.10 Limitations

The NSAAQ survey was used with 86 teachers from Lower South Island of New Zealand, which could statistically be considered a small sample. The findings from this sample were used to generate the design of the intervention; however, it cannot be assumed that similar needs would be identified in other New Zealand regions. The NSAAQ survey would need to be conducted with teachers in other regions to identify their NoS needs, and the intervention then modified according to evidence from the survey results.

A number of limitations are evident from the use of the NSAAQ as the survey instrument to assess existing understanding of the NoS in science teachers in New Zealand schools. The first assumption was that the phrases used in the opposing statements of the survey questions conveyed the same meaning for respondents in New Zealand as had been accepted in the United States where the tool was developed. Without specific analysis and questioning of my respondents there was no way to ascertain if they shared the same understanding of each aspect of the survey. Evidence from Question 4 indicated that for one specific distractor, 84.6% of respondents held a naïve view, selecting that science knowledge is objective rather than science knowledge is subjective, which the accepted NoS view is. In the intervention, these two statements led to spirited debate in each of the three groups about the difference between the idea that science relies on objective measurements while the knowledge that is developed from these measurements is subjective due to the personal ideas and differing background information each scientist brings to the resolving of the evidence. As the debate had confused some participants, a reading on the misconceptions of science was used which led to clarification of these ideas for participants.

The intervention increased theoretical understanding of the NoS for the small group of teachers from the Lower South Island region of New Zealand, a total of 42 teachers in three clusters. This is a small sample size, so the intervention design would need to be trialled in other regions of New Zealand to ensure it was a suitable tool to build teacher NoS understanding to enable the intent of the *NZC* to be addressed.

Chapter 6. Recommendations, Implications and Identification of Areas for Future Research

6.1 Introduction

This chapter comments on some aspects of the findings that have implications for different groups within the New Zealand Education system: from the Ministry of Education, to professional development providers, and to schools and their teachers. It considers the implications of addressing issues raised in the study and makes some recommendations for these groups. The final section considers and identifies areas that could benefit from further research to enable the implementation of the intent of the science learning area as a mandated part of the *NZC* (Ministry of Education, 2007).

6.2 Recommendations

As a result of this study, a number of recommendations emerged that have relevance to both the New Zealand education sector and the wider science community. The recommendations are outlined in no particular order, but follow-up of these could enhance science education, and the science teaching and learning programmes in schools. This would impact positively on student achievement through developing the processes of science, enhancing student engagement leading to increased ability for New Zealand to contribute internationally through improved understanding of the nature of science and its relevance to society.

6.2.1 Use of generic model to build NoS understanding of science in *NZC*.

The Generic design presented in the Chapter 4 Results provides a tool to be used in science professional development with both primary and secondary teachers to build their

understanding of the NoS in line with the intent of the Science Learning Area of *NZC*. For this to be successfully implemented, this study has shown that the professional development needs to be long term and in depth, with support on an individual school basis at the classroom level, to build sustainable and embedded teacher practice. For this to occur there needs to be a commitment from the Ministry of Education for funding of in-depth professional development over a longer term that utilises appropriately trained facilitators with a full understanding of both the NoS and the *NZC*.

6.2.2 Use of generic model in other learning areas of *NZC*.

The design for delivery of the NoS professional development based on the 5E model of constructivist teaching and learning could be adapted to provide a design for delivering ongoing or in-depth professional development in other *NZC* contexts (Ministry of Education, 2007). To do this, the model only needs modifications of the activities to provide a tool that could address the intent of the *NZC* and inform professional development participants of constructivist and social constructivist approaches to teaching and learning (see Table 10). Use of the tool is being trialled in the NCEA secondary Professional Learning and Development Contract across the eight learning areas in 2012, and as a consequence, could lead to a better “balance of teacher- and student-directed learning” (Gordon, 2009, p. 739) in more Year 11 to 13 classrooms across New Zealand and greater active engagement of students in the learning process.

Table 10: Modified Generic Design

Workshop component	Outcome for participants	Activities
Engage/Elicit	Focus for session established through activity, prior knowledge and ideas shared	Hands – on, minds – on activities carried out in small groups to brainstorm questions and prioritise ideas to find out more about in session included practical and online activities
Explore	Building of evidence to form theoretical and practical knowledge relating to focus	Selected readings, resources, modelling and investigations
Explain	Use valid and relevant pedagogical and subject specific information to suggest an explanation/process relating to the focus	Use both qualitative and quantitative evidence to develop a response in small groups; discuss appropriateness of explanation as a whole group
Extend	Adapt and develop explanation to participant’s own teaching situation	Individuals or small groups plan/develop another way of using ideas to build student understanding of the identified aspect with students
Evaluate	Reflection on relevance of focus to individual teaching situation	Individual reflection using questions- How has my understanding of the session focus changed in relation to this new learning? How will my teaching change as a result of this understanding?

6.2.3 Use of generic model by in-service teacher educators (ISTE).

The implementation of the *NZC* required ISTE to address the intent of the document in their approaches to professional learning and development. As a consequence, the focus of many of these approaches has been to focus on the use of the Teaching as Inquiry approach outlined under effective pedagogy. This approach leads teachers to reflect on their practice more effectively for a target group of students, and develop strategies to enhance the achievement

of these students (Ministry of Education, 2007). This study incorporated reflection for participants, but more importantly, used workshop sessions designed on the 5E constructivist model approach to teaching and learning. The results in Chapter 4 demonstrated that the design not only built teacher reflection, but also led to the development of a more balanced teacher- and student-directed approach to learning as teachers engaged more effectively with constructivist approaches to learning (Gordon, 2009). Constructivist approaches to learning underpin the intent of the *NZC*, thus the recommendation is that ISTE consider incorporating key elements of this generic design into workshop planning to help teachers build their capability to enhance student engagement in the learning process.

6.2.4 Leaders of learning in science.

The results of the NSAAQ survey to identify teachers understanding of NoS indicates that teachers have not developed an understanding of the intent of the *NZC* simply through reading the document. This indicates that left without support, teachers will not begin to teach through the NoS. The inability to adopt the NoS as the overarching and unifying strand is possible due to lack of knowledge about the elements of the NoS, and due to many teachers' positivist theoretical perspective to the teaching of science. Operating from this perspective means they accept science as being objective, and their teaching is likely to focus on the sharing of factual scientific knowledge (Crotty, 1998).

As indicated in the literature review, New Zealand educators have a history of supporting teachers in the implementation of any new educational development, so teachers have not been left to unpack new innovations in curriculum on their own. With the introduction of *Science in the New Zealand Curriculum* in 1993, the policy-to-practice approach was used which provided nation-wide teacher in-service support to address the requirements of that document (B. Bell, 2005). In a similar way, the introduction of assessment in years 11 to 13 through the National Certificate of Educational Achievement (NCEA) from 2001 was

accompanied by extensive teacher support that included teacher only days. The introduction of the revised learning area achievement objectives has not seen such widespread support; rather support has been focussed on the realigned assessment Achievement Standards for NCEA. As B. Bell (2005) notes, “teacher development is usually required before any difference in the students’ received curriculum is noticed by students” (p. 181), thus to achieve widespread adoption of the NoS as the overarching and unifying strand through which the contextual strands will be covered teacher education must be considered essential.

The recommendation from this study is to divert away from leaving schools to implement the intent of the science learning area on their own, and develop a nation-wide professional learning and development (PLD) focus. This should provide in-depth support to build science teachers’ understanding of the NoS in order that their teaching will change from a content focus to a process focus, ultimately leading to greater student engagement in science. The PLD support could adopt the intervention design from this research to work with building the NoS understanding of two teachers who then act as lead teachers in supporting a cluster they work with, to in turn build their understanding and NoS capability. Such an approach has been shown to be effective in this trial, and could be extended across New Zealand, but would require resource commitment from central agencies as well as schools. Existing funding is only allowing this approach to be activated on a small scale with small numbers of teachers, so it will be slow to spread across the country.

6.2.5 Gluckman report recommendations.

Gluckman’s (2011) report “Looking ahead: Science education for the twenty-first century learner” was released as a result of his evaluation of the current state of primary and secondary school science education in New Zealand and provided suggestions for priorities to be addressed to ensure enhanced science education opportunities in the future. One of the

challenges identified is ways for teachers to maintain relevant science knowledge and access to technology:

This will increasingly depend on both teachers and students having a closer relationship with the science community. To some extent, teachers can be assisted to keep their relevance by giving them short sabbatical periods to spend in a research laboratory, and that certainly helps build both their confidence and their relationships to the science community. We have seen a number of developments in New Zealand whereby the science community has made itself accessible to schools. (Gluckman, 2011, p. 6)

The suggestion from the Gluckman (2011) report that all teachers of science should have experience working alongside scientists in research, would be important to follow up, as little from this study provides evidence that research experience necessarily increases teachers' understanding of the NoS. The NSAAQ survey data showed science teachers with tertiary research degrees were as likely to hold naïve views of the NoS as those with no tertiary science study. In addition, the recognised focus for the teaching of science in New Zealand schools is through the NoS as the “overarching and unifying strand - through which students learn what science is and how scientists work; and build a foundation for understanding the world” (Ministry of Education, 2007, p. 28). While not distancing school science from the science community, the *NZC* places emphasis on four fundamental aspects of science. There is less focus on gaining extensive, in-depth science knowledge; rather, the development of the skills and processes of science is emphasised, leading to students becoming scientifically literate and able to make scientific decisions utilising valid social and ethical perspectives. Perhaps an aspect that this study can more effectively address is the need identified by Gluckman (2011) for the “opportunity for significant on-going professional development in science as well as in education is essential” (p. 6). I would suggest that in the first instance,

the significant need is for all teachers of science, whether of primary or secondary students, to become confident in their understanding of the NoS and of constructivist approaches to the learning of science. Only then will science be approached through the NoS and become focussed on building students' confidence in "participating in society as critical, informed and responsible citizens in a society in which science plays a significant role" (Ministry of Education, 2007, p. 17).

6.2.6 Initial teacher education NoS focus.

The findings from this research indicate the need to ensure science programmes for all initial teacher education courses have a strong emphasis on the NoS. Currently this is difficult as many of these students come to their teacher education courses with limited interest or achievement success in science. As a consequence, the short time available to science learning tends to emphasise the building of science content knowledge, however it would be more important to focus on building of NoS capability. Science content knowledge can be learned from books, whereas this research indicates that to date, NoS understanding has not been adequately introduced through texts as it is about the development of scientific processes and scientific ways of thinking. An issue will be that this will be even harder to incorporate within a one year postgraduate course as proposed in the 2012 Budget.

6.2.7 Nature of in-depth PLD in science.

The intent of the intervention design was to incorporate both on-line and face-to-face learning experiences for participants. As there were no credits for participation in the on-line community as part of this study, there was no compulsion to engage. Perhaps also the lack of an active New Zealand science on-line community is also a reason for this lack of engagement; if it were a forum for the exchange of ideas, and responses and suggestions for activities, and if it provided a greater range of information, perhaps participation would

improve. In future, there should be a focus within the intervention on building a strong online community to consider and debate ideas and share reflections on theoretical perspectives of science. By developing this component, a more sustainable community of science practitioners is likely to be established who will support each other in the quest to better understand and teach aspects of the NoS.

6.2.8 Addressing Education Review Office (ERO) Report: Science in The New Zealand curriculum: Years 5 to 8.

In May 2012 the Education Review Office (ERO) released the report “Science in the New Zealand Curriculum: Year 5 to 8” which presents “ the overview of science education in Years 1 to 8 in 100 schools reviewed during Terms 1 and 2, 2011” (p. 1) The report indicates that “effective practice in science teaching and learning was evident in less than a third of the 100 schools” (p. 1). The report makes a number of recommendations, some to the Ministry of Education relating to the “opportunities for support and on-going professional learning development for teachers (p. 22).

The intervention design developed in this study could provide an appropriate tool to enable the provision of targeted professional learning development to address the identified need of this report. The report recommends “that schools review the priority given to science teaching and learning in their curriculum” (Education Review Office, p. 22). I would suggest that this recommendation would provide little change in practice without professional development to build their understanding of the intent of the science learning area within the *NZC* as well as their understanding of the NoS. The intervention design model is currently being refined to address the need to integrate literacy and numeracy into science teaching and learning in primary schools, thus it has the flexibility to address the needs identified by ERO (Education Review Office, 2012).

6.3 Implications

This study has demonstrated that teacher NoS theoretical understanding can be developed through a professional development programme, and that this increased NoS understanding leads to changes in science teaching practice. The three key elements of the intervention design will need to be incorporated into any professional development programme if the intervention were to be adopted by the Ministry of Education as a means of addressing the reported low engagement and achievement in science as reported by ERO in 2010 and May 2012. For this to be successful in refocussing teachers on the intent of the science area of *NZC*, sufficient resourcing would need to be provided to:

- train facilitators to deliver nationwide;
- fund the professional development across New Zealand to a level that allows for the:
 - in-school component
 - workshop series
 - on-line community with a facility for a site manager.

6.4 Identification of Areas for Future Research

Further research could be carried out to identify if the NoS understanding of New Zealand teachers of science is similar to the cohort studied in this region. If this is found to be similar then the intervention could be trialled further and refined to provide a tool to use with in-service and pre-service teachers to develop their understanding of the intent of the *NZC* (Ministry of Education, 2007).

The impact of the intervention on student understanding of the NoS could be studied in more detail alongside further study of the impact of increased teacher NoS capability on teaching

practice. It is possible the NSAAQ survey could be used with students, as it was used with senior school students in USA, or it could be further developed for use with younger students.

Another area for further study involves the examination of whether there are links between the level of study of tertiary science and the NoS understanding of teachers, or whether it is dependent on practical scientific research experience of teachers. In either situation, the study could determine whether increased understanding of the NoS led to incorporation of multiple NoS experiences into teaching and learning programmes, resulting in increased student NoS understanding. Evidence provided by Hipkins (2006) and Hemler and Repine (2006) suggests this does not always occur. Considering the suggestion that arose from discussions on the Gluckman (2011) report that all teachers of science should have experience working alongside scientists in research, it would be important to follow up this aspect.

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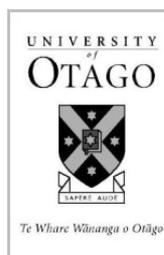
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Appendix 1. Ethics Application



APPLICATION TO THE UNIVERSITY OF OTAGO HUMAN ETHICS COMMITTEE FOR ETHICAL APPROVAL OF A RESEARCH OR TEACHING PROPOSAL INVOLVING HUMAN PARTICIPANTS

1. University of Otago staff member responsible for project:

Associate Professor Mary Simpson

2. Department: Humanities, College of Education

3. Contact details of staff member responsible:

Associate Professor Mary Simpson, Associate Dean (Teacher Education)

College of Education

Ph 479 3795

Email mary.simpson@otago.ac.nz

4. Title of project:

The effect of building teacher's Nature of Science understanding through a professional development programme on science teaching practice.

5. Brief description in lay terms of the purpose of the project:

The Nature of Science has been introduced in the New Zealand Curriculum (2007) as the overarching strand through which the contexts of science are developed. This is a new focus for the teaching of science in NZ schools, and therefore raises the issue of how best to address the professional development needs of teachers to build their Nature of Science capability. This project will develop a professional development programme with a group of primary and

secondary teacher. Participation in the programme will help the teachers gain a theoretical understanding of the Nature of Science. The teachers' classroom practice will then be reviewed to see if their knowledge of the Nature of Science is evidenced in their practice.

6. Indicate type of project and names of other investigators and students:

Student Research Names

The project is Kate Rice's EdD research

7. Is this a repeated class teaching activity?

No

If applying to continue a previously approved repeated class teaching activity, please provide Reference Number:

8. Intended start date of project:

October 2009

Projected end date of project:

February 2011

9. Funding of project.

Is the project to be funded:

(a) Internally

(b) Externally

Please specify who is funding the project:

No external funding, this is part of normal Education Support Services work under the Effective Teaching and Learning output for Science Curriculum delivery for Ministry of Education contract

10. Aim and description of project:

The aim of this project is to develop a professional development programme with a group of primary and secondary teachers to determine whether gaining an understanding at a theoretical level about the Nature of Science will lead to science teaching through the lens of the Nature of Science as the norm in practice.

The Nature of Science has been introduced in the New Zealand Curriculum (2007) as the overarching strand through which the contexts of science are developed. This is a new focus for the teaching of science in NZ schools, and therefore raises the issue of how best to address the professional development needs of teachers to build their Nature of Science capability.

11. Researcher or instructor experience and qualifications in this research area:

Researcher is a qualified Secondary Science Teacher and Facilitator with Education Support Services

12. Participants

Teachers of Year 7 to 10 Science in schools in Otago/Southland region

Students of these teachers' classes

12(a) Population from which participants are drawn:

Teachers of Year 7 to 10 Science will be invited to complete an initial questionnaire on Nature of Science understandings, excluding those with whom I have worked in 2009 as B7.2 In-depth schools

Students from participating teachers' classes

12(b) Specify inclusion and exclusion criteria:

Inclusion criteria:

- for initial Nature of Science bipolar semantic survey, criterion will be any teacher in the region who teaches science in Year 7 - 10*
- for professional development programme the criterion will be willingness to participate in short term, in-depth professional development in 2010*

Exclusion will be teachers that have worked with the researcher in 2009 on Nature of Science activity development

12(c) Number of participants:

- *At least 50 teachers for initial Nature of Science survey*
- *Two clusters of 10 – 12 teachers for professional development programme*
- *Students – 4 from one class of each teacher on the professional development programme*

12(d) Age range of participants:

- *Teachers – none will be under 18 years*
- *Students - 11 to 16 years*

12(e) Method of recruitment:

- *By invitation for Nature of Science bipolar semantic survey*
- *By application for Science professional development through Education Support Services annual invitation process*

12(f) Please specify any payment or reward to be offered:

- *No payment or reward will be offered*

13. Methods and Procedures:

Design Interventions

The professional development programme will be designed to

- *identify congruence of teachers' understanding of Science learning area with the intent of the New Zealand Curriculum, and then develop a programme of learning to address the congruence or lack of it;*
- *initially focus on unpacking a topic such as scientific argument as a tool to focus on aspects of Nature of Science Understanding Science and Communicating in Science;*
- *incorporate some structured activities to develop Nature of Science aspects, such as scientific investigation and scientific understanding or participating in socio-scientific issues;*
- *be flexible to allow for modification as participants needs and interests determine;*
- *be responsive to teachers, and allow for discussion, reflection, sharing of aspects trialled by teacher;*
- *be modified in response to findings/feedback from the first workshop session in collaboration with the teachers input;*
- *run for 12 to 15 week cycles, involving participants in between 80 and 100 hours of activities including 5 workshop sessions; up to 5 classroom observations and feedback*

sessions; in-school meetings; on-line sharing community; individual journaling, reading, activity development and reflection;

- *align the theory underpinning the approach, the design of the professional development programme, and interviews and observations of teachers and professional development session practice, as well as the measurement processes engaged (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003);*
- *modified from feedback through the first iteration, and then used with a second group of teachers in the revised format.*

Instruments and data collection

Data collection processes would include the following methods.

1. *Bipolar semantic differential survey will be used with a large group of primary and secondary teachers to ascertain what teachers consider to be the important aspects of science, with particular focus on Nature of Science (see Appendix 1). Using this with teachers participating in the intervention will provide an indication of changes in teachers' Nature of Science understanding with the programme, and comparison with a wider cohort. (Waters-Adams, 2006)*
2. *VNoS (Views of Nature of Science questionnaire) questionnaire developed by Khishfe and Lederman (2007) will be used with teachers at the first workshop of the intervention programme and repeated at end of the programme to provide an understanding of the teachers' Nature of Science beliefs and any changes.*
3. *Individual semi-structured Interviews will be conducted pre and post intervention with each teacher on programme to clarify Nature of Science views and correlate/confirm with VNoS survey findings. These will be either at school or alongside workshop programme.*
4. *Workshops will be videotaped to allow the learning community development to be followed and any possible issues identified, either in my facilitation or among participants' responses and interactions.*
5. *Classroom observations will be used to identify congruence between espoused and actual practice, and to observe and record Nature of Science processes in teaching programme to identify next steps for intervention programme. These will involve all teachers on the intervention at start and after 3 sessions. Reflection and feedback on the observations will be provided following observations to allow teachers to identify aspects for further development or trialling.*
6. *Student surveys using student VNoS version will be used before and after the teacher participation in the intervention to identify student Nature of Science understandings of Year 7 and Year 10 students, and changes over time with their teacher on the programme. The responses could be compared with students of same Year group whose teacher is not involved in the programme in same school/other school. To ensure reliability, surveys would be carried out by someone familiar to students in the students' usual environment/classroom during a science lesson. Students from one class for each teacher in the programme would be included.*
7. *Student voice will provide evidence of congruence between what teachers believe/state they are teaching and students' learning/understanding of Nature of Science. Responses to specific questions on learning and Nature of Science (Appendix 3) will identify students' common ideas on Nature of Science and learning concepts in each teacher's class. Sharing student voice with teachers can provide an impetus for change in practice and also in identifying needs to focus workshop content on.*

8. *Document analysis including staff meeting records, lesson plans from during professional development programme, teachers' planning and teacher archival materials will be used to identify professional development in Science, approaches to teaching and planning, compare espoused and actual practice.*
9. *Personal data of a limited nature will be collected from participating teachers to allow trends relating to gender, tertiary science level attainment, years of teaching, confidence in teaching science contexts to be identified.*

Data analysis

Thematic analysis of documents, classroom observations and interviews will be carried out using a qualitative data analysis programme such as NVIVO throughout the intervention. Video analysis will be peer reviewed to ensure lack of bias, and to provide support and guidance. Thus workshops will be refined as iterations of the Design-based Research process, leading to a programme that addresses the teachers' identified needs by building Nature of Science capability. At the same time, developing their knowledge and theory of practice to enable them to plan and implement learning programmes that effectively develop student capability in the Nature of Science by challenging students' understanding of scientific concepts.

Quantifiable data from questionnaires would be analysed using appropriate statistical methods, possibly ANOVA, but this will be determined when the questionnaire type is finalised.

Responses to the first underpinning question "What are teachers' existing understandings of Nature of Science?" will be gained from bipolar semantic survey, VNoS questionnaire and semi-structured interviews.

Both qualitative and quantitative data will be gathered, via interviews, classroom observations, review of documentation and a repeat of VNoS survey Interviews will be used to provide data for the second question – "How does a targeted in-depth professional development approach build teachers' understanding of Nature of Science as described in the Science Learning Area of NZC (2007)?"

To provide data on the third question "How is increased Nature of Science understanding evidenced in teacher practice?" qualitative and quantitative data from classroom observations, analysis of assessment activities and planning, student VNoS and bipolar semantic surveys will be used.

Results

The analysed data will be discussed with reference to the three underpinning research questions, and any emerging themes will be identified and discussed. Issues identified from the research process will be identified and discussed. Features of the design intervention will be summarised and features requiring further investigation and development raised. Emergent theoretical perspectives from the design research will be outlined.

14. Compliance with The Privacy Act 1993 and the Health Information Privacy Code 1994 imposes strict requirements concerning the collection, use and disclosure of personal information. These questions allow the Committee to assess compliance.

14(a) Are you collecting personal information directly from the individual concerned?

YES

If you are collecting the information **indirectly**, please explain why:

14(b) If you are collecting personal information directly from the individual concerned, specify the steps taken to make participants aware of the following points:

An information sheet will be provided for all participants, and completion of the bipolar semantic Nature of Science Survey will indicate willingness to participate.

Please see attached Information Sheet

Personal information will be used to identify trends in responses to the Nature of Science survey, and these findings will be shared with participants.

Participants may withdraw from participation in the project at any time and without any disadvantage of any kind.

Participants will be given the opportunity to preview the transcripts of interviews and correct personal information during the data analysis phase, and are welcome to request a copy of the results of the project.

14(c) If you are not making participants aware of any of the points in (b), please explain why: N/A

14(d) Does the research or teaching project involve any form of deception?

NO

If yes, please explain all debriefing procedures:

14(e) Please outline your storage and security procedures to guard against unauthorised access, use or disclosure and how long you propose to keep personal information:

Data collected will be stored in secure storage in the researcher's office at College of Education. Original documentation used in writing the thesis will be archived for five years after its publication in the College of Education storage facility. After that time any personal information will be destroyed.

14(f) Please explain how you will ensure that the personal information you collect is accurate, up to date, complete, relevant and not misleading:

Personal data collected and collated will be checked with individual participants to ensure its accuracy, and written material incorporating the information will be checked for relevance and accuracy with the individuals concerned.

14(g) Who will have access to personal information, under what conditions, and subject to what safeguards against unauthorised disclosure?

Personal information including video tapes, audio tapes, transcripts of interviews, planning materials and lesson plans will be accessed by researcher and supervisor. Participants will have access to the raw data and with individual permission may be used during the professional development sessions with other participants. The results of the research will be made available to participants when the project is completed. Participants will be made aware of these aspects in the consent form.

14(h) Do you intend to publish any personal information and in what form do you intend to do this?

No – it is not intended for personal information per se to be published, rather summaries of the information will be used that will not lead to identification of individuals.

14(i) Do you propose to collect information on ethnicity?

There is no intention to collect information on ethnicity

15. Potential problems:

It is not intended to cause discomfort to participants as the professional development programme will involve science investigations and discussions with fellow science teachers.

Student participants will only be required to respond to a structured interview and the VNoS questionnaire which should not place any individual in a position of discomfort.

16. Informed consent

The information sheet and the consent form are attached to this application.

11. Fast-Track procedure

Do you request fast-track consideration? (*See Important Notes to Applicants attached*)

NO

18. Other committees

If any other ethics committee has considered or will consider the proposal which is the subject of this application, please give details:

Not applicable

19. Applicant's Signature:

Date:

20. Departmental approval: *I have read this application and believe it to be scientifically and ethically sound. I approve the research design. The Research proposed in this application is compatible with the University of Otago policies and I give my consent for the application to be forwarded to the University of Otago Human Ethics Committee with my recommendation that it be approved.*

Signature of *Head of Department:

Date:

**(In cases where the Head of Department is also the principal researcher then the appropriate Dean or Pro-Vice-Chancellor must sign)*

Please attach copies of the Information Sheet and Consent Form

Appendix 2. Letters, Information sheets and consent forms

October 2009

The Principal

Dear Principal

My name is Kate Rice and I am undertaking research investigating the effect of building teacher's Nature of Science understanding through a professional development programme on science teaching practice as part of the requirements for a Doctor of Education through the University of Otago under the supervision of Associate Professor Mary Simpson.

The initial research involves a survey of teachers in Otago and Southland schools to find their current understanding of the Nature of Science. The findings of this survey will be used to develop the content for the Professional Development programme. Teachers of science to Year 7 to 13 students are invited to participate in this initial survey.

The second part of the research involves the trialling of a professional development programme to build teachers' understanding of the Nature of Science as outlined in NZ Curriculum 2007.

Schools are invited to express interest in participating in the Professional Development programme "Developing Nature of Science Understanding for Science Teaching to NZ Curriculum 2007 intent" to be run commencing in either Term 1 2010 or Term 3, 2010. It is anticipated that two participants per school teaching Science within Years 7 – 10 would engage in the professional development which will run over a 20 week period and include classroom support. Details are provided in the attached information sheet for participants.

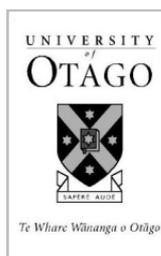
I would invite your school staff to consider participating in this research opportunity.

Please indicate their willingness to be involved in either part of the research by returning the attached form.

Thank you in anticipation of your support.

Regards

Kate Rice
EdD candidate
Adviser in Science and NZ Curriculum,
Secondary Assessment Facilitator
Education Support Services
University of Otago College of Education
PO Box 56
Dunedin
021 793 771 or 03 479 4992



The effect of building teacher's Nature of Science understanding through a professional development programme on science teaching practice.

Expression of interest in participating in proposed research

School

Number of teachers willing to complete initial survey on Nature of Science Understanding in 2009

Teachers willing to participate in Professional development programme in 2010

Name	Contact email	Main year level science teaching

Preferred time for Professional Development programme

January – July 2010

July – December 2010

**Please fax back to
Kate Rice
Education Support Services
University of Otago College of Education
Fax 03 479 4296**



Reference Number **09/161**

October 2009

The effect of building teacher's Nature of Science understanding through a professional development programme on science teaching practice.

INFORMATION SHEET FOR PARTICIPANTS

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you of any kind and we thank you for considering our request.

What is the Aim of the Project?

The aim of this project is to develop a professional development programme with a group of primary and secondary teachers to determine whether gaining a theoretical understanding of the Nature of Science will change science teaching practice.

This project is being undertaken as part of a Doctor of Education research project.

What Type of Participants are being sought?

Teachers of Year 7 to 10 Science are invited to participate in this research project. Any teacher who has participated directly in the Southland Science Cluster or the Science Lead teacher programme in 2009 will not be eligible as they have participated in activities focussed on Nature of Science.

Students in classes of participating teachers will be invited to participate in VNoS surveys and structured interviews.

What will Participants be Asked to Do?

Should you agree to take part in this project, you will be asked to participate in a professional development programme over a 15 - 20 week period that involves

- Participation in surveys on the Nature of Science to identify your understanding of Nature of Science and the theoretical underpinning of science teaching practice.
- Participation in 5 four hour workshops that engage in developing the aspects of the Nature of Science through a combination of structured activities, discussion, reflection and sharing ideas with other participants

- Trialling ideas from workshops with classes as part of your normal teaching programme – up to 20 hours
- up to 5 classroom observations and feedback sessions - up to 6 hours;
- in-school meetings to share with other staff at school – up to 10 hours
- on-line sharing community involvement – up to 20 hours
- individual journalling, reading, activity development and reflection – up to 20 hours;

Please be aware that you may decide not to take part in the project without any disadvantage to yourself of any kind.

Can Participants Change their Mind and Withdraw from the Project?

You may withdraw from participation in the project at any time and without any disadvantage to yourself of any kind.

What Data or Information will be Collected and What Use will be Made of it?

- Survey data will be collected using a Nature of Science Bipolar semantic survey, and a Views of Nature of Science (VNoS) survey to identify teacher understanding of Nature of Science.
- This project involves an open-questioning technique with teachers. The general line of questioning includes teaching approaches used in science, understanding of Science learning area of New Zealand Curriculum and Nature of Science. The precise nature of the questions which will be asked have not been determined in advance, but will depend on the way in which the interview develops. Consequently, although the University of Otago Human Ethics Committee is aware of the general areas to be explored in the interview, the Committee has not been able to review the precise questions to be used.

In the event that the line of questioning does develop in such a way that you feel hesitant or uncomfortable you are reminded of your right to decline to answer any particular question(s) and also that you may withdraw from the project at any stage without any disadvantage to yourself of any kind. The interviews will be taped and transcribed by typists and used by researchers to identify trends and issues that arise during the professional development intervention.

- Workshops will be videotaped to allow the learning community development to be followed and any possible issues identified, either in the researcher's facilitation or among participants' responses and interactions. The tapes will be destroyed once analysis has been completed.
- Classroom observations will be used to observe and record Nature of Science processes in teaching programmes to identify next steps for the professional development programme both at start and after 3 workshop sessions. Reflection and feedback following the observations will allow teachers to identify aspects for further development or trialling.

- Student surveys using the student VNoS version will be used before and after the teacher participation in the intervention to identify student Nature of Science understandings of Year 7 and Year 10 students, and changes over time with their teacher on the programme. Students from one class for each teacher in the programme would be included.
- Student voice will be used to determine students' learning/understanding of Nature of Science. Student voice responses will be shared with teachers to provide an indication of students' teaching needs and also to identify possible foci for following workshops.
- Documents will be collected to indicate professional development in Science, approaches to teaching and planning and will include relevant staff meeting records, lesson plans from during professional development programme, teachers' planning and teacher archival materials such as student activities and resources used in science programmes.
- Personal data of a limited nature will be collected from participating teachers to allow trends relating to gender, tertiary science level attainment, years of teaching, confidence in teaching science contexts to be identified.

The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve your anonymity.

You are most welcome to request a copy of the results of the project should you wish.

The data collected will be securely stored in such a way that only those mentioned below will be able to gain access to it. At the end of the project any personal information will be destroyed immediately except that, as required by the University's research policy, any raw data on which the results of the project depend will be retained in secure storage for five years, after which it will be destroyed.

Reasonable precautions will be taken to protect and destroy data gathered by email. However, the security of electronically transmitted information cannot be guaranteed thus caution will be used in the electronic transmission of sensitive material.

What if Participants have any Questions?

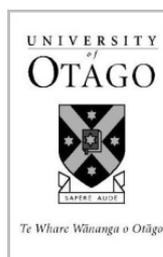
If you have any questions about our project, either now or in the future, please feel free to contact either:-

Kate Rice
Education Support Services, University of Otago College of Education
Ph 03 479 4992
Email kate.rice@otago.ac.nz

OR

Associate Professor Mary Simpson, Associate Dean (Teacher Education)
College of Education
Ph 03 479 3795
Email mary.simpson@otago.ac.nz

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 03 479 8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.



Reference Number **09/161**

October 2009

The effect of building teacher's Nature of Science understanding through a professional development programme on science teaching practice.

CONSENT FORM FOR PARTICIPANTS

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:-

1. My participation in the project is entirely voluntary;
2. I am free to withdraw from the project at any time without any disadvantage;
3. Personal identifying information including video and audio tapes will be destroyed at the conclusion of the project but any raw data on which the results of the project depend will be retained in secure storage for five years, after which they will be destroyed;
4. This project involves an open-questioning technique. The general line of questioning includes teaching approaches used in science, understanding of Science learning area of New Zealand Curriculum and Nature of Science. The precise nature of the questions which will be asked has not been determined in advance, but will depend on the way in which the interview develops. In the event that the line of questioning develops in such a way that I feel hesitant or uncomfortable, I may decline to answer any particular question(s) and/or may withdraw from the project without any disadvantage of any kind.
5. As the project does include classroom observations, workshops and interviews, the researcher will endeavour to reduce any discomfort or risk to participants, however if I feel discomfort at any of these components of the research, I may discontinue with no disadvantage of any kind.
6. There is no remuneration or compensation with participation in the research, and understand that data will not be used in any commercial way.
7. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve my anonymity.

I agree to take part in this project.

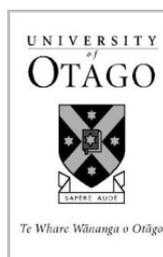
.....

(Signature of participant)

.....

(Date)

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October 2009

The effect of building teacher's Nature of Science understanding through a professional development programme on science teaching practice.

INFORMATION SHEET FOR

PARENTS / GUARDIANS AND STUDENT PARTICIPANTS.

Thank you for showing an interest in this project. Please read this information sheet

carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you of any kind and we thank you for considering our request.

What is the Aim of the Project?

The aim of this project is to develop a professional development programme with a group of primary and secondary teachers to determine whether gaining a theoretical understanding of the Nature of Science will change science teaching practice.

This project is being undertaken as part of a Doctor of Education research project.

What Type of Participants are being sought?

Students in classes of teachers participating in the Nature of Science Professional Development programme are invited to participate in Views of Nature of Science (VNoS) surveys and structured interviews.

What will Student Participants be Asked to Do?

Should you agree to take part in this project, students will be asked to

- participate in two surveys on the Nature of Science to identify your understanding of Nature of Science, one prior to the student's teacher beginning a professional development programme and the second at the end of the 15 week period that the teacher is involved in the programme.
- take part in a structured interview to provide information on how the student's teacher has helped the student's learning in Science.

Please be aware that students may decide not to take part in the project without any disadvantage to themselves of any kind.

Can Participants Change their Mind and Withdraw from the Project?

Students may withdraw from participation in the project at any time and without any disadvantage of any kind.

What Data or Information will be Collected and What Use will be Made of it?

- Student surveys using the student VNoS version will be used before and after the teacher participation in the intervention to identify student Nature of Science understandings of Year 7 and Year 10 students, and changes over time with their teacher on the programme. Students from one class for each teacher in the programme will be included.
- Student voice will be used to determine students' learning/understanding of Nature of Science. Student voice responses will be shared with teachers to provide an indication of students' teaching needs and also to identify possible foci for following workshops.
- Personal data of a limited nature will be collected from participating students to allow trends relating to gender, science level attainment, age and interest in science.

The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve your anonymity.

You are most welcome to request a copy of the results of the project should you wish.

The data collected will be securely stored in such a way that only those mentioned below will be able to gain access to it. At the end of the project any personal information will be destroyed immediately except that, as required by the University's research policy, any raw data on which the results of the project depend will be retained in secure storage for five years, after which it will be destroyed.

Reasonable precautions will be taken to protect and destroy data gathered by email. However, the security of electronically transmitted information cannot be guaranteed thus caution will be used in the electronic transmission of sensitive material.

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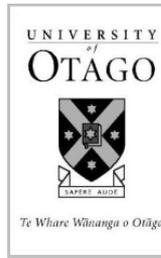
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October 2009

The effect of building teacher's Nature of Science understanding through a professional development programme on science teaching practice.

CONSENT FORM FOR PARENTS/GUARDIANS of STUDENTS

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:-

- My child's participation in the project is entirely voluntary;
- I am free to withdraw my child from the project at any time without any disadvantage;
- Personal identifying information such as the audiotapes will be destroyed at the conclusion of the project but any raw data such as transcripts of the interview on which the results of the project depend will be retained in secure storage for five years, after which they will be destroyed;
- There is no intention that the research should cause discomfort or risk to participants, however if my child feels discomfort, I can withdraw my child from the project.
- There is no remuneration for participation in this research, nor will data gathered from participants be used for commercial purposes.

The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve my anonymity.

I agree for my child to take part in this project.

.....

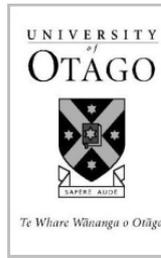
.....

(Signature of parent/guardian)

(Date)

.....
(Name of child)

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 03 479 8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.



Reference Number **09/161**

October 2009

The effect of building teacher's Nature of Science understanding through a professional development programme on science teaching practice.

CONSENT FORM FOR CHILD PARTICIPANTS

I have been told about this study and understand what it is about. All my questions have been answered in a way that makes sense.

I know that:

- Participation in this study is voluntary, which means that I do not have to take part if I don't want to and nothing will happen to me. I can also stop taking part at any time and don't have to give a reason;
- Anytime I want to stop, that's okay.
- The researcher, Kate Rice will audiotape me so that she can remember what I say, but the tape will be thrown away after the study has ended.
- If I don't want to answer some of the questions, that's fine.
- If I have any worries or if I have any other questions, then I can talk about these with Kate Rice.
- The paper and computer file with my answers will only be seen by Kate Rice and the people she is working with. They will keep whatever I say private.
- Kate Rice will write up the results from this study for her University work. The results may also be written up in journals and talked about at conferences. My name will not be on anything written up about this study.

I agree to take part in the study.

.....

Signed

.....

Date

Appendix 3. NSAAQ Questionnaire

THE NATURE OF SCIENCE AS ARGUMENT QUESTIONNAIRE (NSAAQ)

This is the survey of teachers' Nature of Science understanding to establish baseline data for research into the effectiveness of a science professional development programme focussed on building teacher's Nature of Science understanding. The Professional development programme will be conducted during 2010 with two clusters of Science teachers in the Otago Southland region.

Thank you for agreeing to participate in this survey of science teachers participating in the Nature of Science professional development programme in the Otago Southland region.

Directions: Read the following pairs of statements and then circle 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

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? The statements below describe scientific knowledge from different viewpoints.

Indicate which viewpoint you agree with the most using the scale below...

	Viewpoint A	A not B	A > B	A = B	B > A	B not A	Viewpoint B
1	Scientific knowledge describes what reality is really like and how it actually works.	1	2	3	4	5	Scientific knowledge represents only one possible explanation or description of reality.
2	Scientific knowledge should be considered tentative.	1	2	3	4	5	Scientific knowledge should be considered certain.
3	Scientific knowledge is subjective.	1	2	3	4	5	Scientific knowledge is objective.
4	Scientific knowledge does not change over time once it has been discovered	1	2	3	4	5	Scientific knowledge usually changes over time as the result of new research and perspectives
5	The concept of 'species' was invented by scientists as a way to describe life on earth.	1	2	3	4	5	The concept of 'species' is an inherent characteristic of life on earth; it is completely independent of how scientists think.
6	Scientific knowledge is best described as being a collection of facts about the world.	1	2	3	4	5	Scientific knowledge is best described as an attempt to describe and explain how the world works.

How is scientific knowledge generated?

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

The statements below describe different viewpoints for how scientific knowledge is generated.

Indicate which viewpoint you agree with the most using the scale below...

	Viewpoint A	A not B	A > B	A = B	B > A	B not A	Viewpoint B
7	Experiments are important in science because they can be used to generate reliable evidence.	1	2	3	4	5	Experiments are important in science because they prove ideas right or wrong.
8	All science is based on a single scientific method	1	2	3	4	5	The methods used by scientists vary based on the purpose of the research and the discipline.
9	The methods used to generate scientific knowledge are based on a set of techniques rather than a set of values.	1	2	3	4	5	The methods used to generate scientific knowledge are based on a set of values rather than a set of techniques.
10	Science is best described as a process of exploration and experiment.	1	2	3	4	5	Science is best described as a process of explanation and argument.
11	An experiment is used to test an idea.	1	2	3	4	5	An experiment is used to make a new discovery.
12	Within the scientific community, debates and discussions that focus on the context, processes, and products of inquiry are common.	1	2	3	4	5	Within the scientific community, debates and discussions that focus on the context, processes and products of inquiry are rare.

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.

The statements below describe different viewpoints about what counts as reliable and valid scientific knowledge.

Indicate which viewpoint you agree with the most using the scale below...

	Viewpoint A	A not B	A > B	A = B	B > A	B not A	Viewpoint B
13	Scientific knowledge can only be considered trustworthy if the methods, data, and interpretations of the study have been shared and critiqued.	1	2	3	4	5	Scientific knowledge can be considered trustworthy if it is well supported by evidence.
14	The scientific method can provide absolute proof.	1	2	3	4	5	It is impossible to gather enough evidence to prove something true.
15	If data was gathered during an experiment it can be considered reliable and trustworthy.	1	2	3	4	5	The reliability and trustworthiness of data should always be questioned.
16	Scientists know that atoms exist because they have made observations that can only be explained by the existence of such particles.	1	2	3	4	5	Scientists know that atoms exist because they have seen them using high-tech instruments.

	Viewpoint A	A not B	A > B	A = B	B > A	B not A	Viewpoint B
17	Biases and errors are unavoidable during a scientific investigation.	1	2	3	4	5	When a scientific investigation is done correctly errors and biases are eliminated.
18	A theory should be considered inaccurate if a single fact exists that contradicts that theory.	1	2	3	4	5	A theory can still be useful even if one or more facts contradict that theory.
19	Scientists can be sure that a chemical causes cancer if they discover that people who have worked with that chemical develop cancer more often than people who have never worked that chemical.	1	2	3	4	5	Scientists can only assume that a chemical causes cancer if they discover that people who have worked with that chemical develop cancer more often than people who have never worked that chemical.

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

The statements below describe different viewpoints for what scientists do and what they are like.

Indicate which viewpoint you agree with the most using the scale below...

	Viewpoint A	A not B	A > B	A = B	B > A	B not A	Viewpoint B
20	In order to interpret the data they gather scientists rely on logic and their creativity and prior knowledge.	1	2	3	4	5	In order to interpret the data they gather scientists rely on logic only and avoid using any creativity or prior knowledge.
21	Scientists are influenced by social factors, their personal beliefs, and past research.	1	2	3	4	5	Scientists are objective, social factors and their personal beliefs do not influence their work.
22	Successful scientists are able to use the scientific method better than unsuccessful scientists.	1	2	3	4	5	Successful scientists are able to persuade other members of the scientific community better than unsuccessful scientists.
23	Two scientists (with the same expertise) reviewing the same data will reach the same conclusion.	1	2	3	4	5	Two scientists (with the same expertise) reviewing the same data will often reach different conclusions.
24	A scientist's personal beliefs and training influence what they believe counts as evidence.	1	2	3	4	5	What counts as evidence is the same for all scientists.
25	The observations made by two different scientists about the same phenomenon will be the same.	1	2	3	4	5	The observations made by two different scientists about the same phenomenon can be different.
26	It is safe to assume that a scientist's conclusions are accurate because	1	2	3	4	5	A scientist's conclusion can be wrong even though scientists are

	they are an expert in their field.						experts in their field.
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Please complete the following demographic information survey. The data collected will be securely stored in such a way that only those mentioned below will be able to gain access to it. At the end of the project any personal information will be destroyed immediately except that, as required by the University's research policy, any raw data on which the results of the project depend will be retained in secure storage for five years, after which it will be destroyed.

Demographic survey

Name	
Male / Female	Age in years
Teaching level	Time teaching (in years)
Highest level of Academic qualification	Highest Science qualification
Highest Teaching qualification	Science subjects studied at Tertiary level
Time teaching at current school (in years)	Indicate the Ethnic groups with which you identify

If you have any questions about our project, either now or in the future, please feel free to contact either:-

Kate Rice

Education Support Services, University of Otago College of Education

Ph 03 479 4992

Email kate.rice@otago.ac.nz

OR

Associate Professor Mary Simpson, Associate Dean (Teacher Education)

College of Education

Ph 03 479 3795

Email mary.simpson@otago.ac.nz

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Appendix 4. Reflection tools

SEMI STRUCTURED INTERVIEW QUESTIONS FOR PARTICIPANTS

How do you run Science (Department) in your school?

Pick up on–

- *Attitude to management theories*
- *Relationship with teachers in department/syndicate*
- *Role of HOD/Syndicate Leader/Science Lead teacher*
- *Time in school/position*
- *Practical examples of routines etc in the department*

How would you describe the teaching that happens in Science?

Pick up on

- *Teaching style*
- *Use of resources*
- *Classroom organisation*

Has the introduction of the revised NZ Curriculum led to any changes to teaching?

Pick up on

- *Learning area focus*
- *Processes vs content/contexts*
- *Nature of Science aspects*
- *Communicating in Science understanding*
- *Lesson structures*
- *Student involvement/engagement*
- *Teaching style*
- *Assessment approaches and focus*
- *Use of resources*

Is the implementation of Science in the NZC having any effect on the content of units you

Pick up on

- *Approach to processes*
- *Approach to content*
- *Resources used such as texts, activities*

What do you understand by the Nature of Science?

Pick up on

- *Ideas from p28/29 of Curriculum*
- *Ideas from Achievement Objectives of NZC*

Will the implementation of Science using revised NZC result in any changes in assessment practices?

Pick up on

- *Formative assessment activities*
- *Topic tests*
- *Context vs contents*
- *Processes vs content*

JOURNALLING QUESTIONS

What did the session today challenge in my thinking?

What parts of the session made me feel I was taking a risk?

What parts of the session did I enjoy?

How might I use ideas from this session with other teachers?

How might I incorporate ideas from this session into my teaching and learning programmes?

What actions am I going to take as a result of this session?

When?

With what class?

What support might I need to carry this action out?

What changes should be made to this session?

STUDENT VOICE SEMI-STRUCTURED INTERVIEW QUESTIONS

Student voice was obtained using three questions:

What are you learning?

Why are you learning this?

How does your teacher help you with your learning?

THINKING OBJECTS

Identify an existing ARB activity that fits with your current topic – or one you already use with the topic.

- Identify an aspect of Nature of Science that this activity could be used to develop with your class.
- Give the activity a Title and a NoS Focus heading
- Modify/redesign the activity and its existing questions so that it builds the specified NoS capability using a 21st century learner focus.
- Write a paragraph that describes how you have changed the activity so that it builds an aspect of Nature of Science capability.
- Trial the modified activity with your class, get them to complete the activity feedback resource.
- Share your task and the students' responses with the other participant from your school, carry out any necessary modifications.
- Post to the wiki site

Reflection Bookmarks

REFLECTION BOOKMARK	REFLECTION BOOKMARK	REFLECTION BOOKMARK
Strategy I tried	Strategy I tried	Strategy I tried
Class	Class	Class
What happened	What happened	What happened
Why it happened	Why it happened	Why it happened
What I could do differently	What I could do differently	What I could do differently
When I will try it again	When I will try it again	When I will try it again
Who with	Who with	Who with

Appendix 5. Details of workshops 1-5

Detail of Professional Development Programme designed to build teachers

Nature of Science capability final version

5E aspect	Workshop 1	Workshop 2 Investigating in Science	Workshop 3 Understanding about science	Workshop 4 Communicating in Science	Workshop 5 Participating and Contributing
Engage	Engaging activity <i>Classifying buttons, paperclips, Classification of everyone Activity)</i> Establish protocols, Build rapport, Group forming, NSAAQ survey Time 1	Engaging activity – <i>Challenge -Make a traffic light drink</i> Reflection on teaching strategies and student learning	Engaging activity - <i>Ice Balloons or Ice Hands</i> Reflection on teaching strategies and student learning	Engaging activity <i>You-tube – Sound activity</i> Reflection on teaching strategies and student learning	Engaging activity <i>Plant reproduction</i> Reflection on teaching strategies and student learning
Explore	What is NoS in New Zealand Curriculum <i>(Think/pair/share or Brainstorm)</i> What is internationally accepted understandings of NoS? <i>(Reading)</i> <i>Process station Activity</i>	NoS understandings relating to investigations in science <i>(Agree/Disagree on Myths of Science)</i> <i>Practical activities to explore NoS investigating</i> <i>(Hinged Mirrors/Floating eggs)</i> Feedback on findings re student NoS capability	Reflection on NoS understandings on understanding about science Testable questions agree/disagree Practical activities to explore NoS understanding science <i>Tricky tracks scenario Word or sentence activity – generation of theories</i> <i>Questioning resource – rewrite questions from Ice activity</i>	Reflection on NoS understandings about communicating in science <i>Sound resource – finding out using range of texts</i> <i>Connections activity</i> <i>Cause and effect statements</i> Practical activities to explore NoS communicating in science <i>(Use of sound resource, and writing frames, Matrix for expln writing)</i>	Reflection on Nature of Science understandings of socio scientific issues and science <i>Zoos debate</i> <i>Birds fly gracefully activity –fact vs opinion</i> Practical activities to explore NoS participating and contributing <i>(Windfarm debate)</i>
Explain	What are processes of science? <i>Big Ideas activity + Reading</i> <i>(to construct tentative explanations of natural phenomena)</i>	What makes a testable question? Analysis of Investigating in Science strand Explain why it is important for students to transform data	Analysis of Understanding in Science strand Explain how Dog and Turnip activity can help build this	Analysis of communicating in Science strand Explain why experience of different science texts is important for students	Analysis of Participating and Contributing Strand Explain why students should engage with socioscientific

	How does NoS relate to the processes of science?	into evidence supporting explanations			issues from a young age
Extend	<p>Identify aspects of NoS important for students (<i>reading and Foam Activity</i>)</p> <p>Identify/plan NoS activity and assessment to determine student NoS capability using NZ Science exemplar matrices</p> <p>Implementation Plan</p> <ul style="list-style-type: none"> • Readings • In-school visits for observations and feedback • Moodle/wiki use • Reflective journal 	<p>Designing an investigation for own question</p> <p>Designing and Planning activities for use at school</p>	<p>How can we develop students' understanding about science that is not solely through recall of facts?</p> <p>Designing and Planning activities for use at school</p>	<p>How can we build students' ability to communicate in science?</p> <p>Designing and Planning activities for use at school</p>	<p>What makes a good activity to develop socio scientific capability in students?</p> <p>Designing and Planning activities for use at school</p>
Evaluate	Reflection on session – aspects to change/keep/remove, include facilitation	Reflection on session – aspects to change/keep/remove include facilitation Time to write in reflective journals	Reflection on session – aspects to change/keep/remove include facilitation Time to write in reflective journals	Reflection on session – aspects to change/keep/remove include facilitation Time to write in reflective journals	Reflection on session – aspects to change/keep/remove include facilitation Time to write in reflective journals NSAAQ completed

Possible Workshop Readings

Ebbers, M. (2002). Science text sets: Using various genres to promote literacy and inquiry.

Language Arts, 80(1), 40 - 50.

Rowell, P., & Ebbers, M. (2004). Shaping school science: Competing discourses in an inquiry-based elementary program. *International Journal of Science Education*, 26(8), 915-934.

Rowell, P. M., & Ebbers, M. (2004). School science constrained: Print experiences in two elementary classrooms. *Teaching and Teacher Education*, 20(3), 217–230.

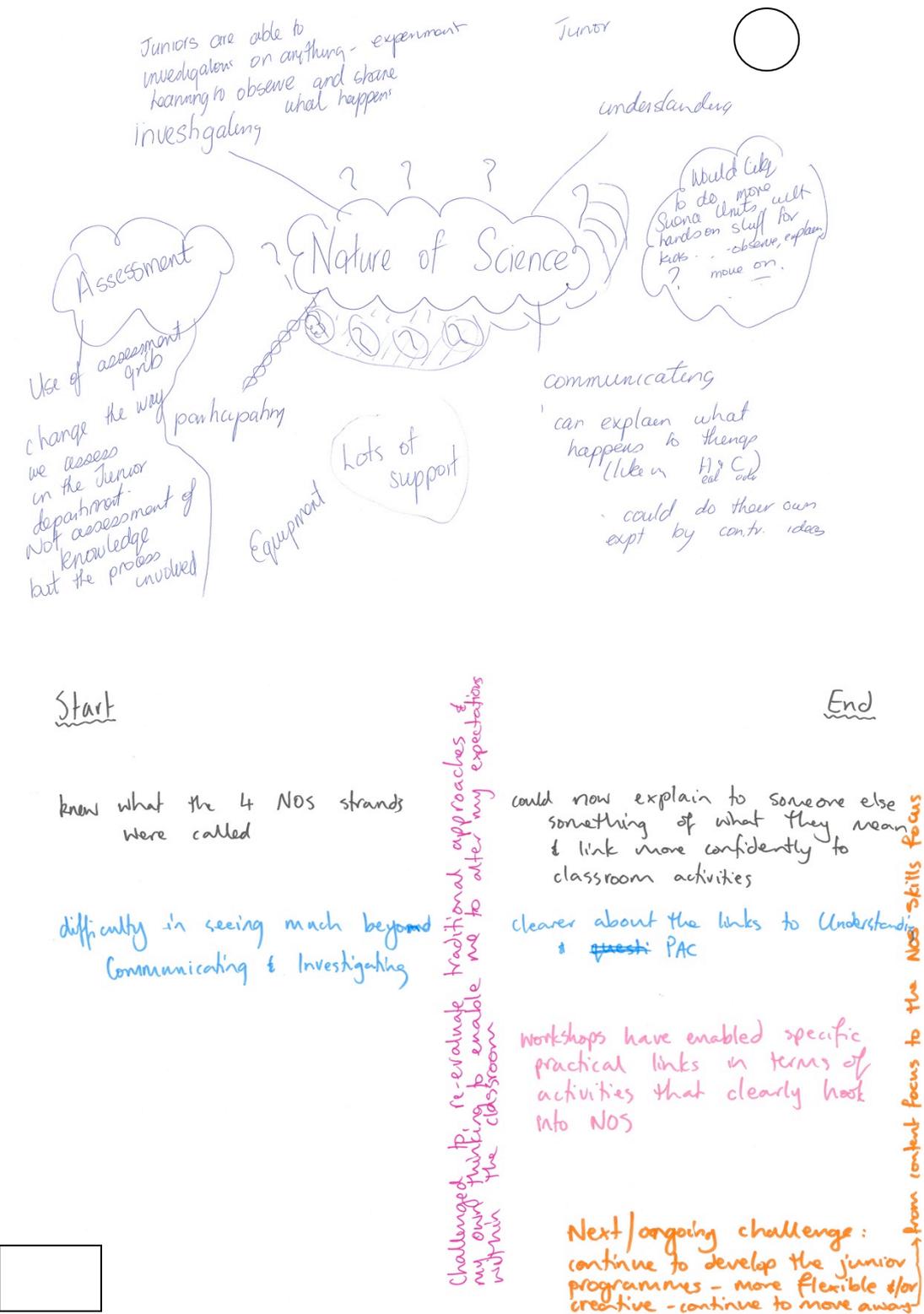
Rowell, P. M., & Ebbers, M. (2004). An uncertain role for literacy in elementary science. Paper presented at the Australian Association of Research in Education, Melbourne. downloaded from <http://www.aare.edu.au/02pap/row02074.htm>

From <http://arb.nzcer.org.nz/supportmaterials/science/> the following ARB Resources

- Thinking about how language works
- Science investigation
- Interrelationships

Appendix 6. Samples of participant responses

Pictorial reflection on change in understanding over the NoS intervention from two participants



One Participant's response to JOURNALLING QUESTIONS

What did the session today challenge in my thinking?

Again, the links between practical activities, some theory and the Nature of Science

Fair Test/6 categories was an eye opener

What parts of the session made me feel I was taking a risk?

New Knowledge and understanding of sci teaching

What parts of the session did I enjoy?

Great mix at practical and ideas behind the teaching

How might I use ideas from this session with other teachers?

Develop ARB resources to fit with NOS better for use with classes

How might I incorporate ideas from this session into my teaching and learning programmes?

Incorporate ideas on NoS into my teaching

What actions am I going to take as a result of this session?

Do the ARB - modify thing to have a task ready for next workshop

When? *Next week*

With what class? *Year 10*

What support might I need to carry this action out?

Help with using a practical focus to the lesson that lets students engage and explore

What changes should be made to this session?

A little more time in school groups to develop/plan one activity

Sample of completed Bookmarks from two participants

REFLECTION BOOKMARK
Strategy I tried create a magnet out of a wire, nail
Class + battery to pick up paperclip
What happened Kids floundered a bit but loved time to play
Why it happened They got motivated and competitive
What I could do differently Do less verbal + more written.
When I will try it again Next time we are going to build circuits tomorrow
Who with IOSY

REFLECTION BOOKMARK
Strategy I tried - Observing, asking questions - Reading reflection - Soder -> pick up words -> make sentences
Class Yr 9 x 10
What happened -> Reading Reflection -> students were more focused -> obs., asking questions -> interesting questions came out.
Why it happened -> Different way of learning
What I could do differently -> Using Brainstorming -> Writing statements
When I will try it again -> In my next lesson of yr 9 (Solar System)
Who with Yr 9.

Reflections from two participants at different sessions

Two Bookmark reflections from the same participant at different sessions

REFLECTION BOOKMARK	REFLECTION BOOKMARK
Strategy I tried Focusing on 5 Es. <i>YouTube clips to intro.</i>	Strategy I tried Student driven investigation
Class Bottom Year 10s	Class Top 9
What happened Students interested from the beginning.	What happened - Did energy heating peanuts. - Students then had to work out and carry out how to work out efficiency of jug
Why it happened Students were intrigued/keen/interested from the start.	Why it happened → Needed extending, a challenge.
What I could do differently Keep it up.	What I could do differently - Allocate more time as valuable
When I will try it again Trying to do it most lessons, as it Who with keeps them interested/engaged.	When I will try it again Assessment: project about energy changes/efficiency of appliance at home Who with Same class.