The impact on elementary (primary) teachers' self-efficacy and knowledge and utilisation of nature of science through participation in a reform-style professional development program.

Author:
Connor, Ricky

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The impact on elementary (primary) teachers' self-efficacy and knowledge and utilisation of nature of science through participation in a reform-style professional development program

Rick Connor

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CONTENTS

ABSTRACT

Significant barriers to the teaching of science at elementary school level include teachers' confidence, their science subject matter knowledge and the technical complexity of resources necessary to demonstrate scientific concepts. Even experienced teachers with sound pedagogical skills in the mechanics of general classroom teaching can have low self-efficacy in science knowledge and teaching, impacting on their overall pedagogical content knowledge for science, a knowledge identified by Shulman (1986) as a critical element in the knowledge base of teaching.

A contributor to teacher's pedagogical content knowledge for science is their understanding of the nature of science. This study outlines and reports on a pendulum-based reform-style professional development program conducted in elementary schools in Sydney, New South Wales, Australia that involved the modelling of a pedagogical approach to the teaching of aspects of the nature of science using the pendulum as the context.

The pendulum lessons developed for the program utilised simple, cheap and readily available materials. Pre- and post-test were conducted utilising the Self-Efficacy Teaching and Knowledge Instrument for Science Teachers (SETAKIST), Views on the Nature of Science (VNOS) Form (D) and a researcher-developed pendulum questionnaire. Two case studies are reported to provide examples of how teachers approached curriculum and teaching practice innovation as a result of participation in the reform-style professional development program.

The findings from and analysis of both the quantitative and qualitative phases employed in this study indicate that a reform-style professional development program, unlike a standard-model program, has a positive impact on both teachers' knowledge and teaching efficacy. The study also provides evidence that conducting the professional development activities in situ of teachers' classrooms has a positive impact on the incorporation of nature of science teaching and learning strategies during curriculum development and in classroom practice.

Abbreviations

PD	Professional development
NOS	Nature of Science
PCK	Pedagogical Content Knowledge
VNOS-D	Views of nature of science form D
VNOS-C	Views of nature of science form C
VNOS-E	Views of nature of science form E
SETAKIST	Self-Efficacy Teaching and Knowledge Instrument for Science Teachers
STEBI	Science Teaching Efficacy Beliefs Instrument

Note: Although this study was conducted in an Australian setting where the term ‘primary’ is used to denote what are internationally referred to as ‘elementary’ teachers, for consistency with international literature, ‘elementary’ is used throughout the thesis.

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CHAPTER 1

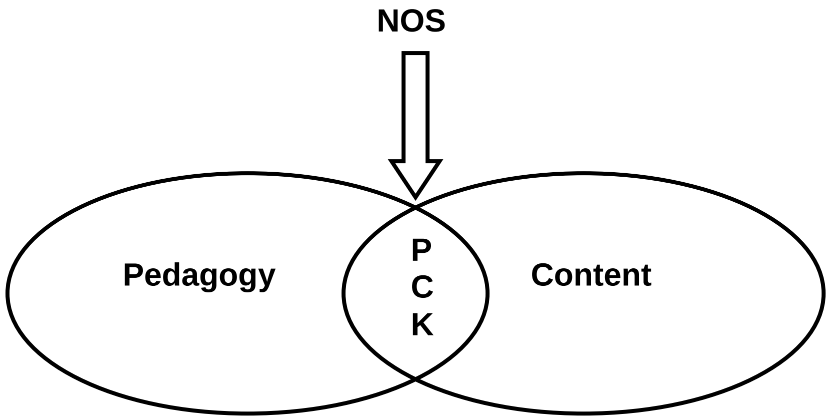
Introduction

1.1 Background and Aims

The research conducted and reported in this thesis investigates the impact on self-efficacy beliefs and nature of science views (NOS) views between teachers participating in a reform-style professional development (PD) program and teachers participating in a standard (traditional) program. Simplified test instruments for assessing teacher self-efficacy for science teaching and science knowledge and for assessing teacher views on the nature of science were employed. Also reported is the change in teacher understanding of key science concepts that were used as lesson contexts for explicitly targeting nature of science aspects.

This chapter presents the general theoretical framework for the thesis and research questions investigated within that framework. The theoretical framework focuses on (a) how teachers' self-efficacy beliefs influence their classroom practices, (b) how nature of science (NOS) understanding contributes to increased scientific literacy, (c) how pedagogical knowledge for NOS is developed from the components of content knowledge for NOS, general science content knowledge and pedagogical practice for NOS instruction. A graphical representation of the hypothesised relationships for NOS pedagogical content knowledge specified in the theoretical framework is presented in Figure 1.1:

Figure 1.1 A graphical representation of the relationships outlined in the theoretical framework



Research into the status of science in elementary school has identified a number of key restraints preventing practicing elementary teachers from developing and delivering effective learning and teaching strategies in response to curriculum requirements. These restraints can be summarized as low teacher confidence or efficacy in their ability to teach effective science lessons, teachers' lack of science content background knowledge and the underdevelopment of teachers' pedagogical content knowledge for aspects of the nature of science.

Almost universally at both the Australian and International level, a major rationale for the redevelopment of elementary science curriculum over the past two decades, has been the notion of improving the scientific literacy of students over the compulsory years of schooling. Elementary teachers therefore, not only have to cope with the science concepts demands of a new curriculum, but also with addressing the main ideas of the definition of scientific literacy described in the curriculum rationale.

A principal aspect in definitions of scientific literacy is an understanding of the nature of science. The nature of science is seen by many researchers to be critical in improving both teachers' and students' scientific literacy. There is a strongly held view within this research community that increasing teachers' and students' understanding of the nature of science needs to be explicitly planned for in teacher preparation and teacher inservice and explicitly addressed by deliberate teaching and learning strategies in classroom lessons. There is extensive research in the area of teacher preservice on the outcomes of college science teaching method programs that explicitly address the nature of science and some research for practicing secondary school science teachers. But few studies targeting nature of science aspects with practicing elementary teachers have been reported.

Various models have been proposed to demonstrate how components such as science concept knowledge, nature of science, scientific literacy, pedagogy and classroom context are related to the preservice training of prospective teachers and inservicing of practicing classroom teachers. A favoured model in current research is the integrative model where all components are seen as being integrated by a teacher into effective classroom teaching. This integration is seen as developing a teacher's science pedagogical content knowledge for nature of science, yet most studies on professional development programs for elementary teachers report on the components as separate entities, indicative of the initial structure and rationale of the PD program.

Regardless of the quality of developed professional development programs, the key determinate identified by the literature in whether teachers' will incorporate new knowledge and /or pedagogical approaches in their classroom, is teacher educational beliefs. Pajares found that there was a *strong relationship between teachers' educational beliefs and their planning, instructional decisions, and classroom* *practices* (Pajares, 1992, p.326). Teachers hold many beliefs and attitudes that affect their attitudes and behaviour in the classroom (Brunning et al., 2004). One key educational belief is a teacher's confidence to perform specific tasks (self-efficacy). Bandura (1997) identified self-efficacy as a cognitive process in which people construct beliefs about their capacity to perform at a given level of attainment**.** Self-efficacy is not only associated with the amount of effort but also the quality of that effort in terms of critical thinking and levels of cognitive engagement (Pintrich & Schunk, 2002).

As with the nature of science, there is extensive research on teacher efficacy at the preservice level and even at the secondary school level, but few empirical studies have been reported for practicing elementary teacher efficacy. Given the low efficacy levels for science teaching reported in many of the studies on the status of elementary school science, the test instruments employed to assess efficacy beliefs and teacher views on the nature of science may themselves contribute even further to lower efficacy.

Several research questions are raised from the literature review and the theoretical framework. There is insufficient research evidence on the stability of practicing elementary teachers' self-efficacy for science teaching and knowledge and their views of the nature of science through participation in professional development. As well, comparison of the outcomes of differing inservice PD program designs targeting each is unrepresented in the literature. Moreover, if selected aspects of NOS are explicitly addressed in each of the programs, is increased understanding of these aspects comparable? Hence, the following research questions are posited.

Research question 1. Does participation in professional development developed on tenets of the nature of science impact on the self-efficacy of elementary teachers for science knowledge and science teaching.

Research question 2. Is there a difference between the impact on self-efficacy of elementary teachers for science knowledge and science teaching through participation in structurally different professional development programs?

Research question 3. Does participation in professional development impact on NOS views of elementary teachers?

Research question 4. Is there a difference between the impact on NOS views of elementary teachers through participation in structurally different professional development programs?

1.2 Significance of the study

The research reported in this thesis contributes to new knowledge in several ways. Principally, the research focuses on practising elementary teachers, an area of study that has been given minimal attention. Most research on teachers' views of the nature of science has been conducted in the context of preservice elementary or middle/high school teaching candidates. Secondly, the research reports on the utilisation of two test instruments, VNOS-D and SETAKIST, which are either more recent instruments or were applied and analysed in a new way. Thirdly, the research was conducted through a reform-based PD program conducted in situ of the teachers' classrooms with a cohort substantially larger in number than previous reported research.

A mixed-methods methodology was employed using both quantitative and qualitative methods followed by an attempt to integrate the data collected by each method. One of the purposes employing mixed methods was to develop a relatively holistic 'picture' of the phenomena in question.

1.3 Overview of the chapters to follow

In chapter 2, a review of the literature is presented. The literature review begins with findings on the status of science in elementary schools internationally and within Australia and science curriculum development and reform. The literature review then addresses self-efficacy for science teaching and the attempts to measure it. The literature review also addresses the concept of pedagogical content knowledge, models that have been proposed to describe how it contributes to effective science teaching. Finally, the literature review covers the concept of scientific literacy and the contribution of nature of science understanding to the development of a teacher's scientific literacy. However, the main contribution of the literature review is to the development of the theoretical framework on which this thesis is based.

In chapter 3, methodological issues relevant to the study and techniques used to analyse the data are explained. A discussion of mixed-method research is also included, along with a description of the PD program materials employed.

Chapter 4 reports the findings from Phase 1 - The intervention

Chapter 5 reports the findings from Phase 2 – Case studies and debriefs

In chapter 6, the research questions for the thesis are revisited. This is then followed by a discussion of implications for theory and practice and directions for future research.

CHAPTER 2

Immediate background to the current research

2.1 Introduction

Based on previous research on the status of science in elementary school, key factors inhibiting its effective teaching have been identified as common across international settings. These key factors include teacher self-efficacy for teaching science, teacher lack of science subject matter knowledge (SMK) and the quality of teacher professional development. Lower teacher self-efficacy and lack of science SMK are intricately linked and have been shown to result in a lack of emphasis on science in elementary classrooms.

Recent reforms in science curricula place enhanced scientific literacy at the forefront of desired curriculum outcomes and the literature suggests that NOS understanding is a key contributor to scientific literacy (Tytler, 2007). There have been calls for NOS to be treated as a content area of equal importance as other SMK (Flick & Lederman, 2004; Lederman, 1999, 2006). Crucially, if NOS understanding is recognised as a key area of SMK for science, teachers’ lack of NOS understanding may also contribute to lower self-efficacy for knowledge and teaching of science.

There has been a call for further research into the link between NOS understanding and its influence on elementary teachers’ self-efficacy (Hanson & Akerson, 2006). Teacher self-efficacy is a particularly critical issue at the elementary school level (Palmer, 2011). There is insufficient research evidence on the stability of *practicing* elementary teachers' self-efficacy for science teaching and knowledge through participation in professional development that targets their views of the nature of science. As well, comparison of the outcomes of differing inservice PD program designs targeting this combination is unrepresented in the literature. Hence, it should be worthwhile to investigate variations in self-efficacy beliefs and NOS views between teachers' participating in a reform-type PD program and teachers participating in a standard traditional program. Moreover, if selected aspects of NOS are explicitly addressed in the programs, is increased understanding of these aspects comparable between the two types of programs?

The research described here aims to reveal the impact on practicing elementary teachers' self-efficacy for teaching and knowledge in science and their views on the nature of science in the context of a reform-based PD program. This chapter summarises literature relevant to achieving this aim. (Note that where the reader is drawn to three or more citations for a particular concept or comment, these are provided as footnotes). Section 2.2 reviews the role of teacher self-efficacy in knowledge and teaching of science and means of measuring this important attribute. Section 2.3 outlines the concept of pedagogical content knowledge (PCK) and how its development may contribute to enhanced self-efficacy in teachers of science. Section 2.4 reviews the concept of scientific literacy and its role in science education reform. Section 2.5 outlines the role of an understanding of the nature of science to a teacher's scientific literacy, the main aspects of the nature of science and means of measuring teachers' views on the nature of science. Section 2.6 reviews the contribution of nature of science to science pedagogical content knowledge. Section 2.7 explains the theoretical principles and methods used in the PD program delivered to enhance elementary teachers' self-efficacy and NOS understanding. Section 2.8 outlines the research questions driving this study. Section 2.9 provides a summary of the contribution made by Chapter 2 to the thesis argument.

2.2 Teacher self-efficacy as an inhibitor to calls for reform in science education

The elementary years are crucial in developing pupils' longer term interest in science (Ofsted, 2004). It was seen as crucial for elementary teachers to not only set in place the knowledge foundations for continued studies in science but, to also engender in students a passion and understanding for the significance of these subjects in modern society (VCAA, 2000). Early research has suggested that poor science instruction at the elementary level contributes to the generally negative attitudes of students at the secondary level and beyond (Mullins & Jenkins, 1988). A comprehensive UK study found elementary students' attitudes to science were beginning to decline as they entered the last year of elementary instruction prior to secondary school (Murphy et al., 2005). In the last year of the 1980s, the situation in Australian elementary schools was so dire that in their review of teacher education in mathematics and science, Speedy and colleagues (1989) considered recommending that science not be taught at the elementary school level because it was taught badly so often.

Throughout the 1990s, key reforms in science education were called for in reports conducted in a number of countries. These included the *US National Science Education Standards (NSES)* developed in 1996 by the National Research Council and the American Association for the Advancement of Science's *Project 2061: Science for All Americans Benchmarks* (AAAS, 1989), *Science –A curriculum profile for*

Australian schools (Curriculum Corporation, 1994b) and *Science in the National Curriculum* (DfES,1995). All the reform documents relating to science require systemic changes in science education (Sandall, 2003) beyond knowledge of scientific concepts towards students as scientifically literate through understandings of science and its processes (Weiss et al., 2003). This calls for teachers of science to work toward a more complex and interdependent set of goals (VCAA, 2000) than they had previously not encountered and may have little training for; goals for teaching science as an active discipline, enhancing student understanding of the nature and history of science and science as a human creative endeavour.

Teachers are important to the success of such science education reforms if system wide school changes are to take place (Bybee, 1993; Fullan & Miles, 1992) but government and independent studies indicate that actual classroom practice demonstrate instructional practices that run counter to the intended reforms (Plourde, 2002). In Weiss and colleagues' US national survey of Science and Mathematics Education, classes at all levels were much less likely to emphasize having students learn to explain ideas in science or learn to evaluate arguments based on scientific evidence, two skills essential to scientific inquiry (Weiss et al., 2001). A UK Office for Standards in Education (Ofsted) subject report highlighted concerns that teaching in science is more didactic than for other subjects (Ofsted, 2004, Postnote, 2003).

Factors seen as limiting elementary school teachers' ability to adhere to the reform document requirements included the level of variability of knowledge and conceptual understanding of science, together with teacher confidence in and enthusiasm for delivering engaging science lessons (Osborne & Simon, 1996; VCAA, 2000), lack of clarity over the reason why they are teaching science, particularly scientific inquiry (Ofsted, 2004) and lack of confidence, expertise and training to be effective teachers of science (Murphy et al., 2005). A large scale UK study was conducted by Murphy, Neil and Beggs (2007), utilising mainly telephone interviews of 300 elementary teachers and a number of focus groups, on issues with the teaching of science in elementary school. They found that the major issue of concern in elementary science was teacher confidence; a concern identified and unchanged from a study conducted 10 years previously (Harlen et al., 1995).

The results of international assessments such as Trends in Mathematics and Science Study (TIMSS) and The Program for International Student Assessment (PISA) give supporting evidence to these limiting factors in science education. The first is that most students do not receive lessons that portray science as a dynamic discipline that encourage conjecture, investigation, theorizing, and application. Rather, most lessons characterize science as a static body of factual knowledge and procedures (Bybee & Stage, 2005). A second factor highlighted is that, according to the National Science Education Standards, *the most important resource is professional teachers* when evaluating science education programs (NRC, 2000, p.218). Bybee is convinced *that the decisive component in reforming science education is the classroom teacher...unless classroom teachers move beyond the status quo in science teaching, the reform will falter and eventually fail* (Bybee, 1993 in Fetters et al., 2002, p.144).

Good science pedagogy is dependent upon a knowledge of and proficiency in specific teaching strategies for science. It relies on teachers who are broadly and deeply knowledgeable and sufficiently confident in their knowledge to be able to change and innovate (Sandall, 2003). Elementary teachers are generalists and not science specialists and, as in many other countries, just as in Australia, lack a firm background of science in their own education and consequently have incomplete understanding of science concepts[1]. This contributes to a teacher's lack confidence in teaching science (Harlen & Qualter, 2004).

One cannot simply give quality science curriculum materials to a teacher and expect quality science instruction (Lumpe et al., 1999). Studies have indicated that, particularly at the elementary school level, low confidence or efficacy levels towards science and/or science teaching tend to lead to sporadic teaching of science, the teaching of science during inadequate blocks of time, or the omission of science instruction from the school[2]. Efficacy has been linked to a teacher's willingness to find improved ways of teaching or engage in classroom innovation[3]. Any innovation in context, practice, materials, or technology should take teachers' existing beliefs into account (Eisenhardt et al., 1988 in Levitt, 2002).

Studies on teachers' subject beliefs are thought to be the key to our attempt to understand the intricacies of how teachers teach and children learn[4]. Teachers are the "change agent" of educational reform and that beliefs of teachers should not be ignored (Lumpe & Haney, 1998). When teachers' beliefs about teaching and learning are acknowledged and addressed, there is the capacity for sustained changes in behaviour (Pajares, 1992) and professional development is more likely to be

[1] See Harlen, 1997; Harlen & Holroyd, 1997; Kruger & Summers 1989.
[2] See Enochs & Riggs, 1990; Hanson & Akerson, 2006; Highlights Report, Horizon, 2003; Ofsted, 2002, 2004.
[3] See Allinder, 1994; Guskey, 1988; Hoy & Spero, 2005; Stein & Wang, 1988.
[4] See Bybee, 1993; Hollingsworth, 1989; Pajares, 1992 in LaPlante, 1997

successful in bringing about such sustained changes (Bybee 1993; Loucks-Horsley et al., 2003).

Bandura (1997) identified a cognitive process in which people construct beliefs about their capacity to perform at a given level of attainment as self-efficacy. Although there had been a great deal of work demonstrating the importance of teachers' self-efficacy perceptions, the early literature lacked data on how one might intervene with teachers to enhance their efficacy perceptions (Hagen et al., 1998). Given that self-efficacy may be specific to the context in which it is studied, there is a lack of data on how science teaching efficacy might be improved for *practicing* or *inservice* teachers. As well, it is likely that there exists an efficacy "threshold" (Hagen et al., 1998) that teachers must exceed if they are to take a chance with a pedagogical innovation.

Bandura (1986, 1997) proposed that self-efficacy is derived from four sources of information:

1. mastery experiences
2. physiological and emotional states
3. vicarious experiences
4. social (verbal) persuasion

Mastery experiences, successfully completing an action in a particular domain (Hagen et al., 1998), are seen as the most powerful source of self-efficacy because they provide authentic evidence to whether a task has been successfully completed by a learner[5]. Vicarious experiences are those in which the skill in question is modelled by someone else, but the degree to which the observer identifies with the model

[5] See Bandura, 1997; Pajares, 1996; Pintrich & Schunk, 2002.

moderates the effect on the observer's self-efficacy (Bandura, 1977). The more closely the observer identifies with the model, the more persuasive are the models' successes and failures (Bandura, 1994) and the stronger will be the impact on self-efficacy (Tschannen-Moran et al., 1998).

People who are persuaded verbally or encouraged that they possess abilities and skill to master given activities are likely to persist with a given challenge or innovation (Bandura, 1994). As with vicarious experience, the potency of verbal persuasion (such as information conveyed from others), depends on the credibility, trustworthiness, and expertise of the persuader (Bandura, 1986). Physiological and emotional states such as anxiety and stress, along with one's mood, provide information about self-efficacy beliefs. Some people may interpret their stress reactions and tension as signs of vulnerability to poor performance whereas others view these as energizing facilitators of performance (Bandura, 1994). Mood also affects people's judgments of their personal efficacy. Mood can bias how much efficacy is derived from experiences. Success under positive mood spawns high level of perceived efficacy .Failures under negative mood breed a low sense of personal efficacy (Bandura, 1997).

Professional development programs may make available to teachers three of these sources of information identified by Bandura:

1. The inservice provides structured opportunities for teachers to practise the skills and apply the knowledge in their own schools (mastery)
2. The inservice provides a forum for teachers to witness the successes of others (vicarious experiences)

3. The inservice provides occasions in which teachers with experience in the innovation persuade newcomers that they are acquiring the target skills and can implement them successfully (verbal persuasion) (Ross, 1994).

As well, indirect influences such as resources support (lesson plans, equipment etc) and social networks will also play a part. However, even with this level of information, change is a gradual and difficult process for teachers (Guskey, 1988). An inservice program conducted by Stein and Wang (1988) reported success in improving teacher self-efficacy (Ross, 1994) but the results demonstrated a lag in self-efficacy beliefs as teachers attempted to put a new method into practice (Tshannen-Moran et al., 1998). Bandura (1997) referred to this as teachers “holding provisional status” in self-efficacy beliefs while they test the newly acquired knowledge and skills.

Therefore substantial follow-up interventions may be necessary during this “provisional” period as a short duration of any inservice may be an additional factor inhibiting the development of teaching skills (Ross, 1994). This may take the form of verbal persuasion during further workshops accompanied by the development of new skills through mastery experiences, two of Bandura’s (1986, 1997) key sources of teacher self-efficacy. Encouragement and support are particularly important as change is implemented and temporary dips in efficacy occur (Tshannen-Moran, Woolfolk-Hoy & Hoy, 1998).

Ross (1994) noted the difficulty of bringing about changes in teacher self-efficacy unless a more interactive PD program was implemented that included teacher practice (Roberts et al, 2000). The PD program utilised in this study whilst inclusive of developing and making available resource materials to participating teachers and using verbal and social persuasion, places those resources within vicarious experiences conducted by the researcher in situ of the participating teacher's own classroom. This 'in situ modelling' by a person that the teacher identifies as similar to themselves has the potential to provide authentic evidence for the classroom teacher that they can teach science to their own class (Palmer, 2011). It will be necessary for the researcher 'in situ' to be perceived as similar to the classroom teacher and the process conducted to establish this is described in a later chapter.

One such vicarious experience will focus on the nature of classroom discourse during a science lesson, especially in the area of teacher questioning. Teacher questions are a frequent component of science talk. Of particular interest are questions and strategies that elicit what students believe and why[6]. However, teacher questioning is too often of the nature that presents knowledge as pre-determined and uncontested[7]. Mehan (1978) described the basic level of discourse to be what he termed "Initiation-Reply-Evaluation" (IRE) and Lemke (1990) identified the same dominant discourse structure which he labelled "Triadic Dialoque" or "Question-Answer-Evaluation"(Polman & Pea, 2001).

Developing a discourse community in one's classroom can be a powerful form of professional development. Specifically, in a discourse community, it is not just the students who learn, but the teacher as well (Sherin, 2002). Van Zee and colleagues (2001) trialled professional development activities that provided explicit examples of

[6] See Arons, 1983; Driver, 1983; Roth, 1996; Simon et al., 2008: van Zee & Minstrell, 1997 in van Zee et al, 2000.
[7] See Claxton, 1991; Driver et al., 1998; Russell, 1983.

discussions that might help teachers interested in shifting towards more interactive practices. Such interactive practices between students as well as between the students and teacher can result in clarifying understanding of specific science content, identifying and resolving differences in understanding, solving problems, raising new questions, and answering existing questions, and designing investigations (Levitt, 2002).

But the skills necessary to achieve higher levels of discourse in the classroom are general lacking[8]. Considerable evidence shows that moving from teacher-directed classrooms to more student-centred classrooms places complex demands on teachers (Fennema & Nelson, 1997 in Sherin, 2002). First, teachers have a different role to play and second, leading a discourse community requires that teachers develop new understandings of content and pedagogy (Sherin, 2002). Teachers in such student-centred classrooms must make constant decisions on how to respond to students' thinking, they need to create the classroom climate in which this can flourish (Driver et. al., 1998) and they need an understanding of the form and content of the classroom discourse, where the form is '*knowing how to talk' and the content is 'knowing what to say'* (Wood, 1997).

The relationship between "knowing what to say" and teacher content knowledge is pointed for teachers when preparing to teach science in elementary school. When teaching unfamiliar topics, teachers express more misconceptions and they talk longer and more often and mainly pose questions of low cognitive level[9]. Teacher educators must be aware that elementary teachers are sufficiently intelligent and resourceful to

[8] See Cross & Price, 1996 in Driver et al., 1998; Geddis, 1991.
[9] See Hashweh, 1987; Carlsen, 1993 in Van Driel et al., 1997.

be able to find ways to increase their content knowledge if they are given the tools and shown the importance of doing so (Akerson et al., 2011). Yet knowing the science alone is not enough, teachers also want to learn effective ways of making science comprehensible to their young students (Daehler & Shinohara, 2001). Teachers will require help to *go beyond the knowledge of the subject matter per se to the dimension of subject matter knowledge for teaching* (Shulman, 1986, p.9).

Given the current climate of curriculum reform it is important to that one considers the willingness of teachers to participate in change processes and thus strategies for enhancing self-efficacy belief will need to be addressed in the implementation of these changes. (de Laat & Watters, 1995) For example, when dealing with inservice teachers, what kinds of challenges or changes are strong enough to provoke a re-examination of established efficacy beliefs? (Tschannen-Moran & Woolfolk Hoy, 2001).

2.3 Measuring self-efficacy for knowledge of and teaching in science

Tschannen-Moran and colleagues (1998) list a number of unresolved issues perplexing researchers in the area of teacher efficacy that are pertinent to this study:

1. Is teacher efficacy a trait that can be captured by a teacher efficacy instrument, or is it specific to given contexts?
2. Are the traditional assessments of teacher efficacy adequate to the task?
3. What contributes to the development of strong, positive teacher efficacy?
4. How malleable is the sense of efficacy once it is established?

They provide a summary (Table 2.1) of the instruments utilised to obtain a measure of teacher efficacy. The first of these instruments were founded on Rotter's social learning theory with particular reference to his contention that teachers have generalised expectancies for internal versus external control of reinforcement (Rotter, 1966 in Tschannen-Moran et al., 1998). Later studies conducted by the RAND organisation attempted to correlate teacher efficacy in terms of their willingness to implement innovations.

Table 2.1:

Early instruments measuring Teacher Efficacy

Instrument	Researcher(s)	Structure
RAND measure	Armor et al., 1976	2 items on a 5-point Likert scale from "strongly agree" to "strongly disagree." Scoring: sum of the 2 item scores
Teacher Locus of Control	Rose and Medway, 1981	28 items with a force-choice format. Scoring: Half of the items describe situations of student success (I+), and half describe student failure (I-)
Responsibility for Student Achievement	Guskey, 1981	Participants are asked to give a weight or percentage to each of the 2 choices. Scoring: a global measure of responsibility, with 2 subscales: responsibility for student success (R+) and responsibility for student failure (R-)
Webb Efficacy Scale	Ashton et al., 1982	7 items, forced choice. Participants must determine if they agree most strongly with the 1^{st} or the 2^{nd} statement

Subsequent researchers developed efficacy instruments founded on Bandura's social cognitive theory and construct of self-efficacy (Bandura, 1986, 1994, 1997).

Self-efficacy is a future-oriented belief about the level of competence a person expects he or she will display in a given situation and is therefore distinct from other conceptions of self, such as self-concept, self-worth, and self-esteem, in that it is specific to a particular task (Tschannen-Moran et al., 1998). The following summary (Table 2.2) given by Tschannen-Moran and colleagues of efficacy instruments based on Bandura's social cognitive theory contains one such instrument specific to science teaching (STEBI).

Table 2.2:

Later instruments measuring Teacher Efficacy

Instrument	Researcher(s)	Structure
Ashton Vignettes	Ashton et al., 1982	50 items describing problem situations concerning various dimensions of teaching. Self-referenced: "extremely ineffective" to "extremely effective". Norm-referenced: "much less effective than most teachers" to "much more effective than other teachers".
Teacher Efficacy Scale	Gibson and Dembo, 1984	30 items on a 6-point Likert scale from "strongly disagree" to "strongly agree" Scoring: a global measure of teacher efficacy derived from the sum of all items. Two subscales: personal teaching efficacy and general teaching efficacy.
Science Teaching Efficacy Belief Instrument	Riggs and Enochs, 1990	25 items on a 5-point Likert scale from "strongly disagree" to "strongly agree"
Bandura's Teacher Efficacy Scale	Bandura, 1997	30 items on a 9-point scale anchored at "nothing", "very little", "some influence", "quite a bit", "a great deal".

		7 subscales.

Gibson and Dembo's (1994) Teacher Efficacy Scale (TES) was one on the most widely used instruments for measuring teacher efficacy. Although the initial used in the development of the TES were based on Rotter's (1966) locus of control theory, Gibson and Dembo argued that these items correspond with Bandura's constructs of self-efficacy and outcome expectancy. The original 30-item measure was based on two factors, called personal teaching efficacy (PTE), assumed to reflect self-efficacy, and general teaching efficacy (GTE), assumed to capture outcome expectancy. These 30 items were subsequently reduced by Gibson and Dembo after factor analysis to 16 items, 9 for PTE and 7 for GTE.

As the use of this revised TES became widespread, inconsistencies were identified in the discriminant validity of PTE and GTE scores (Coladarci & Fink, 1995; Tschannen-Moran et al., 1998). Also described by Tschannen-Moran and colleagues are problems reported with the use of TES by researchers including:

- the loading of one GTE factor on the PTE factor and the weakness of the loading of one item on either factor (Soodak & Podell, 1993)
- PTE and GTE factors corresponding NOT to self-efficacy and outcome expectancy, but to internal versus external orientation, reflecting locus of control theory rather than self-efficacy theory (Guskey & Passaro, 1994)

Nevertheless, the development of the Gibson and Dembo instrument was a boon to the study of teacher efficacy (Tschannen-Moran et al., 1998) as it led to the construction of further instruments, including those specific to science teaching.

Teacher efficacy has been defined as both context and subject-matter specific. The teacher efficacy model holds that efficacy beliefs should be referred to specific tasks. Pajares (1996) observed that self-efficacy judgments are most predictive of behaviour when evaluation of one's capability is matched to a specific outcome (Henson, 2001). Recognising that many standard efficacy instruments overlook the specific teaching context, some researchers have modified the Gibson and Dembo instrument to explore teachers' sense of efficacy within one particular curriculum area rather than globally.

Pajares (1996) complained that, in relation to student self-efficacy, global measures obscure what is being measured. Assessment of efficacy without reasonable context specificity may actually be assessment of a different construct altogether. The previously mentioned problem of discriminant validity between PTE and GTE using TES and reported by Coladarci and Fink (1995) points to this (Henson, 2001).

In an effort to measure teacher self-efficacy in the subject-specific domain of science, Riggs and Knochs (1990) developed the Science Teaching Efficacy Belief Instrument (STEBI) subsequently used by researchers to examine factors related to science teaching self-efficacy in elementary teachers. Consistent with Gibson and Dembo, they found two separate factors, one they called personal science teaching efficacy (PSTE) and a second they called science teaching outcome expectancy (STOE).

Studies utilising the STEBI instrument found that:

- Teachers with a higher sense of PSTE reported more time spent teaching science and developing science concepts (Riggs & Jesunathadas, 1993)PSTE was related to a composite measure of science teaching performance(Riggs et al., 1994)

- PSTE was related to the rating a teacher gave to the personal relevance of science and a teacher's enjoyment of science activities (Watters & Ginns, 1995)
- Teachers with low PSTE spent less time teaching science, used a text-based approach, were rated weak by site observers and made fewer positive changes in their beliefs about how children learn science (Riggs, 1995)
- Teachers with low scores on STOE were rated as less effective in science teaching, rated themselves as average, and were rated as poor in attitude by site observers (Enochs et al., 1995)

Like TES, STEBI has been critiqued for the validity of the outcome expectancy measurement. (Henson, 2001; Roberts & Henson, 2000). While there is general agreement that the first factor, PTE or PSTE for science, has to do with one's own feeling of competence as a teacher, the meaning of the second factor has been questioned. Roberts and Henson (2000) developed an instrument that could address both the methodological and theoretical problems of efficacy instruments within the field of science. This instrument is called the Self-Efficacy Teaching and Knowledge Instrument for Science Teachers (SETAKIST) (Appendix 2).

SETAKIST is based on a two-construct method of measuring efficacy without the construct of outcome expectancy. The two constructs are teaching efficacy construct (8 items) and the other is knowledge efficacy construct (8 items). The teaching construct is similar to the personal teaching efficacy constructs in both the TES and

STEBI with rewording to reflect the science content. Examples of the teaching efficacy items are, “I do not feel I have the necessary skills to teach science” and “Even when I try very hard, I do not teach science as well as I teach most other subjects.” It was decided that this construct did not require much refining as previous studies have shown it to be relatively stable (Roberts & Henson, 2000).

Roberts and Henson’s decision to include knowledge and instruction constructs in their SETAKIST instrument is that **both** are necessary for effective instruction and a teacher must *demonstrate knowledge of that subject matter as a prerequisite for teaching* (Shulman, 1986). The knowledge efficacy construct is intended by Roberts and Henson to approximate efficacy for science pedagogical content knowledge. Examples of knowledge efficacy items are, “When teaching science, I usually welcome student questions” and “I understand science concepts well enough to teach science effectively.”

This instrument was piloted on a sample of 274 science teachers with teaching experience ranging from one year to twenty-three years. All of these teachers were either science teachers or science specialists for elementary students in their respective schools. Using confirmatory factor analysis, the results of the fit indices suggested good data fit for the two-factor model (Roberts and Henson, 2000). The importance of the SETAKIST instrument according to Roberts and Henson is the unification of the concepts of perceived teaching ability and perceived grasp of content knowledge and that *measures and models of teacher efficacy should account for knowledge efficacy, or a teacher’s confidence in his or her mastery of content knowledge* (Roberts & Henson, 2000, p.13).

This unification of the concepts of teaching ability and content knowledge was one of the key factors in the choice of this self-efficacy instrument in this study. Referring back to the theoretical framework in Chapter 1, the contributors to pedagogical knowledge for nature of science include enhanced teaching skills for NOS and a more developed knowledge of NOS aspects.

2.4 Pedagogical content knowledge

For many elementary teachers a lack of teacher content knowledge is a key limiting factor in raising student achievement but more than just “straight” content knowledge is needed (Bybee & Stage, 2005). The focus on scientific literacy in the reform documents requires a teacher to be knowledgeable in science beyond an understanding of science subject matter to an understanding of how content, processes and the nature of the scientific enterprise are intertwined. Such an understanding contributes to what Shulman called pedagogical content knowledge (PCK) (Shulman, 1986). Helping teachers develop PCK will take sustained and systemic professional development.

Shulman argued that the study of teachers’ understanding of subject matter content and the relationship between this understanding and teaching practice may be the “missing paradigm” in educational research (Shulman, 1986). He suggested three categories of content knowledge:

- Subject matter content knowledge (SMK)
- Pedagogical content knowledge (PCK)

- Curricular knowledge

PCK, or the "subject matter for teaching" became a central area of research, so much so that by 1987, Shulman listed it as one of seven knowledge bases for teaching (Gess-Newsome & Lederman, 1999).

When Shulman proposed pedagogical content knowledge as one of the knowledge bases for teaching, he placed it on an equal footing with content knowledge, general pedagogical knowledge, knowledge of learners, knowledge of educational contexts and knowledge of the philosophical and historical aims of education (Gess-Newsome, 1999). Simplified, these knowledge bases could be listed as:

- Subject matter knowledge – teacher's quantity, quality, and organisation of information, conceptualisation and underlying constructs in their major area of study

- Pedagogical knowledge – teacher's knowledge of generic instructional variables such as classroom management, pacing, questioning strategies, handling of routines and transitions

- Pedagogical content knowledge – represents a teacher's ability to convey the underlying details and constructs in their field of specialisation in a manner that makes it accessible to their students

The epistemological concept of pedagogical content knowledge offers the potential for linking the traditionally separated knowledge bases of content and pedagogy (Veal & MaKinster, 1999) and understanding it as a specific form of teacher knowledge and one of the knowledge bases for teaching (Shulman, 1986**).** This has led to research in the characteristics of this knowledge and the development of teacher education programs to enhance it in preservice and practicing teachers.

Although recognised as a new term in educational research, pedagogical content knowledge had its genesis in earlier debates by educators on the importance or otherwise of the need for teachers to situate their subject knowledge in the context of their classroom teaching (Bullough, 2001). Bullough outlines the views of a number of early educators from as early as 1888 that he believes *laid the seeds for PCK* (Bullough, 2001, p.658), beginning with the comments of Parr, the then president of the National Education Association Department of Normal Schools (USA) who stated that:

> An analysis of the process of teaching shows that there is a special knowledge in each subject that belongs to instruction. This is quite distinct from academic knowledge. And that: the purpose of teaching-knowledge is acquaintance with the processes of the learning mind in the order of mastery (Parr, 1988, in Bullough, 2001, p.658).

Bullough goes on to quote a number of speakers at the 1907 conference of the National Education Association with views consistent with Parr especially with regard to the importance of the context in which the discipline was to be taught:

> To be available for teaching purposes, scholarship must have been acquired or at least overhauled form the teacher's point of view (Hanus, 1907 in Bullough, 2001, p. 659).

Not all speakers shared these views, arguing that mastery of the discipline was the key factor in teacher knowledge, and that the best place to gain this mastery was in the formal setting of colleges and universities taught by subject or discipline specialists. This dichotomy between the subject specialists and their insistence on subject matter knowledge and those teacher educators who proposed that content be presented in the context of teaching or from the viewpoint of how children learn best (Bullough, 2001) was to continue into the next century.

Those who supported the acquisition of subject matter knowledge as the key component of teacher preparation would contend that a subject "expert" would make a more effective teacher. The focus on knowledge acquisition per se in teacher education obscures the critical issue of subject-related pedagogical knowledge that ultimately influences classroom practice (Parker, 2004) and the quality of student learning increases when teachers pay attention to pedagogical knowledge factors (Zeidler, 2002).

The findings of various studies on the effect on a teacher's subject matter knowledge on their teaching practices have shown supporting evidence[10], contrary evidence[11] or inconclusive evidence (Poulson, 2001). However, Poulson expresses concern that in Britain the assumption that teachers with greater subject matter knowledge teach better has governed multiple attempts to improve education through policy, research and practice, by focusing on what teachers know, or what they should know (Poulson, 2001).

Poulson's concern was with the emphasis on developing the subject knowledge of elementary teachers, both in preservice and inservice. Although subject matter

[10] See Brickhouse, 1989: Roth, Anderson & Smith, 1987; Smith & Neale, 1989
[11] See Duschl & Wright, 1989; Lederman & Zeidler, 1987; Zeidler & Lederman, 1989

knowledge and its transformation during teaching was the basis of Shulman's research, it was in the context of secondary school science teaching and Shulman advised caution in the application of the subject matter research to the elementary setting:

> whilst he believed that much of the work held reasonably well for teachers in primary school, he was 'reluctant to make that claim too boldly' (Poulson, 2001, p.43).

Elementary teachers are required to teach several subject areas, and the knowledge required to teach science to elementary school children may not reflect the knowledge required for secondary school science teaching (Poulson, 2001) where the knowledge may be domain-specific and it would be difficult to maintain confidence in the subject matter of elementary teachers across such a broad curriculum (Edwards & Ogden, 1998).

The pedagogical content knowledge base for an elementary teacher, whilst still a product of the interrelatedness of subject matter knowledge and pedagogical knowledge, should be examined more on how tacit knowledge of the subject matter is developed as distinct from the formal knowledge of subject matter (Edwards & Ogden, 1998). Tacit knowledge forms part of a strand of research into teachers' knowledge bases identified by Fenstermacher as being concerned with experienced-based, practical knowledge (Fenstermacher, 1994).

Poulson conducted studies on the subject matter knowledge and teaching practices of teachers of elementary school literacy and mathematics and found that responses to questions items were better when the questions were framed in the context of classroom teaching (Poulson, 2001).

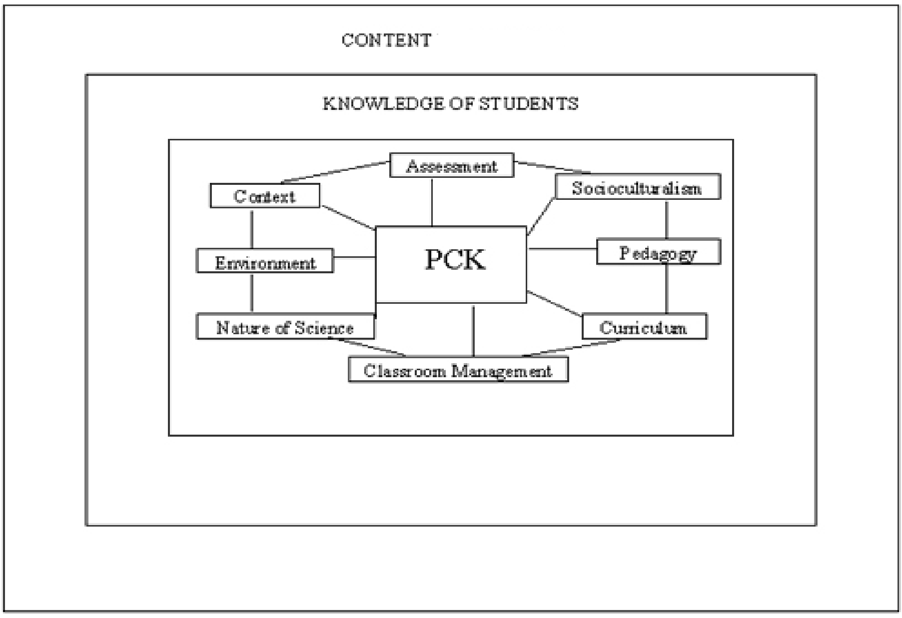
This is not to say that subject matter knowledge plays only a small or insignificant part in influencing science teaching practices of elementary teachers; rather it is more beneficial for teachers to focus on a particular content and the *ways* (my emphasis) in which that content is translated in teaching (Smith & Neale, 1989).).

Teachers need to use subject matter knowledge to lead discussions, provide explanations and generate problem solving applications (Smith & Neale, 1989). Akerson and colleagues' (2000) study of how experienced and novice teachers use student ideas in the context of inquiry teaching highlighted how the level of a teacher's subject matter knowledge understanding influenced both how student ideas were elicited and how these questions were used in instructional strategies. The teacher with the greatest experience and highest level of content knowledge had a wider repertoire of strategies whereas the novice teacher with little classroom experience and a low level of subject matter knowledge discouraged student ideas so she would not have to deal with them. The conclusion drawn by the authors is that with experience teachers begin to expect, elicit and address ideas.

A number of researchers have developed models of pedagogical content knowledge showing the interrelatedness of pedagogical and subject knowledge with the teaching context in which the teacher practices. The models indicate the attributes (Veal & MaKinster, 1999) or categories (Morine-Dershimer & Kent, 1999) that their designers claim contribute to a teacher's pedagogical content knowledge. Veal and MaKinster's model show eight contributing attributes (Figure 1) after content knowledge and knowledge of their students has been developed:

Figure 2.1:

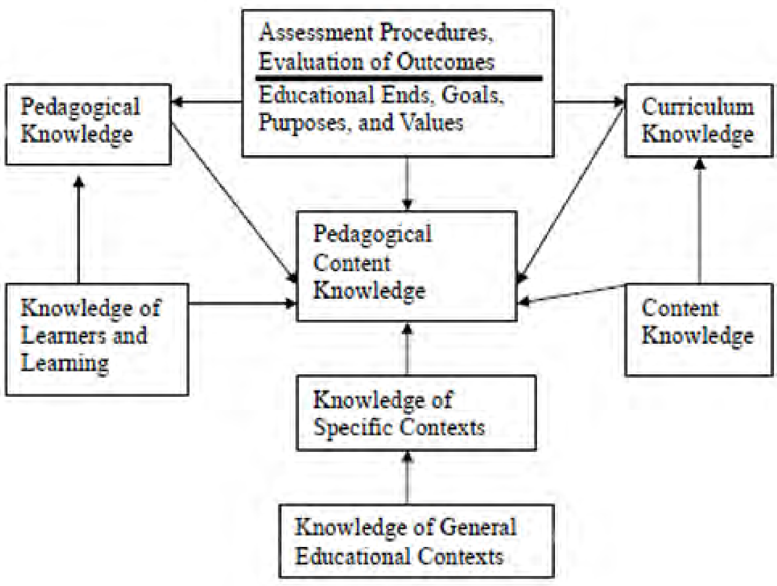
Taxonomy of PCK Attributes (Veal and MaKinster)



Morine-Dershimer and Kent's model of contributing categories (Figure 2) is no less expansive:

Figure 2.2:

Categories contributing to PCK (Morine-Dershimer and Kent)



The complexity of each of these models (Figures 2.1 & 2.2) may reflect the complexities of the relationship between subject knowledge and beliefs about pedagogy in the elementary school classrooms as described in Aubrey's (1996) study of mathematics teaching in infant schools in England. Gess-Newsome however suggests that such knowledge divisions that contribute to pedagogical content knowledge as shown in the above models is overly defined (Gess-Newsome, 1999). Gess-Newsome (1999) proposes that all the different views of PCK can be categorised as either integrative or transformative (Figure 2.3):

Figure 2.3:

Integrative and Transformative PCK Models

2a Integrative

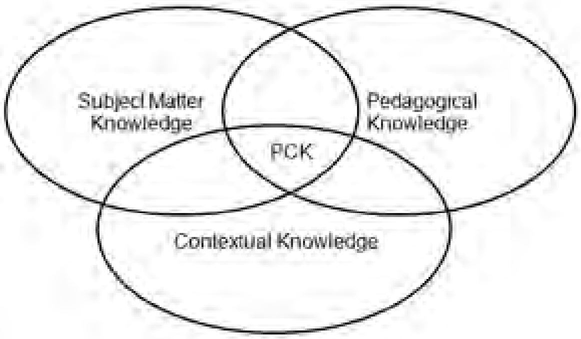
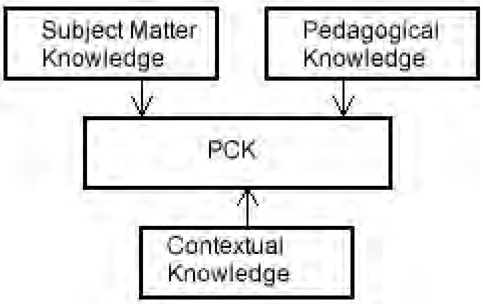


Figure 2b Transformative



In the integrative view, knowledge of teaching is the integration between other forms of educator knowledge; hence, PCK is a mixture. In other words, PCK does not really exist as its own domain and teaching is seen as an act of integrating knowledge of subject, pedagogy, and context. When teaching in the classroom, knowledge from all these domains are integrated by the educator to create effective learning opportunities. The transformative view holds that different forms of educator knowledge (subject matter knowledge, pedagogical and contextual knowledge) are transformed into a new form of knowledge (PCK). In the transformative model PCK is the synthesis of the knowledge needed in order to be an effective educator. Appleton (2006) suggests that integrative and transformative PCK may be used at different times by the same teacher, depending on classroom events. Thus, there may be places for both transformative and integrative PCK models in the overall picture.

The relative merits of transformative and integrative models need consideration. Abd-El-Khalick (2006), for example, argues that integrative models lack explanatory power, as no mechanism is suggested that shows how the interaction between SMK, pedagogy and contextual factors results in PCK. Banks, Leach and Moon (2005) suggest a teacher‘s personal subject construct, which could be the missing link. This combines experiences from teaching with other factors held by the teacher such as purposes and orientations – a teacher mixes these with subject, pedagogical and school knowledge to create PCK. Transformative models imply a mechanism exists – this is used to convert SMK to PCK, to use SMK in creating PCK, to adapt SMK for school use and /or more.

The integrative model (Figure 2a) is indicative of a professional development program that places teacher knowledge development in the context of classroom practice[12]. This model reflects how the translation of professional knowledge into classroom practice requires the synthesis of subject knowledge and knowledge and understanding of the

[12] See Moje & Wade, 1997; Poulson, 2001; Smith & Neale, 1989; van Driek, Verloop & de Voss, 1998; Wilson & Berne, 1999.

teaching and learning of science (Parker, 2004). The transformative model (Figure 2b) is more consistent with standard professional development models and teacher preparation programs that target individual categories with the danger that teachers may never see the importance of knowledge integration and continue to emphasise the importance content over pedagogy (Gess-Newsome, 1999).

2.5 Scientific literacy and its role in science education reform

Reforms in science education over the last two decades have included scientific literacy as a key element of standards, benchmarks and developed curricula. Elementary teachers therefore need to develop teaching and learning activities in response to these reforms. The issue for writers of syllabuses to be used by elementary teachers is determining from the relative reform documents what "level" of scientific literacy is achievable at the elementary school level. Although scientific literacy had been used by philosophers and science educators prior to 1958, Paul DeHart Hurd first used the term as a major theme for science education in his 1958 article entitled: *Science Literacy: Its meaning for American Schools* (Hurd, 1958).

Hurd's view of scientific literacy encompassed not only the understanding of science (concepts) but also the history of science and the connection between science and society (Bybee, 1997). In a later article: *Scientific Literacy: New Minds for a Changing World* (Hurd, 1998) Hurd describes the then view of scientific literacy prevalent in the National Science Foundation Courses at that time as *understanding the classical structure of disciplines and their mode of inquiry* (Hurd, 1998, p.408).

Such courses were disciplined bound and career-oriented rather than being embedded in contexts promoting socially responsible and competent citizens (Hurd, 1998).

By the 1970s, most science educators promoted a shift from a focus on the structure of the science disciplines towards the relationship between science and society and the technological applications of science (DeBoer, 2000). The American National Science Teachers' Association described a scientifically literate person as one who *understands the interrelationships between science, technology and other facets of society, including social and economic development* (NSTA, 1971, p.47 in DeBoer, 2000, p.588). This relationship between science, technology and society was to influence a number of key statements by international government education authorities and science education associations into the 1980s.

In 1982, the NSTA published *Science-Technology-Society: Education for the 1980s* with a list of characteristics of a scientifically literate individual that included the need to understand the limitations and usefulness of science and technology, to know sources of scientific and technological information, and to use this information in decision making (Boujaoude, 2002). The development of such individual characteristics would address the concerns expressed by the National Commission on Excellence in Education in*: A Nation at Risk: The Imperative for Educational Reform* (NCEE, 1983) regarding a generation of individuals that were scientifically and technologically illiterate.

There were critics of the science-technology-society combination fearing science would lose out to technological issues and social analysis (DeBoer, 2000), with a lack of attention to the science basics. Bybee (1997) was also critical of the changes made by science educators to science programs and practices without a shared vision of what they were trying to accomplish. International reform documents produced between 1989 and 1996 attempted to describe scientific literacy therefore in terms of science content, science processes and social context (AAAS Benchmarks for Science Literacy, 1993; Australia: Curriculum Corporation, 1994; Science for All Americans: Project 2061, 1989; National Science Education Standards, 1996; Science in the National Curriculum (DfES, 1995).

Most of the definitions for scientific literacy in each document contain features of the definition provided in Project 2061:

> one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognises both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes (AAAS, 1989, pp. ix – x).

Science educators therefore constructed school syllabuses with specific outcomes for student scientific literacy. As an educational goal, scientific literacy was considered as any other educational goal and therefore something achievable by all students at the end of instruction (Koballa et al., 1997).

This view was challenged by Shamos in: *The Myth of Scientific Literacy* (Shamos, 1995). Shamos' criticism was based on the broad definition of scientific literacy found in the standard documents; a definition written by so many people it contains *virtually* *all of the objectives of science education that have been identified over the years* (Laugksch, 2000, p.590) and open to interpretation, assumption and differing perspectives on how to achieve it (Champagne & Lovitts, 1989; Hodson, 2002). Bybee (1997) even criticised the selective interpretation of the US National Science Education which Laugksch (2000) explained as a consequence of the different interest groups across the spectrum of education.

Shamos proposed three forms of scientific literacy: cultural, functional and true. Cultural scientific literacy is the simplest form held by most educated adults with a general level of science knowledge; functional scientific literacy requires a command of science vocabulary allowing conversation and coherent literacy (read and write) level in science topics; and the final form, true scientific literacy, the most difficult to attain as the individual must know something about the scientific enterprise (Laugksch, 2000), including the nature and history of science. Shamos believes that it is a waste of (educational) resources and naïve to think that students can achieve a "true" form of scientific literacy, and at best can be said to have attained a "functional" level (DeBoer, 2000; Laugksch, 2000).

Rather than scientific literacy, Shamos proposes that school educators should aim for scientific awareness (Bybee, 1997), where science content is used to exemplify the nature of science and technological aspects of science concept usage rather than trying to grasp the abstractions of science (DeBoer, 2000). Examples of earlier curriculum reform documents that used an alternative to 'literacy' include those developed by the Scottish Curriculum Council who used the term 'scientific capability' (SCC, 1996) which included scientific curiosity, understanding, creativity, competence and sensitivity and in Australia, the Victorian P – 10 Curriculum and Standards (Science) where 'scientific capability' was described as:

> Building students' science capability is critical to help them develop the skills and understanding necessary to meet these challenges and make responsible, informed choices (VCAA, 1995).

How this view of scientific literacy as *'scientific awareness'* fits in with international testing such as TIMMS and PISA remains to be seen although the definition of scientific literacy given for analysis of questions in the most PISA provides some clue:

> 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, 2003, p.133).

This definition has been adopted by the Australian National Assessment Program for assessing scientific literacy levels of Year 6 students and at least contains elements of the t of the nature of science.

Whether curriculum writers design syllabuses for teachers to develop in their students a scientific awareness (Shamos, 1995), a scientific capability (SCC, 1996), a scientific "image" (Eisenhart, Finkel & Marion, 1996, p.282) or to 'enhance' scientific literacy (Millar & Osborne, 1998), the term 'scientific literacy for all learners' expresses the major goal of science education (Bybee, 1997). Since the compulsory years of school science education in most developed countries span the elementary and lower secondary years, a number of researchers have devised frameworks or dimensions of scientific literacy to show what may be expected of students within a continuum of educational experience.

Bybee developed a framework for scientific literacy that he describes as a *constellation of knowledge, ability, skill, and understanding referred to as scientific literacy* (Bybee, 1997, p.119). He draws on the US Benchmarks (1993) and Standards (1996) documents to construct a framework that describes dimensions of scientific literacy that include: *scientific illiteracy, nominal literacy, functional scientific and technological literacy, conceptual and procedural literacy* (Bybee, 1997, pp.119-121). Although he warns that these dimensions are not to be interpreted as developmental stages, he states that scientific literacy is best defined as a *continuum of understanding about the natural and the designed world, from nominal to functional, conceptual and procedural, and multidimensional* (Bybee, 1997, p.86).

A number of Bybee's dimensions reflect Shamos' (1995) forms of scientific literacy and both have been compared by Koballa and colleagues to "levels" of scientific literacy (Koballa et al., 1997). These levels, listed as I to VII, are aligned by the authors as follows:

- Level I scientific illiteracy
- Levels II and III – Bybee's nominal and functional levels – Shamos' cultural,
- Levels IV and V – Bybee's conceptual and procedural – some aspects of Shamos' true
- Level VI and VII – Bybee's multidimensional – Shamos' true

Koballa and colleagues' levels VI and VII, Bybee's multidimensional and Shamos' true form incorporate an understanding of science beyond the concepts and procedures to include that history and nature of science (Bybee, 1997) and a comprehension of the influence of human culture on science and science's influence on human culture (Koballa et.al., 1997) and the scientific enterprise (Shamos, 1995).

Although the authors point out that Shamos would contest whether students can achieve beyond Levels II and III, they contend that it is realistic to expect K – 12 teachers to help most students move beyond the minimum levels of scientific literacy and not simply teach vocabulary and isolated facts (Koballa et.al., 1997). Assisting teachers in moving students to higher 'dimensions', 'levels' or 'forms' would be much more successful if the: *burden of requiring all students to achieve mastery of a specific body of content was removed* (DeBoer, 2000, p.598); a position held ten years earlier in Project 2061:

> Our fundamental premise is that the schools do not need to be asked to teach more and more content, but rather to focus on what is essential to scientific literacy and to teach it more effectively (AAAS, 1989, p ix).

The problem for curriculum writers and classroom teachers is the range of conceptions of scientific literacy in the science education literature identified by Norris and Phillips (2003), presented in Millar (2006):

Table 2.3:

Conceptions of "scientific literacy" in the science education literature

Understanding of basic scientific ideas
Understanding science and its applications
Knowledge of what counts as science; the ability to distinguish science from non-science
Ability and wish to be an independent, lifelong science learner
Ability to use scientific knowledge in problem-solving
Knowledge needed for intelligent participation in science-based social issues
Understanding of the nature of science
Appreciation of, and comfort with, science including a sense of wonder and curiosity
Knowledge of the risks and benefits of science
Ability to think critically about science and to deal with scientific expertise

(from Norris & Phillips, 2003 in Millar, 2006, p. 1502)

This list is not exhaustive but it is evident that defining scientific literacy is a complex task (Boujaoude, 2002). DeBoer recommends that *we should accept the fact that scientific literacy is simply synonymous with the public's understanding of science and that this is necessarily a broad concept* (DeBoer, 2000, p.594). Moreno (1999) states that the reform documents provide guidelines for what students should know and be able to do as they progress through the grades K -12. The guidelines emphasise the importance of helping students develop a base of knowledge and skills that will continue to grow throughout their lifetime. In other words, scientific literacy is a lifetime pursuit (Koballa et. al., 1997). Teachers will need to realise that where science literacy is a goal in the classroom, teaching should take its time (Nelson, 1999) and that less-is-more (Moreno, 1999). As DeBoer warns: *we need to realise we cannot do everything* (DeBoer, 2000, p.594).

What then is the contribution that science in elementary classrooms can make to the attainment of scientific literacy in students? Harlen and Qualter attempted to answer this question by stressing that the focus for elementary science teaching should be on developing the simple foundations needed for advanced thinking:

> We teach the parts, not just because they are interesting in themselves, but in order for all children to develop an overall understanding that helps them to make sense of new phenomena and events. Having this overview is what is known as scientific literacy (Harlen & Qualter, 2004, p.61).

2.6 Teacher understanding of the nature of science as an indicator of their scientific literacy

Science educators would advocate that an understanding of the NOS and its processes, as well as the content of science, is a key element to achieving scientific literacy (Moss & Abrams. 2001; Tytler, 2007). To be able to convey to their students adequate NOS conceptions, teachers should themselves possess informed conceptions of the scientific enterprise (Abd-El-Khalick & Lederman 2000, Matthews, 2000). Studies have concluded that irrespective of their academic background, science teachers possess limited knowledge of the history and philosophy of science (Gallagher, 1991; King, 1991) and as a consequence, hold inadequate or naive conceptions of the nature of science (Abd-El-Khalick & BouJaoude, 1997 in van Driel et.al. 1998). To teach NOS a teacher must have not only a firm understanding of NOS but also knowledge of effective pedagogical practices relative to NOS and the intentions and abilities to merge these two elements in the classroom (Schwartz & Lederman 2002). Enhancing these qualities should be planned for instead of being anticipated as a side effect or secondary product of science content (Akindehin, 1988 in Abd-El-Khalick & Lederman, 2000).

McComas and Olsen's (1998) analysis of nature of science studies in science education standards documents in the USA, Canada, England, New Zealand and Australia demonstrated a consensus regarding the nature of science issues that should inform science education. Criticism by Alters (1997) that no singular consensual view exists and the "science wars" debate[13] that occupied the decade leading up to McComas and Olson's analysis, led Monk and Osborne to be critical of the dichotomy that they saw existing between the historians and philosophers of science and classroom teachers:

> As long as the two communities maintain their mutual distance, this important aspect of science education will remain marooned in a sea of good intentions (Monk & Osborne, 1997, p.408).

Matthews (1998) called for "modest goals" when teaching about the nature of science in an attempt to encourage teachers who have limited background knowledge and professional experience with elements of the philosophy of science to incorporate NOS studies in their classrooms. Citing Robinson's (1968) call for agreement with an extensive list of 85 logical-empiricist positions about science, Matthews contends it would have wiser to aim for being interested in the proposition. McComas, Almazoroa, and Clough (1998) and Smith and Sharmann (1999), like Matthews, support a limited approach to NOS studies in the classroom: *we are making recommendations for K – 12 science students and teachers – not philosophers of science* (McComas et al., 1998, p.512).

[13] See Hodson, 1988; Smith, Bell, Lederman, McComas & Clough, 1997.

But Smith and Sharmann warn, as did Matthews, about improving teachers' understanding of these limited, yet key elements, to avoid "evangelism" (Smith & Sharmann, 1999) or as Matthews points out, having teachers instruct students in *believing what I believe about epistemology* (Matthews, 1998, p.167). Rudolph (2000) however was critical of formulating a general, lower-level set of statements from all the competing NOS views to provide consensus for science educators. He warned that simplification may lead to NOS studies not being integrated into the curriculum and only existing as a stand-alone topic.

By 1998, Abd-El-Khalick, Bell and Lederman proposed that disagreements about what form of the nature of science should be taught were irrelevant to K –12 science instruction and there was now: *an acceptable level of generality regarding the NOS that is acceptable to K – 12 students and also relevant to their daily lives* (Abd-El-Khalick et al., 1998, p.418). These general aspects of NOS, also identified by Schwartz and Lederman (2002) were listed as:

- Science knowledge is *tentative*
- Scientific knowledge has a basis in *empirical evidence*
- Observations and interpretations are based on current scientific perspectives (*subjective* or *theory-laden)* as well as *personal subjectivity*
- Scientific knowledge is the product of human *imagination* and *creativity*
- Scientific investigations are influenced by the society and culture in which they are conducted (*sociocultural embeddedness)*
- There are differences between *observation* and *inference*
- There are differences between *theories* and *laws*

These aspects in various forms and description had found their way into a number of national science standards documents as identified by McComas and Olson (1998).

Osborne and colleagues' study (2003) of the expert science community then sought to establish whether the picture of science represented in the school science curriculum was sufficiently comprehensive and whether the balance in the curriculum between teaching about the content of science and the nature of science was appropriate. The expert community consisted of leading and acknowledged international experts of science educators; scientists; historians, philosophers; and sociologists of science; experts engaged in work to improve the public understanding of science; and expert science teachers.

The nine themes that emerged from the study had many similarities with the results of McComas and Olson's 1998 study, leading these researchers to contend that *the nature of science can no longer be marginalised on the basis that there is little academic consensus about what should be taught* (Osborne et al., 1998, p.714). This consensus about the contested nature of science is due to the agreed NOS elements being a 'vulgarised account' but at least can provide for teachers and students *a basic understanding of the processes and practices of science and of the nature of the knowledge that these produce* (Osborne et al., 1998, p.716). However, even if presented to teachers in curriculum documents as a basic set of themes, *they represent a challenge for traditional science teaching, which tends to come from a restricted perspective on learning* (Tytler, 2007, p.25).

2. 7 Scientific literacy in an Australian context

In an Australian setting, curriculum changes impacting on elementary science and its outcomes in scientific literacy began with the 1989 Hobart Declaration on Schooling providing a framework to assist schools and school systems to develop specific objectives and strategies, particularly in the areas of curriculum and assessment based on common and agreed national goals. Goals specific to science referred to developing student skills in analysis and problem-solving and an understanding of the role of science and technology in society, together with scientific and technological skills.[14] The Hobart Declaration was superseded by both the 1999 Adelaide Declaration and the 2008 Melbourne Declaration, by which time science had become one of eight key learning areas with a national statement and profile (Curriculum Corporation, 1994). Principal among the national statement (Curriculum Corporation, 1994a) and profile (Curriculum Corporation, 1994b) was the rationale for school science based on scientific literacy for all students (Goodrum et al., 2001). The focus was shifted from content acquisition to broader conceptual understanding coupled with development in processes, skills and attitudes:

> Every Australian primary school classroom needs science……..which ensures students entering secondary school have an appreciation of scientific thinking (PMSEIC, 2003, p.12).

The majority Australian states and territories responded to the national statement by reviewing and rewriting their science curriculum with the addition of scientific literacy

[14] Downloaded from: http://www.mceetya.edu.au/mceecdya/hobart_declaration,11577.html.

in the corresponding rationales and/or aims. The table (Table 2.4) below summarises the analysis of the aims and rationale for each state and territory curriculum for the intended curriculum in relation to scientific literacy which Posner (2004) describes as the ‘purpose’ of the curriculum:

Table 2.4:

Scientific literacy in Aims and Rationale of Australian State and Territory Science Curriculum document

State/Territory	Name of Document	Scientific Literacy
Australian Capital Territory (ACT)	Science Curriculum Framework (1993)	*Criteria for Selection of Content:* “Before any decisions are made about content, teachers should also carefully consider the teaching strategies and desired outcomes of their science programs and, with their students, choose the content most likely to enable achievement of the outcomes. It is essential that the content of the science course will: • develop scientific literacy and numeracy “(p.46)
New South Wales (NSW)	Science and Technology K - 6 Syllabus and Support Document (1991)	No mention in rationale or aims
Northern Territory	Northern Territory Curriculum Framework	In the introduction to the *Science Learning Area:* “The Science Learning Area is designed to develop scientific literacy that places a high priority on helping all citizens to be interested in and to understand the world around them.”
Queensland	Key Learning Area Syllabus Years 1 - 10	In the Rationale under the subheading: *Reflective and Self-Directed Learner:* “Learners consider their own learning styles, strengths and limitations as they evaluate and manage their own thinking and monitor their progress in developing scientific literacy.”
South Australia	South Australian Curriculum Standards and Accountability Framework Science Early Years and Primary Years Band 3,4 and 5 (2001)	In the Introduction to the Primary Years Band 3, 4 and 5 “Science education contributes to developing scientifically literate global citizens who will better be able to make informed decisions about their personal lives and how environments can be sustained.”

Table Continues

State/Territory	Name of Document	Scientific Literacy
Tasmania	The Essential Learnings and the Science Learning Area	Under the heading: *Why is Science Learning Important?* "The purpose of science education is to develop scientific literacy which is a high priority for all citizens......"
State/Territory	Name of Document	Scientific Literacy
Tasmania	The Essential Learnings and the Science Learning Area	Under the heading: *Why is Science Learning Important?* "The purpose of science education is to develop scientific literacy which is a high priority for all citizens......"
Victoria	Victorian Essential Learning Standards P -10 Curriculum and Standards Science	In the Introduction to the *Discipline Based Learning Strand:* "Building students' science capability is critical to help them develop the skills and understanding necessary to meet these challenges and make responsible, informed choices."
Western Australia	Curriculum Framework Curriculum Guide Science 2005	No mention in rationale or aims

Australian elementary school teachers over the last two decades have been required to incorporate syllabus statements into classroom practice. These statements are developed by the relevant state and territory curriculum specialists based on each state and territory's curriculum reform documents. In relation to the purpose or perspective of the curriculum, a review of the Australian state and territory K – 6 curriculum documents was conducted by the researcher to identify explicit and/or implicit attention to aspects of scientific literacy and subsequently which aspects of the nature of science are included to support its development.

These identifiable aspects of scientific literacy chosen for identification were:

Nature of science with reference to:

- Science as a way of knowing

- Science as a human endeavour
- History of science
- Applications of science
- Societal impacts of scientific endeavour
- Relationship between science and technology
- Relationship between science and the environment

Explicit attention was considered as the use of specific scientific literacy phrases and/or terminology, where implicit attention was considered as an aspect of scientific literacy being inferred from generic phrases and/or terminology. Only those curriculum sections describing K – 6 science statements were reviewed for such phrases and/or terminology.

Table 2.5:

Aspects of Scientific Literacy in Australian Elementary Curriculum Documents

State/Territory	NOS A Way of Knowing	NOS A Human Endeavour	History of Science	Applications of Science	Societal Impacts	Science and Technology	Science and Environment
ACT	Explicit	Explicit	Implicit	Explicit	Explicit	Explicit	Explicit
NSW	Limited	Limited	Limited	Explicit	Explicit	Explicit	Explicit
Northern Territory	Implicit	Implicit	Limited	Explicit	Implicit	Implicit	Explicit
Queensland	Implicit	Implicit	Explicit	Explicit	Explicit	Explicit	Explicit
South Australia	Explicit	Explicit	Explicit	Explicit	Explicit	Explicit	Explicit
Tasmania	Implicit	Implicit	Limited	Implicit	Implicit	Implicit	Implicit
Victoria	Explicit	Explicit	Explicit	Explicit	Explicit	Explicit	Explicit
Western Australia	Implicit	Explicit	Implicit	Explicit	Explicit	Explicit	Explicit

The nature of science aspects labelled as *A Way of Knowing* and *A Human Endeavour* (see Table 2.5) include those aspects of the nature of science described in the literature as: science knowledge is tentative, empirically based, subjective (theory-laden), the product of human inference, imagination, and creativity, is socially and culturally embedded (Abd-El-Khalick, Bell & Lederman, 1998), along with the relationship between science and technology (McComas, 2004) and science and the global environment (McComas & Olson, 1998).

Table 2.6 below summarises a review of state and territory documents for nature of science aspects:

Table 2.6:

Aspects of Nature of Science in Australian Primary Curriculum

State/Territory	Tentativeness	Empirically based	Subjective	Creativity, Imagination	Culturally Embedded	Science and Technology	Science and Environment
ACT	Implicit	Explicit	Limited	Explicit	Explicit	Explicit	Explicit
NSW	Limited	Limited	Limited	Implicit	Explicit	Explicit	Explicit
Northern Territory	Implicit	Implicit	Implicit	Explicit	Explicit	Implicit	Explicit
Queensland	Implicit	Implicit	Explicit	Implicit	Explicit	Explicit	Explicit
South Australia	Explicit	Explicit	Explicit	Explicit	Explicit	Explicit	Explicit
Tasmania	Implicit	Implicit	Limited	Implicit	Implicit	Implicit	Implicit
Victoria	Explicit	Explicit	Explicit	Explicit	Explicit	Explicit	Explicit
Western Australia	Implicit	Explicit	Explicit	Explicit	Explicit	Explicit	Explicit

Almost all documents make specific references to an understanding or awareness of how different cultures have attempted to explain phenomena, utilized technology and impacted on the local or global environment. The aspects less well-represented are those for tentativeness, science being empirically based and the subjective nature of theory.

2. 8 Scientific literacy assessment in an Australian context

Having set national goals following the Adelaide Declaration, in July 2001, the Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA, now the Ministerial Council for Education, Early Childhood Development and Youth Affairs, MCEECDYA) agreed to the development of assessment instruments and key performance measures for reporting on student skills, knowledge and understandings in elementary science. It directed the newly established Performance Measurement and Reporting Taskforce (PMRT), a nationally representative body, to undertake the national assessment program (ACARA, 2009).The *National Assessment Program – Science Literacy* was to measure trends over time beginning in 2003 on a three-year cycle. The purpose of the assessment was to assist teachers to gauge their own students' proficiency in scientific literacy (MCEETYA, 2003).

A scientific literacy progress map (Table 2.7) was developed based on the construct of scientific literacy and an analysis of state and territory curriculum and assessment frameworks. The progress map describes the development of scientific literacy across three strands of knowledge which are inclusive of elements of the OECD–PISA 2000 (OECD, 2000) definition for scientific literacy:

1. demonstrating understanding of scientific concepts
2. recognising scientifically investigable questions

3. identifying evidence needed in a scientific investigation

4. drawing or evaluating conclusions

5. communicating valid conclusions.

These elements have been clustered into three more holistic strands:

- Strand A: Formulating or identifying investigable questions and hypotheses, planning investigations and collecting evidence.

- Strand B: Interpreting evidence and drawing conclusions from their own or others' data, critiquing the trustworthiness of evidence and claims made by others,
and communicating findings.

- Strand C: Using science understandings for describing and explaining natural phenomena, and for interpreting reports about phenomena (ACARA, 2009).

The scientific literacy progress map describes progression in six levels from 1 to 6:

Table 2.7:

Scientific Literacy Progress Map

Level	Strands of Scientific Literacy		
	Strand A Formulating or identifying investigable questions and hypotheses, planning investigations and collecting evidence. Process strand: experimental design and data gathering.	Strand B Interpreting evidence and drawing conclus from their own or others' data, critiquing t trustworthiness of evidence and claims m by others, and communicating findings. Process strand: interpreting experimental d	Strand C Using understandings for describing and explaining natural phenomena, and for interpreting reports about phenomena. Conceptual strand: applies conceptual understanding.
6	Uses scientific knowledge to formulate questions, hypotheses and predictions and to identify the variables to be changed, measured and controlled. Trials and modifies techniques to enhance reliability of data collection.	Selects graph type and scales that display the data effectively. Conclusions are consistent with the data, explain the patterns and relationships in terms of scientific concepts and principles, and relate to the question, hypothesis or prediction. Critiques the trustworthiness of reported data (e.g. adequate control of variables, sample or consistency of measurements, assumptions made in formulating the methodology), and consistency between	Explains complex interactions, systems or relationships using several abstract scientific concepts or principles and the relationships between them. SOLO taxonomy: Abstract relational

Table Continues

Level	Strands of Scientific Literacy		
5	Formulates scientific questions or hypotheses for testing and plans experiments in which most variables are controlled. Selects equipment that is appropriate and trials measurement procedure to improve techniques and ensure safety. When provided with an experimental design involving multiple independent variables, can identify the questions being investigated.	Conclusions explain the patterns in the data using science concepts, and are consistent with the data. Makes specific suggestions for improving/extending the existing methodology (e.g. controlling an additional variable, changing an aspect of measurement technique). Interprets/compares data from two or more sources. Critiques reports of investigations noting any major flaw in design orinconsistencies in data.	Explains phenomena, or interprets reports about phenomena, using several abstract scientific concepts. SOLO taxonomy: Abstract multistructural
4	Formulates scientific questions, identifies the variable to be changed, the variable to be measured and in addition identifies at least one variable to be controlled. Uses repeated trials or replicates. Collects and records data involving two or more variables.	Calculates averages from repeat trials or replicates, plots line graphs where appropriate. Interprets data from line graph or bar graph. Conclusions summarise and explain the patterns in the science data. Able to make general suggestions for improving an investigation (e.g. make more measurements).	Explains interactions, processes or effects that have been experienced or reported, in terms of a non-observable property or abstract science concept. SOLO taxonomy: Abstract unistructural
3	Formulates simple scientific questions for testing and makes predictions. Demonstrates awareness of the need for fair testing and appreciates scientific meaning of ‘fair testing’. Identifies variable to be changed and/or measured but does not indicate variables to be controlled. Makes simple standard measurements. Records data as tables, diagrams or descriptions.	Displays data as tables or constructs bar graphs when given the variables for each axis. Identifies and summarises patterns in science data in the form of a rule. Recognises the need for improvement to the method. Applies the rule by extrapolating and predicting.	Describes the relationships between individual events (including cause and effect relationships) that have been experienced or reported. Can generalise and apply the rule by predicting future events. SOLO taxonomy: Concrete relational
2	Given a question in a familiar context, identifies that one variable/factor is to be changed (but does not necessarily use the term ‘variable’ to describe the changed variable). Demonstrates intuitive level of awareness of fair testing. Observes and describes or makes non-standard measurements and limited records of data.	Makes comparisons between objects or events observed. Compares aspects of data in a simple supplied table of results. Can complete simple tables and bar graphs given table column headings or prepared graph axes.	Describes changes to, differences between or properties of objects or events that have been experienced or reported. SOLO taxonomy: Concrete multistructural
1	Responds to the teacher’s questions and suggestions, manipulates materials and observes what happens.	Shares observations; tells, acts out or draws what happened. Focuses on one aspect of the data.	Describes (or recognises) one aspect or property of an individual object or event that has been experienced or reported. SOLO taxonomy: Concrete unistructural

A standard for scientific literacy was established as part of the first cycle of the national assessment in 2003 to provide parents, educators and the community with a clear picture of the level of proficiency that students are expected to demonstrate by the end of Year 6 (ACARA, 2009). Initially, in 2003, three Proficiency Levels, corresponding with Levels 2, 3 and 4 of the Scientific Literacy Progress Map, were identified. However, as 90 per cent of students' scores were within Level 3 in 2003, three further Proficiency Levels within Level 3 were created in 2006 (Table 2.8), providing five levels for reporting student performance in the assessment. The proficiency standard was deemed to be Level 3.2 on the Proficiency Level continuum (MCEETYA, 2006) and is the main reference point for monitoring scientific literacy in Australian primary schools over time (ACARA, 2009).

Table 2.8:

Proficiency Levels in Scientific Literacy Progress Map

Proficiency Level	Assessment Strand Descriptors	Descriptor: a student at this level may display skills like
4 and above	Strand A: Formulates scientific questions, identifies the variable to be changed,the variable to be measured and in addition identifies at least one variable to be controlled. Uses repeated trials or replicates. Collects and records data involving two or more variables. Strand B: Calculates averages from repeat trials or replicates, plots line graphs where appropriate. Interprets data from line graph or bar graph. Conclusions summarise and explain the patterns in the science data. Able to make general suggestions for improving an investigation (e.g. make more measurements). Strand C: Explains interactions, processes or effects that have been experienced or reported, in terms of a non-observable property or abstract science concept.	When provided with an experimental design involving multiple variables can identify the questions being investigated. Conclusions summarise and explain the patterns in the data in the form of a rule and are consistent with the data. Explains interactions that have been observed in terms of an abstract science concept.

Table Continues

Proficiency Level	Assessment Strand Descriptors	Descriptor: a student at this level may display skills like
3.3	Strand A: Formulates simple scientific questions for testing and makes predictions. Demonstrates awareness of the need for fair testing and appreciates scientific meaning of ‘fair testing’. Identifies variable to be changed and/or measured but does not indicate variables to be controlled. Makes simple standard measurements. Records data as tables, diagrams or descriptions. Strand B: Demonstrates awareness of the need for fair testing by keeping a variable controlled when changing a second variable. Records data as tables or constructs bar graphs from collected or given data. Strand C: Describes relationships between individual events (including cause and effect relationships) that have been experienced or reported.	Demonstrates an awareness of the principles of conducting an experiment and controlling variables. Extrapolates from an observed pattern to describe an expected outcome or event. Applies knowledge of relationship to explain reported phenomenon.
3.2	Strand A: Formulates simple scientific questions for testing and makes predictions. Demonstrates awareness of the need for fair testing and appreciates scientific meaning of ‘fair testing’. Identifies variable to be changed and/or measured but does not indicate variables to be controlled. Makes simple standard measurements. Records data as tables, diagrams or descriptions. Strand B: Displays data as tables or constructs bar graphs when given the variables for each axis. Identifies and summarises patterns in science data in the form of a rule. Recognises the need for improvement to the method. Applies the rule by extrapolating and predicting. Strand C: Describes the relationships between individual events (including cause and effect relationships) that have been experienced or reported. Can generalise and apply the rule by predicting future events.	Collates and compares data set of collected information. Gives reason for controlling a single variable. Interprets data and identifies patterns in – and/or the relationships between – elements of the data. Interprets information in a contextualised report by application of relevant science knowledge.

The NAP-Science Literacy has been administered three times at three-year intervals since 2003. Approximately 5 – 6 % (close to 14,000 students) of Australian students in year 6 of elementary schooling has participated in each assessment. Cut-off points denoting the boundaries between Proficiency Levels were established in 2003 as shown below:

Figure 2.4: Cut-off points for Proficiency Levels

(ACARA, 2009, p.32)

A score of 653 or more locates students in Proficiency Level 4 and above. Similarly, scores in the range of 262 to 653 relate to Proficiency Level 3 on the assessment framework.

Given that the final Scientific Literacy Scale was developed from the 2006 assessment, it is possible to develop an overview of trends since 2003 if adjustments were made to the 2003 results based on the later developed scale (ACARA, 2009):

Figure 2.5:

Trends in mean scores in scientific literacy in 2003, 2006, 2009

AUST	Mean Score
2003	409
2006	400
2009	392

(ACARA, 2009, p.30)

Across the three assessments conducted so far, the percentage of students who were proficient at Level 3.2 and above were:

Figure 2.6:

Percentage of students proficient above Level 3.2

2003	2006	2009
59%	54%	52%

There is no statistical difference between these means and percentages as the test utilised in 2006 and subsequently used as a template in 2009 contained more discriminatory items than those in 2003 and there was more comprehensive sampling conducted in 2006, 2009 (MCEETYA, 2006; ACARA, 2009).

2.9 Improving teachers' conceptions of NOS and incorporation of NOS into classroom practice.

Early curriculum programs were based on an implicit approach to improve students' understanding of NOS and failed to develop desired NOS understandings[15]. Hodson (1988) lists some early major curriculum projects that attempted to shift the emphasis away from science as a body of knowledge towards science as a human activity involving processes and procedures. Such programs included Physical Science Study Curriculum (PSSC) physics course, Harvard Physics Program, Biological Sciences Curriculum Study (BSCS), Chemical Bond Approach (CBA), CHEM Study, (all USA), Schools Council Integrated Science Project (SCISP) and Nuffield courses (UK) and the Australian Science Education Project (ASEP) (Australia). The assumption was that when given the curricula, the appropriate materials, and when shown how to use them, teachers would be successful in helping students develop conceptual understandings of NOS (Lederman, 1992).

Hodson argues that one reason for the failure of such curriculum was the teachers' inadequate views about the nature of science and that attitudes and concerns with the nature of science are left to chance. Lederman's 1992 review of the nature of science literature led to his contention that development of science curriculum lacked focus on the importance of the teacher as a variable in its effectiveness in improving students' understanding of the NOS. It was assumed that a teacher's classroom behaviour and

[15] See Duschl, 1990; Hodson, 1988; Ryan & Aikenhead, 1992.

classroom environment are influenced by the teacher's conception of NOS (Lederman, 1992).

Lederman points to confusing research findings on the influence of teacher's conceptions of NOS on their classroom practice with some research supporting a direct influence (Brickhouse, 1990; Gallagher, 1991) as well as the position that there is no influence (Duschl & Wright, 1989; Lederman & Zeidler, 1987). Lederman concluded that improved NOS understanding does not necessarily translate into effective classroom practice and is mediated by a complex set of factors.

Lakin and Wellington conducted a study of 11 science teachers with at least ten years teaching experience with ten to sixteen year-olds finding several areas of conflict confronting teachers of science when attempting to incorporate NOS:

- environmental demands ie the school curriculum, subject supervisors, assessment, pupils
- science schemes that emphasise process
- the concern of whether it will work in the classroom

As well, teachers' lack of knowledge about the nature and history of science emerged strongly in the study during teacher-researcher discussion as did the teachers' lack of confidence with their ability to cope with suggested strategies for nature of science instruction like small group work, reading for learning and discussion (Lakin & Wellington, 1994).

A study of the classroom practices of five teachers (experienced and beginning) who held views consistent with the reforms in the science education documents was conducted by Lederman (1999). Each teacher already had a close working relationship with the researcher and had been selected for the study. The study, whilst showing clear differences between the classroom practices of the experienced teachers when compared to the beginning teachers, also revealed that the nature of science was not an instructional objective or specified as a goal. This finding is consistent with prior research[16] indicating that teachers rarely consider the nature of science when planning for instruction or making instructional decisions.

Whilst understandable that the beginning teachers, still struggling with overall organisational plans for their lessons, were frustrated with the discrepancy between intentions and practice, and the experienced teacher with the highest academic level (PhD) was more concerned with her students getting the foundational knowledge correct, even the other two remaining experienced teachers who did teach in a manner consistent with their own NOS views, did not report that it was an intentional outcome (Lederman, 1999).

Although previous research has proposed that the curriculum may be a limiting factor in teaching NOS, the teachers in this study were free to follow a curriculum emphasis of their own choosing. The teachers had not deliberately incorporated instructional strategies and although the teachers' practices were modelling aspects of NOS, the overwhelming majority of the students interviewed across all five teachers' did not exhibit an understanding of NOS consistent with current reforms (Lederman, 1999). Lederman then suggests that inservice and preservice programs should focus on the internalisation of the view that the nature of science is an important instructional

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[16] See Abd-El-Khalick et al., 1998; Duschl & Wright, 1989; Gess-Newsome & Lederman, 1993; Lederman, Gess-Newsome & Latz, 1994.

objective that should be considered during the development and implementation of every instructional unit, lesson and activity (Lederman, 1999).

Monk and Osborne describe a pedagogic model for NOS instruction with the incorporation of historical contexts. As the learning of science is the *foremost concern of teachers* (Monk & Osborne,1997, p.412), the authors believe that placing the study of the nature of science in some historical context where appropriate allow students (teachers) to see how others have held similar ideas to them at the time of their investigations. Or as Matthews states *appreciate where great minds had difficulty attunes a teacher (and the child) to where lesser minds also have difficulty* (Matthews, 1989 in Monk & Osborne, 1997, p.413). Therefore the lessons utilised in this study used Galileo's investigation of the pendulum to place the NOS aspects in an historical context for the elementary teachers and students.

A key teaching strategy in Monk and Osborne's model is the explicit attention given to aligning student's conceptions of the concept under investigation with class discussion on how the concept was viewed historically. The authors propose that there is a concern that students following a set methodological/experimental approach will not be exposed to questions of "how we know" rather than "what we know". A common mistake is the portrayal of science concepts as *inevitable, rocklike formations that have existed for all time* (Monk & Osborne, 1997, p.410) underpinned by a methodological approach that has lost sight of what Duschl (1994) called the "final form". Monk and Osborne hold the view that teachers are reluctant to consider topics that expose their own knowledge and understanding weaknesses and are reluctant to handle unfamiliar material that threatens their sense of self-confidence. Instituting such an explicit historical approach in the curriculum requires professional development of teachers (Monk & Osborne, 1997).

Nott and Wellington's (1998) describe a professional development approach utilising critical incidents (CI) that may arise in their classrooms. A critical incident is an event which makes *a teacher decides on a course of action which involves some kind of explanation of the scientific enterprise* (Nott & Wellington, 1998, p.581). The incidents do not have to be a deliberate intervention by the teacher and usually arise from the types of questions students ask during classroom activities. The professional development strategy required teachers to express views about science but in the context of their practices in the classroom. Their knowledge of the nature of science is illustrated by discussing and analysing examples from their classroom experiences. The use of critical incidents arising from familiar classroom experiences, according to the authors, creates and confronts teachers' knowledge about the nature of science (Nott & Wellington, 1998).

Critical incidents interrupt the normal flow of the lesson and it is in the discussion with other teachers in a professional development setting that teachers sharpen their awareness of their own understanding of science and make them aware of the possibilities in everyday teaching to teach about the nature of science (Nott & Wellington, 1998.) As such, the authors conclude that professional development in this area cannot rely on transmission models which assume that if we 'fill teachers up' with correct views about the nature of science they will then transmit them to their pupils: *teachers' understandings of the nature of science are rooted as much in their practice as in their formal education* (Nott &Wellington, 1998, p.592).

Schwartz and Lederman examined the knowledge, intentions, and instructional practices of two beginning science teachers as they learned the subject matter of NOS and attempted to teach NOS during their student teaching experience and during their first year of full-time teaching. An explicit/reflective approach was taken in this study involving *purposeful instruction of NOS through discussion, guided reflection, and specific questioning in the context of classroom science activities* (Schwartz & Lederman, 2002, p.207). As part of the reflective process, debrief sessions were held with the two secondary teachers in which they could elaborate on the development of their NOS conceptions and the pedagogical issues that teaching NOS raised in their classroom. These reflections were mainly concerned with personal reflections about teaching NOS.

Similar to Lederman's earlier study (1999), the two teachers had few curriculum constraints in incorporating NOS into classroom practice. The authors point out that many researchers intuitively believe that curriculum restraints are responsible for lack of attention to NOS but even when given flexibility with curriculum *it does not necessarily follow that NOS instruction will occur* (Schwartz & Lederman, 2002, p.209). The study had the following features:

- The teachers were engaged in activities delivered by the researchers to teach about aspects of NOS
- All the activities were followed by extensive debriefing sessions/discussions
- The teachers participated in a science research internship accompanied by explicit NOS instruction and guided reflective journal writing
- They were issued with resource packages and guidelines for implementing NOS activities in their classrooms

- They were encouraged to include specific objectives for NOS and assessment of NOS in their lesson plans
- The teachers then taught classes of their own in a practicum setting

Although the authors contend that the results of this explicit/reflective approach produced two overall success stories these two teachers exhibited contrasting degrees of NOS inclusion into their classroom practices and translation of NOS aspects into lessons other than those specifically designed for NOS study by their classroom students. The authors point out that the teachers had firm intentions to teach NOS aspects but were limited in the end by their subject knowledge, depth of understanding of NOS and lack of pedagogical experience.

A key finding by the authors is that for effective NOS teaching to occur, a teacher requires the pedagogical content knowledge (PCK) for NOS where the three factors of NOS knowledge, pedagogy and science subject matter knowledge intertwine: *subject matter alone, NOS knowledge alone, or pedagogical knowledge alone will not suffice* (Schwartz & Lederman, 2002, p.232). The following conclusions are drawn from this study by the authors:

- Effective NOS instruction sees NOS woven into other science subject matter
- The frequency of teachers' inclusion of NOS into classroom instruction can be improved with strong subject-matter knowledge and strong knowledge of NOS
- A teacher's PCK is a connection of NOS pedagogy, knowledge of NOS and knowledge of science subject matter
- Simply providing teachers with a packet of activities will not suffice to enhance their PCK for nature of science.

Clough (1998) points out that assisting teacher with “keeping the heat on” students misconceptions concerning the nature of science can be achieved:

> through encouraging teachers to reflect on their classroom language when describing science, reflection on their classroom practices and modifying existing materials and activities so they more accurately portray the nature of science (Clough, ,in McComas, 1998, p.205).

Meaningful professional development relative to NOS instruction should empower teachers to develop and revise their own existing teaching materials and activities. It is the pedagogical practices in utilising those activities that is more important than the activities themselves (Clough, 1998).

Barthlomew and colleagues (2004) conducted a study with a volunteer group of 11 UK teachers over a period of a year to teach aspects of the nature of science, its process, and its practices. The teachers were from elementary to secondary school level. Their teaching resources were a set of “ideas-about-science” that were generated from the Delphi study (Osborne et al., 2003) previously described in this literature review:

- Science methods and critical testing
- Scientific and certainty
- Diversity of scientific thinking
- Hypothesis and prediction
- Historical development of scientific knowledge
- Creativity

- Science and questioning

During the first 3 months of the program, four initial one-day meetings were held where the teachers could explore, plan, and develop materials for the explicit teaching of the themes emerging from the delphi study, explore the pedagogical implications, examine the teachers' own understanding of the nature of science and to consider methods of evaluating the learning outcomes for pupils.

No modelling of NOS teaching practices was carried out by the researchers in situ of the teachers' own classroom but the researchers attempted to model good practice through the use of previously developed instructional materials that teachers could incorporate into classroom lessons.

After observations and analysis of videos of the teachers' classroom practices, Barthlomew and colleagues describe two differing approaches to the incorporation of "ideas-about–science' evident in teacher practice. The 'worst' was where a knowledge and understanding of processes were developed "distinctive" and "separate"; for the best, *process and content were integrated in relevant contexts* (Bartholomew et al., 2004, p.675). They found that teachers that exhibited best practice demonstrated common pedagogical features of discourse and classroom activities that engendered open discussions with and between the students on science concepts. Classrooms that did not exhibit such an environment were more common among those teachers that felt they lacked the necessary experience to do so.

Bartholomew and colleagues' findings, whilst not specifically mentioning PCK, lend weight to the Schwartz and Lederman (2002) contention that effective PCK for NOS is a desired teacher quality for successful inclusion of NOS aspects in the classroom. The authors propose five dimensions for teaching students "ideas-about-science":

- Teachers' knowledge and understanding of the NOS
- Teachers' conceptions of their own role
- Teachers' use of discourse
- Teachers' conceptions of learning goals
- The nature of classroom activities

The authors stress the importance of *reflexive epistemic dialogue* (Bartholomew et al., 2004, p.678), which Schartz and Lederman would see as a pedagogical approach that could be specific to improved student NOS understanding. Improving NOS PCK is an outcome of an increased knowledge of NOS and/or "ideas-about-science" occurring when teachers assimilate these ideas and aspects into classroom practice using authentic learning tasks within an appropriate context.

Bartholomew and colleagues seem to be treating PCK, NOS and "ideas-about-science" as disparate entities; Schwartz and Lederman's model (2002) have them intertwined. Schwartz and Lederman introduce the importance of self-efficacy to the NOS picture and note that this is as yet an unexplored dimension in the teaching of NOS:

> A teacher's self-efficacy and outcome expectancy have been correlated to classroom practice and as such, further exploration into connections between teacher beliefs about

> NOS teaching and instructional approach, as well as exploring methods to improve teachers' beliefs regarding NOS, are important areas for research (Schwartz & Lederman., 2002, p.233).

2.10 Professional development

The most traditional form of PD is the typical 'inservice staff training', consisting of workshops and seminars, and has been criticized as *a 'one-shot' experience completely unrelated to the needs of teachers and providing no follow-up* (Villegas-Reimers, 2003, p.93). Teachers have ranked inservice training as the least effective way to learn to teach (Supovitz & Turner, 2000). There have been calls for more intensive, more collegial and longer approaches to professional development (Garet et al, 2001; Shapiro, 2006).

High-quality PD strategies in science must immerse participants in inquiry, question and experimentation. It must model inquiry forms of teaching and focus on subject-matter knowledge and deepen teachers' content skills (Supovitz & Turner, 2000). It must also involve teachers reflecting on their practices (Henriques, 1998; Shapiro, 2006). Adoption of new practices would come about as teachers reflected and systematically tested "what works" in their own context (Richardson & Anders, 1994 in Smith et al, 2003). In a National Centre for the Study of Adult Learning and Literacy (NSCALL) report (2003), Smith and colleagues concluded from a review of teacher professional development literature that:

> the difficulties of trying to meet all these demands through one-shot, traditional professional development such as workshops prompted professional development

> experts to recommend “alternative” or “reform” types of professional development (Smith et al., 2003, p.7).

Some attempts have been made to provide elementary teachers with professional development inclusive of features of a reform-style program. Wang (2001) conducted an inservice program with 10 elementary teachers that included workshops on NOS, observation of demonstration lessons and classroom visitations. The program was conducted over a period of one year. All but one of the participating elementary had a science major in their undergraduate degree. The teachers were required to develop NOS classroom activities based on instruction during the NOS courses conducted at a university. Modelling of NOS teaching strategies were principally limited to strategies presented at these courses with no demonstration lessons in the context of the teacher’s own classroom.

Wang found that the teachers claimed to have gained a better understanding of teaching about NOS although they were not able to address elements of NOS explicitly in their teaching. One reason noted for the failure of the intervention was the lack of proper examples of translating specific aspects of NOS into explicit instructional practices. Wang concluded that teachers need more examples of how views of NOS can be translated into explicit classroom instruction.

A major professional development program linking science with broader literacy, *Primary Connections,* was initiated in Australian elementary schools in 2005 (Australian Academy of Science, 2005). The template for the program was based on elements of two earlier studies conducted in Australian schools (Goodrum et al., 2003; Tytler, 2002; Tytler; 2003). These elements comprised professional learning workshops, exemplary curriculum resources, reflections on practice and identified components of successful implementation of science in classroom instruction (Hackling et al., 2007). The final professional development teaching and learning approach adopted was based on the 5Es learning cycle: Engage, Explore, Explain, Elaborate and Evaluate. The choice of the 5Es learning cycle supports Tytler and colleagues contention that large-scale change initiatives in teacher professional development *frame their efforts in terms of a clear vision of how teachers should operate in the classroom* (Tytler et al., 2004, p.172).

The *Primary Connections* 5Es approach included a number of targeted NOS aspects including fair-testing, hypothesising, use of models and working scientifically, which could be explored within one or more of each of the 5E stages. Teachers were given examples of strategies and investigations they could incorporate into their classrooms allowing students to practice and develop the processes and skills for working scientifically (Hackling et al., 2007) and increase their understanding of nature of science aspects.

A research report on 3000 teacher statements who trialled *Primary Connections* units between 2005 and 2012 concluded that teacher confidence was positively impacted through participation in this reform-style PD program (Skamp, 2012). This conclusion was drawn from teachers' feedback about implementing Primary Connections units. The interpretation of the teachers' statements by the research report author proposes that an understanding of the learning cycle (5E), *could suggest that their 'personal science teaching efficacy' may have increased* (Skamp, 2012, p.11). No further statistical analysis of teacher self-efficacy for knowledge or teaching of science is given in the report but earlier STEBI results from the first trial did show an increase in mean self-efficacy score (Hackling, 2007).

Although NOS aspects were specifically included in the model units trialled by the teachers, no analysis is reported on teachers' NOS views. Findings on the teaching strategies employed and teacher observation on student engagement with NOS aspects indicate mixed responses from teachers as to their approach to incorporating NOS into classroom practice:

> When there was a greater focus on NOS outcomes, then this may not have been recognised by some teachers, and where recognised, students often required additional scaffolding because the 'science' was different to what they may expect (Skamp, 2012, p. 213).

And:

> the development of meaningful process understandings and understandings about the NOS were less common (Skamp, 2012, p.221).

The report makes the recommendations that for *Primary Connections* to be implemented more effectively, further professional learning and support materials will be required for teachers to utilise NOS aspects explicitly for their students during classroom practice (Skamp, 2012, p.222).

In a project entitled "The Nature of Elementary Science Teaching" (NEST), Posnanski (2010) conducted a two-year inservice program with 22 elementary teachers involving weeklong summer institutes and school night sessions, all held at a local university. Part of the program consisted of modelling of explicit NOS teaching strategies by two mentor elementary teachers. The participants were required to develop action research plans on NOS instruction to take back to their classrooms.

Results of the test instrument (VNOS-C) utilised to determine the impact on the teachers' NOS views indicated an overall positive effect on basic NOS understanding. However, the findings also indicated that the understanding of the different NOS aspects was unequal and incomplete. Most importantly, Posnanski found that:

> although the action research plan implementation may have had an indirect effect on teachers representing their understanding of NOS aspects, the manifestation of their understanding in the classroom may have been generalised, limited and short-lived (Posnanski, 2010, p.605).

Henriques (1998) identified modelling as a one important characteristic of successful teacher development programs. Modelling allows teachers to see a target skill or strategy in practice. Observation of successful teaching by credible peers can also provide a source of self-efficacy information, enabling the teacher to decide whether the teaching task is manageable and if situational and personal resources are adequate, thus influencing the observer's teaching competence (Bandura, 1977, 1986, 1997). Studies[17] suggest that professional development programs are needed where a teacher's beliefs are modified through the use of vicarious experiences in the context of the teacher's classroom.

Model lessons are a significant component of NOS-related professional development. Modelling NOS instruction in elementary teachers' classrooms is supported by research

[17] See Tschannen-Moran, Woolfolk Hoy & Hoy, 1998; Czerniak, Lumpe & Haney, 1999.

on situated cognition (Brown et al., 1989). Contextual learning, in this case observing how to teach particular content in one's own context, is crucial. Simply exploring new content or pedagogy is not enough because teachers often view the target content or strategies as too theoretical and impractical. When teachers experience inquiry lessons emphasizing specific NOS elements taught in their own classrooms—or in a demonstration classroom (Luft & Pizzini, 1998), they might be able to better conceptualize how such lessons work with their students.

The chairman of the 2006 European Conference on Elementary Science and Technology Education in Stockholm opened proceedings with the following statement:

> By some mysterious coincidence it has been commonly assumed all over the world that science, as opposed to classical literacy, is too complicated to be taught in elementary school. One of the most important recent insights is that this is completely false. In fact the absolute contrary seems to be true. Small children have naturally (by evolution) engraved mental skills to explore the material (natural) world. In many countries now recent national curricula include science at elementary school level. However, in most cases teachers and schools are not well prepared and comfortable with this and need support and training in order to succeed (EU: 2006, p.5).

Eshach (2006) takes up the main contention in this statement that science is not too complicated for children in elementary school by offering six justifications for exposing young children to science:

1. Because of their innate curiosity, children eagerly embrace all types of science activities.
2. Development of attitudes toward science starts at the early stages of life. Exposing students to science in environments where they can enjoy science develops positive attitudes towards science.
3. Early exposure to scientific phenomena leads to better understanding of the scientific concepts studied later in a formal way.

4. Though there is no consensus on whether or not small children can think scientifically or whether they are mature enough to understand (abstract) scientific concepts, some research indicates that even younger children show the ability to think scientifically and they are able to think about even complex concepts (Metz, 1995).
5. Science is an efficient means for developing scientific thinking: It is essential to encourage students to develop scientific modes of explanations and modelling (Acher et al. 2007) and to develop the science process skills from the earliest school age.

Many researchers have documented developmental constraints in children's understanding of science concepts and conducting of science activities (Driver et al., 1985). In contrast, however, Metz (1995) has argued that, with the use of strategic scaffolds and carefully chosen activities, even young students could participate in the learning of science deemed previously too difficult for them.

Akerson and colleagues' (2011) results from a study of NOS instruction to children from early years' to third grade demonstrated that even young children can begin developing appropriate conceptions about NOS. They recommend that NOS instruction should begin when science instruction begins and should be explicit in contextual classroom activities.

Pendulum studies and related activities may be examples of such contextual activities and scaffolding opportunities. They are rich in the aspects of the nature of science and have implications in the classroom for increasing students' awareness of the scientific process (Matthews, 2002). The use of the pendulum lessons as a case study or context satisfies what Daehler and Shinohara (2001) list as one essential requirement for use as an effective professional development strategy: it focuses on a little piece of content that is fundamentally important, challenging, and by nature, inherently fraught with complexities and ambiguities.

2.11 Summary

This chapter provided a broad overview of the research on teacher pedagogical content knowledge and teacher views on the nature of science, as well as research and literature relating to self-efficacy. In the following chapter, the methodology is described.

CHAPTER 3

Methodology

3.1 Introduction

In this chapter the rationale for the choice of methodology and methods adopted is described. A methodology defines how one will go about studying any phenomenon and is influenced by the kind of research questions posited (Silverman, 2006). The methodological approach is associated with the philosophical assumptions made by the researcher and include elements of the worldview(s) on which the foundation of the study is based[18]. The research questions posited here from the theoretical framework and literature review, and the techniques used to collect and analyse the data, employed theoretical perspectives from both quantitative and qualitative research worldviews.

These theoretical perspectives include deductive and inductive thinking and have led to the choice of a mixed methods design for this study. An argument is presented here that this research design is most closely aligned to a *pragmatic* worldview that *combines deductive and inductive thinking, as the researcher mixes both quantitative and qualitative data* (Creswell, 2007, p.23). The mixed method design consists of two phases and is presented diagrammatically and the principal theoretical perspective for each phase discussed. Finally, an overview of each phase is given; including descriptions of the alternate professional development programs, lesson plans utilized, case studies and teacher debrief reflections.

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[18] See Creswell, 2007; Creswell & Plano Clark, 2007; Guba & Lincoln, 2005.

3.2 Methodological Rationale

> Many researchers, especially in applied fields, identify their initial content area of interest on the basis of insights they had in their workplace, personal lives or a combination of the two (Teddlie & Tashakkori, 2009, p.116**) .**

As a mixed methods approach has been selected for this study, and contains a qualitative phase of equal importance to the quantitative phase, I will outline in the next few paragraphs the personal insights and experiences I bring to this research. Over two decades of classroom science teaching and being involved in teacher professional development, both as a participant and as a developer and deliverer, I have always been interested in strategies to address some of the key constraints to effective science teaching in high school and elementary classrooms. Included among these constraints are availability and use of teaching resources, new subject matter knowledge and understanding syllabus aims and rationales.

In New South Wales, where this study is situated, secondary school teachers have been implementing and teaching new science syllabuses for both the junior and senior science subjects since 2000. The professional development programs designed for these teachers have focussed on new teaching program design and teaching and learning strategies for implementing key requirements of the new syllabuses. In most part, teaching new subject matter at the junior high stage has not been a primary focus, nor identified by the teachers as a necessary component of the professional development programs. For PD programs designed and delivered for senior high school science teachers, new subject matter knowledge has been an added area of focus. This was an area of the new syllabuses that senior high school teachers would identify in conversation and debriefs after the programs as an area in which they were not as confident as their ability to manage resources, specialist equipment and practical classes for teaching science generally.

Elementary teachers involved in these programs are generalists and were constrained in their teaching of science by many of the areas identified by Rennie et. al (2001). Principal among these were their lack of science subject matter knowledge and awareness of teaching and learning strategies to engage their students in “science” rather than simply “design and make”, which is a core aspect of the current K – 6 science and technology syllabus (NSW K- 6 Science and Technology Syllabus, 1993). Therefore, the professional development programs I designed for elementary teachers have focussed on improving their subject matter knowledge as they became experienced with new teaching and learning strategies. These programs were attempting to address both the elementary teachers’ confidence in their knowledge of science and their teaching of science.

As I revisited and refined the programs for both secondary and elementary, and through my involvement in the International History and Philosophy in Science Teaching (IHPST) group, I came to see the importance of addressing science literacy in future programs. Developing students’ science literacy throughout their elementary and high school science experiences is the continuum across the New South Wales science syllabuses. The literature points to the importance of the early years in developing students’ attitudes to science in high school so I concentrated my professional development activities on elementary teachers’ scientific literacy.

The research question(s) should drive the method(s) used rather than approaching the study from a purely theoretical perspective (Onwuegbuzie & Leech, 2005). The research questions posited in this study generate from those professional development activities and work with elementary teachers in schools. In answering those questions, important decisions were required as to the type of data, how to collect and analyse the data and how to describe examples of teachers' practice resulting from participation in the study.

Key data identified as necessary for investigating the research questions on teacher pedagogical content knowledge were teacher self-efficacy for knowledge of and teaching of science, teacher views on the nature of science and subject matter knowledge. This data collection and analysis was conducted as a first phase of the study and utilised a predominantly quantitative approach. In attempting to illustrate examples of changes to teacher practice resulting from participation in the PD program, case studies were conducted and analysed in Phase 2 of the study. The approach to data collection and analysis was purely qualitative.

Creswell (2007) contends that no single study perfectly fits all the elements of either a qualitative or quantitative study. Regardless of whether a researcher sees themselves as either a constructivist-qualitative or an positivist-quantitative researcher, they should be free to use quantitative measures in qualitative research and qualitative measures in quantitative research (Johnson & Onwuegbuzie, 2004). Gage's (1989) analysis of two decades of education research led him to identify studies that combined both quantitative and qualitative methods as being *more fruitful of insights,* *understandings, predictive power and control resulting in improvements in teaching* (Gage, 1989, p.7).

Positivist-quantitative and constructivist-qualitative stances are examples of paradigms or worldviews. A positivist-quantitative worldview involves deductive analysis where data are analysed according to an existing framework, whereas a constructivist-qualitative worldview involves inductive analysis where one seeks to discover patterns, themes and categories in the data (Patton, 2002). As the research questions in this study will be answered through the combination of these two approaches, I have chosen to conduct this study using a pragmatic worldview.

The bottom line for working in a pragmatic worldview is that research approaches should be mixed in ways that offer the best opportunity for answering important research questions (Johnson & Onwuegbuzie, 2004). The focus is on the outcomes of the research, the importance of the questions[19] and involves multiple methods of data collection techniques. It is pluralistic (Johnson & Onwuegbuzie, 2004) and *oriented towards 'what works' and practice* (Creswell, 2007, p.23).

The following (Table 3.1) is an overview of the basic characteristics of the worldview outlined above:

[19] See Bryman, 2006; Tashakkori & Teddlie, 2003; Teddlie & Tashakkori, 2009.

Table 3.1

Basic Characteristics of World Views mentioned in this Study

Objectivist	Constructionist	Pragmatist
Determinism	Understanding	Consequences of action
Reductionism	Multiple participant meanings	Problem centred
Empirical observation and measurement	Social and historical construction	Pluralistic
Theory verification	Theory generation	Real-world practice oriented

Adapted from Creswell & Plano Clark, 2011, p.40.

Pragmatism is typically associated with mixed methods research (Creswell & Plano Clark, 2011, Morgan, 2007) as it rejects the either-or choices from the positivist-constructivist debate (Teddlie & Tashakkori, 2009) and *attempts to fit together the insights provided by qualitative and quantitative research into a workable solution* (Johnson & Onwuegbuzie, 2004, p.16). In other words it allows flexibility in having the quantitative research phase inform the qualitative research phase and vice versa (Onwuegbuzie & Leech, 2005) and thus inform the planning and implementation of intervention strategies (Black & Ricardo, 1994).

Mixed methods design has become more popular in many disciplines including education (Leech & Onwuegbuzie, 2007). The choice of a mixed methods is based on the research questions generated through the literature review, my own experiences with professional development design and delivery and the pragmatic worldview of combining both positivist and constructivist views on knowledge and its creation in practice. The key outcomes in choosing this approach is to allow the quantitative and qualitative findings to be complimentary (Greene, Carcelli & Graham, 1989), to gain a more complete understanding of the phenomena (Johnson & Onwuegbuzie, 2004) and to illustrate the results from one phase in action in another phase (Bryman, 2006).

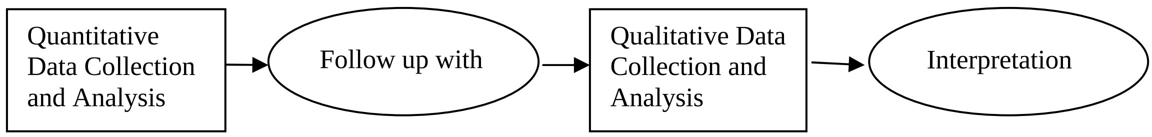
According to Creswell and Plano Clark:

> Mixed methods research is a research design with philosophical assumptions as well as methods of inquiry. As a methodology, it involves philosophical assumptions that guide the direction of the collection and analysis of data and the mixture of qualitative and quantitative data in a single study or series of studies. Its central premise is that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems that either approach alone (Creswell & Plano Clark, 2007, p.5).

Within in this definition, the combination of the quantitative and qualitative approaches has led to various iterations of mixed methods depending on decisions made by the researcher regarding level of mixing (full or partial) of the approaches, the timing of when the different phases are conducted (concurrent or sequential) and the emphasis chosen for each approach (equal status or dominant) (Leech & Onwuegbuzie, 2007). Partial mixing refers to the data from the quantitative and qualitative being mixed (interpreted) only when both the quantitative and qualitative stages have been completed. Sequential refers to one stage following after another has been completed. Emphasis refers to whether one stage has significantly higher priority than does the other stage.

Creswell and Plano Clark (2011) described similar key decisions with an addition of level of interaction (independent or interactive). They propose four basic mixed methods designs; convergent parallel design, explanatory sequential design, exploratory sequential design, and the embedded design. The mixed methods design that most closely aligns with the data collection and analysis in this study is an explanatory sequential design:

Figure 3.1 An explanatory sequential design



An explanatory sequential design starts with the collection and analysis of quantitative data, which has the priority for addressing the study's questions. The first stage is followed by the subsequent collection and analysis of qualitative data. The second, qualitative phase of the study is designed so that it follows from the results of the first, quantitative stage. The researcher interprets how the qualitative results help to explain the results of the initial quantitative results.

Before presenting a diagrammatic representation of the methodological orientation of this study, it should be noted that Phase 1 of the study is predominantly quantitative, using scoring in pre- and post-test of surveys and questionnaires. However, for the survey instrument VNOS-D, combined quantitative and qualitative analysis was conducted. This will described in full in the results chapter. The use of qualitative analysis in Phase 1 does not diminish the basis of the explanatory sequential design. Although typologies of mixed methods design are valuable, they can be creatively manipulated and adapted to address a particular study's questions and setting (Johnson

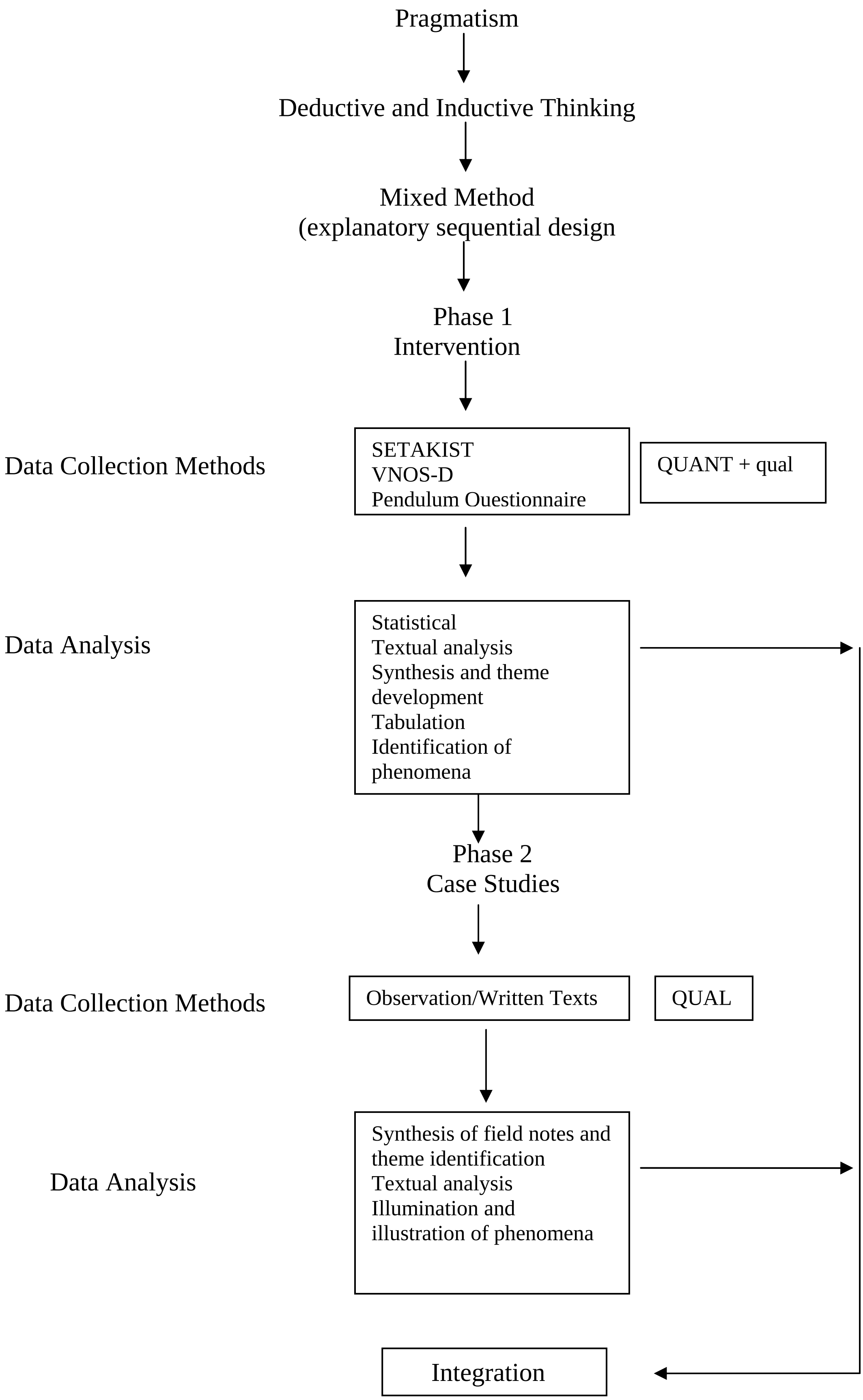
& Ongwuegbuzie, 2004; Teddlie & Tashakkori, 2009). As Creswell and Plano Clark (2011) advise, *use it (the typology) as a guiding framework* (Creswell & Plano Clark, 2011, p.60).

As stated by Tashakkori and Teddlie:

> pragmatists decide what they want to study based on what is important within their personal value systems. They then study that topic in a way that is congruent with their value system, including units of analysis and variables that they feel are most likely to yield interesting responses (Tashakkori & Teddlie, 2003 in Teddlie & Tashakkori, 2009, p.90).

This study is principally concerned with comparing two professional development approaches and their impact on teachers' self-efficacy for the teaching of and knowledge of science and their pedagogical content knowledge for the nature of science. An overview of the methodological orientation is shown below:

Figure 3.2 Overview of the methodological orientation



3.3 Sample

3.3.1 Ethics Approval

Prior to carrying out the study, ethics approval was granted by the University of New South Wales (UNSW) ethics committee. As the researcher had been an employee of the New South Wales Department of Education as a classroom teacher, professional developer of teachers, curriculum reviewer and education officer, a research proposal was submitted to and granted by the Directorate of Strategic Research.

Prior to calling for volunteers to participate in the PD program, the researcher presented the proposal at a Principal's conference of the elementary schools within the districts targeted by the educational authority. These presentations outlined the relationship between the rationale for the project and the requirements of the current NSW K-6 syllabus for Science and Technology. It was made explicit that the pedagogical model on which the PD program was based had been developed from extensive experience as a classroom teacher as well as from research. This allowed the researcher to establish the priority of his teaching experience as the main determinate in how their staff may be open to a classroom intervention program that introduces an innovative pedagogical model. The more closely the observer identifies with a model, the stronger will be the impact on efficacy (Bandura, 1986; Tschannen-Moran et al., 1998).

A letter requesting permission to carry out the research project was sent to those Principals who expressed an interest in taking part in the study (see Appendix 1). The districts of Port Jackson and Bondi in metropolitan Sydney were chosen by the education authority. These districts covered the eastern and inner west suburbs of Sydney, giving a range of school contexts and socio-economic backgrounds. Subsequent to the presentations to principals, the researcher attended a staff meeting at each school outlining the intended program and providing details of the researchers teaching experiences and previous developed professional development activities. Only when both the principal and staff had consulted were volunteers called for.

On volunteering and signing the Participant Information Statement and Consent Form (see Appendix 1), and prior to the initial workshop, all participants were pre-tested in self-efficacy for knowledge and teaching in science, views on the nature of science and knowledge of pendulum behaviour. Participants were instructed on how to code the responses so they could not be identified (see Appendix 1). The participants were a mix of experienced and novice teachers with teaching experience ranging from one year to 20+ years. Common among participants was the lack of formal science studies beyond initial teacher training and no experience with the concepts of the nature of science.

The population was two cohorts of teachers created from volunteers from twenty elementary schools. The cohorts were created randomly on a first-come first-serve basis maintaining the homogenous cross-section of school contexts. The population was divided into a reform-style PD group of fourteen schools (n = 37) and a standard-style PD group drawn from the remaining six schools (n = 18). The minimum number of participants from each school was set at two. This allowed the opportunity for teachers to have continued in-school support during the course of the intervention program.

3.4 Phase 1 The Professional Development Program

The science PD program design was based on the “reform-style” structure. A key feature of reform-oriented site-based professional development activities is the concept of mentoring or coaching (Garet et al., 2001; Veenman & Denessen, 2001) and this type of activity is likely to be more effective because it is often led by current classroom teachers, whom other teachers trust as a source for meaningful guidance on improving teaching (Lieberman & McLaughlin, 1992). In order to provide true vicarious experiences to their staff and potentially impact on their efficacy, the staff would need to have confidence in the researcher as a classroom teacher to have a close identification with the pedagogical approach shown.

Similarly, the potency of verbal persuasion depends on the credibility, trustworthiness, and expertise of the persuader (Bandura, 1986). The reform-style PD program placed the researcher in both the classroom and staffroom, with time devoted to teacher-researcher and teacher-teacher discussions over the full school day. The researcher’s ability to discuss a wide-range of teaching and professional day-to-day demands on classrooms teachers was integral to establishing this trust and credibility between the researcher and the principal and staff of the volunteer schools.

The purpose of utilising a mixed research approach in this study (Table 3.2) was influenced by the pedagogical content knowledge (PCK) model investigated in this study. The data collection method and subsequent analysis for the components that are proposed to contribute to the development of PCK is shown below:

Table 3.2

Mixed method approach for data collection

Research Objective	Instrument	Analysis
Views on the nature of science	VNOS-D modified	qualitative
Self-Efficacy	SETAKIST	quantitative
Conceptual Knowledge	Pendulum questionnaire	quantitative
Pedagogy	Workshop debrief	qualitative

The research questions that investigate this model of PCK drives the choice of the mixed method research, an approach described as “bottom-up” by Tashakkori and Teddlie (2006).

Data were collected at pre- and post-stages of a ten-week PD program. The analysis of data then incorporated aspects of Onwuegbuzie and Teddlie’s (2003) mixed methods data analysis process. These aspects include:

- data reduction (thematic analysis of qualitative data and descriptive statistics on quantitative data),
- data display (pictorial representation such as graphs, charts and tables)
- data transformation (where quantitative data are converted into narrative data and qualitative data are converted into numerical code)
- data correlation (quantitative data correlated with qualitative data)

- data consolidation (both quantitative and qualitative data are combined to create new or consolidated variables, or data sets)
- data comparison
- data integration (where both quantitative and qualitative data are integrated into a coherent whole or set of wholes) (Migiro & Magangi, 2011).

Mixed method research has potential weaknesses of expense, duration and interpretation of conflicting results. Mixed research may necessitate large commitments of personnel to gather observational data over an extended period in alignment with participant questionnaires or completion of test instruments. The researcher needs to understand how to mix the methods appropriately to best gather and report data that illuminates results from both methods (Migiro & Magangi, 2011).

However, a mixed research method strengths lie in *its capacity to produce more complete knowledge necessary to inform theory and practice* (Johnson & Onwuegbuzie, 2004, p.21). This is achieved through the collection of multiple data using different strategies, approaches and methods (Johnson & Turner, 2003). Mixed method research can provide stronger evidence for a conclusion through convergence and corroboration of findings (Migiro & Magangi, 2011).

Professional development is considered an important mechanism for deepening teachers' content knowledge and developing their teaching practices (Desimone et. al., 2002). The research on what constitutes best practice in professional development (Loucks-Horsley et. al., 2003) has identified a number of common features in high-quality professional development programs which Garet and colleagues (2001) analysed in their national sample of 1,027 mathematics and science teachers' professional development experiences through participation in the United States federal Eisenhower professional development program. Their analysis focussed on both "structural" (i.e. the design of the activities) and "core" (i.e. the substance of the activities) features (Garet et. al., 2001).

Loucks-Horsley and Matsumoto (1999) propose four clusters of variables that determine the quality or nature of professional development:

- content (what is to be learned)
- process (how content is to be learned)
- strategies and structures (how content is organised for learning)
- context (conditions under which content is learned).

The content variable includes subject matter, an understanding of learners and learning and knowledge of teaching methods. These content knowledge bases are reflected in the structure of the study in this thesis where the developed lessons included a specific subject matter area, ascertained the prior knowledge of the learners and were inclusive of a variety of pedagogical strategies.

The processes identified by Thompson and Zeuli's research (1999) for an effective PD program are also found within the program described in this thesis. These processes are: create cognitive dissonance (achieved through the use of the VNOS-D questionnaire and an initial workshop); the provision of time and support (the use of an academic coach prior to and beyond the formal lesson observations); ensuring that the dissonance-creating and dissonance-resolving activities are connected to the teachers' own students and context (achieved through vicarious experiences in situ of the teacher’s own classroom); providing a way for teachers to develop their repertoire for practice (teachers’ use of mastery experiences); and provide continuing help in the cycle of surfacing new issues and problems (achieved through mentoring).

The resources issue as identified by Rennie et.al. (2005) was alleviated through the provision to each participating school of a teaching kit consisting of developed lesson plans and sufficient materials to conduct twelve or more lessons. These materials were everyday items that were cheap and readily available, requiring no specialist skill in use or manipulation.

3.5 Test Instruments

3.5.1 SETAKIST

Instruments developed to measure self-efficacy include the Teacher Efficacy Scale (TES) and the more widely used Science Teaching Efficacy Belief Instrument (STEBI) (Enochs & Riggs, 1990). The STEBI instrument consists of two dimensions; the personal science teaching efficacy (PTSE) and science teaching expectancy outcome (STOE). The use of STEBI (Appendix 2) has been called into question by researchers, however, because 60% of the overall variance for outcome expectancy cannot be explained and caution should be applied in the use of this instrument for measuring outcome expectancy (Roberts, Henson, Tharp, & Moreno, 2001, Roberts & Henson, 2001).

To redress these problems, Roberts and Henson (2001) developed the Self-Efficacy Teaching and Knowledge Instrument for Science Teachers (SETAKIST) designed to measure two constructs: teaching efficacy and knowledge efficacy. The teaching efficacy construct portion of this instrument is similar STEBI's personal science teaching efficacy construct. Henson and Roberts based the knowledge efficacy construct on Shulman's (1986) pedagogical content knowledge, expecting *that these factors were related* (p.15). This instrument was piloted on a sample of 274 elementary science teachers or science specialists, and results indicated that it produced a good data fit to the hypothesized model (Roberts & Henson, 2001).

The SETAKIST questionnaire (Appendix 2) was selected for this study as the self-efficacy test instrument as the study was concerned with evaluating the teaching and knowledge efficacies only and not the expected outcome efficacy. Although Roberts and Henson caution that more validation is required in further studies, *the concept of assessing efficacy for pedagogical content knowledge is intriguing and worth investigating* (Roberts & Henson, 2001, p.15).

The test instrument developed by Roberts and Henson (Appendix 2) consists of sixteen Likert scale items consisting of eight items designed to gather information on teachers' self-efficacy for teaching in science and eight items for self-efficacy for knowledge in science teaching:

(a) Self-efficacy for teaching in science items:

2. *I do not feel I have the necessary skills to teach science.*
4. *Given a choice, I would not invite the principal to evaluate my science teaching.*
6. *Even when I try very hard, I do not teach science as well as I teach most other subjects.*
8. *I find science a difficult subject to teach.*
9. *I know the steps necessary to teach science concepts effectively.*
11. *I am continually finding better ways to teach science.*
12. *I generally teach science ineffectively.*

14. I know how to make students interested in science.

(b) Self-efficacy for knowledge in science teaching items:

1. When teaching science, I usually welcome student questions.
3. I am typically able to answer students' science questions.
5. I feel comfortable improvising during science lab experiments.
7. After I have taught a science concept once, I feel confident teaching it again.
10. I find it difficult to explain to students why science experiments work.
13. I understand science concepts well enough to teach science effectively.
15. I feel anxious when teaching science content that I have not taught before.
16. I wish I had a better understanding of the science concepts I teach.

SETAKIST was trialled with five schools who were not to participate in the PD program but who agreed to the trial. The feedback from this indicated that teachers were comfortable with completing the SETAKIST questionnaire, both with the language level and complexity of the questions asked. The two efficacy constructs in the SETAKIST questionnaire address the components of the pedagogical content knowledge model used in this study. In this study, the teaching efficacy and science knowledge constructs are proposed as contributors to pedagogical content knowledge.

3.5.2 VNOS Form D (Modified)

Teachers' views on the nature of science were obtained using the View of the Nature of Science Form D (VNOS-D) (Lederman et al., 2002). VNOS-D was used in preference to VNOS-C following a trial of each form with the above five schools prior to beginning the PD program. Feedback from these schools indicated that the higher literacy levels in science terminology in VNOS-C compared to VNOS-D (Table 3.3) caused some anxiety among teachers as to their ability to produce an appropriate answer.

VNOS-D was designed for eliciting views on the nature of science from middle school students up to approximately 15 years of age. The difference in literacy level between the forms is shown below:

Table 3.3
Literacy level differences between VNOS-D and VNOS-C

VNOS Form D	VNOS Form C
1. What is science?	1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?
2. How is science different from the other subjects you are studying?	2. What is an experiment?
3. Scientists produce scientific knowledge. Some of this knowledge is found in your science books. Do you think this knowledge may change in the future? Explain your answer and give an example.	3. Does the development of scientific knowledge **require** experiments? • If yes, explain why. Give an example to defend your position. • If no, explain why. Give an example to defend your position.
4. (a) How do scientists know that dinosaurs really existed? (b) How certain are scientists about the way dinosaurs looked? (c) Scientists agree that about 65 millions of years ago the dinosaurs became extinct (all died away). However, scientists disagree about what had caused this to happen. Why do you think they disagree even though they all have the same information?	4. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence, or types of evidence, **do you think** scientists used to determine what an atom looks like?
5. In order to predict the weather, weather persons collect different types of information. Often they produce computer models of different weather patterns. (a) Do you think weather persons are certain (sure) about these weather patterns? (b) Why or why not?	5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.
6. What do you think a scientific model is?	6. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change? • If you believe that scientific theories do not change, explain why. Defend your answer with examples. • If you believe that scientific theories do change: (a) Explain why theories change? (b) Explain why we bother to learn scientific theories. Defend your answer with examples.

Table Continues

VNOS Form D	VNOS Form C
7. Scientists try to find answers to their questions by doing investigations / experiments. Do you think that scientists use their imaginations and creativity when they do these investigations / experiments? **YES** **NO** a. If **NO**, explain why? b. If **YES**, in what part(s) of their investigations (planning, experimenting, making observations, analysis of data, interpretation, reporting results, etc.) do you think they use their imagination and creativity? Give examples if you can.	7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence **do you think** scientists used to determine what a species is?

The VNOS Form D was modified by changing item 2 from: "How is science different from the other KLA subjects you are studying?" to: 'How is science different from the other KLA subjects you are teaching?"

Given that confidence for teaching science is already a major identified factor in the quality of elementary school science and that the majority of the cohort teachers in this study had not engaged in science studies since beginning their careers, the use of Form C was seen as possibly exacerbating the issue of teacher confidence. It was decided to proceed with the VNOS-D form as the test instrument with question 2 modified for use with the elementary teachers to: *2. How is science different from the other subjects you are teaching?*

3.5.3 Pendulum Questionnaire

Limited science background knowledge has been identified as a barrier to effective elementary school science teaching (Rennie et al., 2005). As the core concepts within each lesson related to pendulum studies, a questionnaire was developed to measure any improvements in teacher knowledge and understanding of key pendulum properties and behaviour. Questions were developed on the themes of *Length, Angle and Energy, Air Resistance, Gravity* and *Greeks, Galileo and Sea Voyages*. These themes reflected both the content of the lesson plans (Appendix 3) and provided factsheets (Appendix 4).

Although knowledge of specific science concepts is not measured by the SETAKIST questionnaire, the knowledge efficacy questions ask teachers to reflect on their general science background knowledge to which exposure to and an understanding of pendulum concepts may contribute. The divisions of the pendulum questions into four themes allow measurement of increased understanding of those concepts deliberately targeted by the lesson plans, the delivered lessons and/or the provided factsheets.

3.5.4 Initial Workshop

All teachers (experimental and control) were given an initial two-hour workshop. Reference was made throughout the workshop to the development of scientific literacy as a rationale for the review of the current NSW K – 6 Science and Technology syllabus, highlighting changes already made to those of other Australian States and Territories. This was felt important by the researcher to engender confidence in the teachers that the program was based on current theories of improving science education.

The activities chosen for the workshop were drawn from four of the lessons that were to be used in the in-class intervention. These lessons (*Hickory, Dickory, Dock; The Lolly Test; Length v Period; Weight v Period*) engaged teachers in a number of hands-on investigations covering pendulum concepts. The study of the history of pendulum motion and related experiments is rich in the aspects of the nature of science and has implications in the classroom for increasing students' awareness of the scientific process (Matthews, 2002). The use of the pendulum as a case study or context in this intervention program satisfies what Daehler and Shinohara (2001) list as essential requirements for use as an effective professional development strategy: it focuses on a little piece of content that is fundamentally important, challenging, and by nature, inherently fraught with complexities and ambiguities.

The hands-on activities allowed the teachers to familiarise themselves with the equipment provided in the pendulum kit and experience in a classroom scenario the possible procedural errors that their students may also encounter.

The pedagogical approach on which the subsequent intervention was based was modelled by the researcher in this workshop with particular attention to the importance of explicit teacher questioning. The relationship between "knowing what to say" and teacher content knowledge is pointed for teachers when preparing to teach science in elementary school. When teaching unfamiliar topics, teachers express more misconceptions and they talk longer and more often, and mainly pose questions of low cognitive level (Hashweh, 1987, Carlsen, 1993 in Van Driel et.al. 1997).

Teacher educators must be aware that elementary teachers are sufficiently intelligent and resourceful to be able to find ways to increase their content knowledge if they are given the tools and shown the importance of doing so (Akerson et al., 2001). Yet knowing the science alone is not enough, teachers also want to learn effective ways of making science comprehensible to their young students (Daehler & Shinohara, 2001).

Although there is an emphasis in this PD program on incorporating classroom strategies for enhancing teacher discourse, the notion of "how to talk" will be given a broader treatment beyond how to assist classroom discussion to "how to talk for science understanding." Science educators would advocate that an understanding of the nature of science (NOS) is a key element to achieving scientific literacy (Moss & Abrams, 2001) and to be able to convey to their students adequate NOS conceptions, teachers should themselves possess informed conceptions of the scientific enterprise (Abd-El-Khalick & Lederman, 2000; Palmquist & Finley, 1997). To teach NOS a teacher must have not only a firm understanding of NOS but also knowledge of effective pedagogical practices relative to NOS and the intentions and abilities to merge these two elements in the classroom (Schwartz & Lederman 2001). *Enhancing these qualities should be planned for instead of being anticipated as a side effect or secondary product of science content classes* (Akendehin, 1988 in Abd-El-Khalick & Lederman 2000, p.690).

In addition to highlighting the included questions, the second part of the workshop introduced teachers to Galileo’s investigation of pendulum motion, his concept of “idealisation”, and the pendulum’s role in the development of more accurate timing devices. During the pendulum activities conducted with the teachers at these initial workshops, the researcher made explicit to the teachers the importance of Galileo's recognition that "impediments" could affect the swing of a pendulum. The concept of Galileo's "idealisation" (Matthews et al., 2005), where the swing of the pendulum could be analysed in an ideal situation where impediments should be ignored was introduced.

The researcher was able to make reference to a major television series previously broadcast in Sydney on the problem of establishing longitude and the work of John Harrison in building accurate marine timepieces[20]. Many of the teachers were able to recall the series and could make immediate connections between the investigations in the first lessons with accurate timekeeping. These historical problems had already been included in the factsheets to be issued to all teachers.

3.5.5 The Intervention

Over a period of one school term (ten weeks), each member of the experimental cohort then observed and participated in five demonstration lessons on the pendulum given by the principal researcher. The principal researcher remained in situ for each of the five days on which the lessons were delivered. Each lesson had a focus on at least one aspect of the nature of science that was explicitly highlighted to the students during the lesson. During this observation period, equipment for and resources on the pendulum were provided to each participant in the cohort.

Members of the control cohort 2 did not observe demonstration lessons but were given a set of lesson plans (including the five lessons delivered to the experimental cohort) on pendulum concepts. Each control cohort participant was also given access to the pendulum equipment and resources. The principal researcher did not visit or remain in situ at the control cohort schools. There was no further contact with the control cohort

[20] (http://www.bbc.co.uk/dna/h2g2/A306758).

until post-testing. This cohort was undergoing the most common type of professional development and the form most widely criticised, the "workshop" (Garet et. al., 2001). This form of professional development falls into the "traditional' style (Garet et al., 2001) as was used as a counterpoint to the reform-style design used in this study.

Both cohorts were then post-tested with the same test instruments used prior to the PD program. It may be anticipated that the responses given by the control cohort to the test instruments will indicate a lower performance compared to the experimental group. Members of the experimental cohort attended a final workshop where their responses to a number of debrief questions regarding the observed lessons were recorded.

3.5.6 The Lessons Plans

Pendulum studies are not a specific component of the New South Wales K – 6 Science and Technology syllabus. Teachers are required when programming a year’s work to clearly indicate where the syllabus outcome statements are addressed by their teaching program. Therefore it was necessary during the initial preparatory workshop given to all teachers that the lessons were shown to address syllabus outcome statements. The outcome statements addressed by the lessons in this PD program, while not domain specific, targeted the outcomes in the Skills strand and Learning strand. This enabled the programming requirements to be met for each teacher.

Each lesson has these outcome statements clearly identified, and included the rationale for the lesson which highlighted the nature of science aspect(s) addressed by the activities and teacher questioning:

Figure 3.3 Example of Pendulum Lesson Plan

PENDULUM LESSONS

Lesson Plan Title:

Length of the Pendulum V Period of Swing

Grade Levels: 3 - 6

Outcomes:

Stage Two

- INVS 2.7 Conducts investigations by observing, questioning, predicting, testing, collecting, recording and analysing data, and drawing conclusions.
- VA2 Exhibits curiosity and responsiveness to scientific and technological ideas and evidence.
- VA45 Works cooperatively with others in groups on scientific and technological tasks and challenges.

Stage Three

- INVS 3.7 Conducts their own investigations and makes judgements based on the results of observing, questioning, predicting, testing, collecting, recording and analysing data, and drawing conclusions.
- VA2 Exhibits curiosity and responsiveness to scientific and technological ideas and evidence.

VA45 Works cooperatively with others in groups on scientific and technological tasks and challenges.

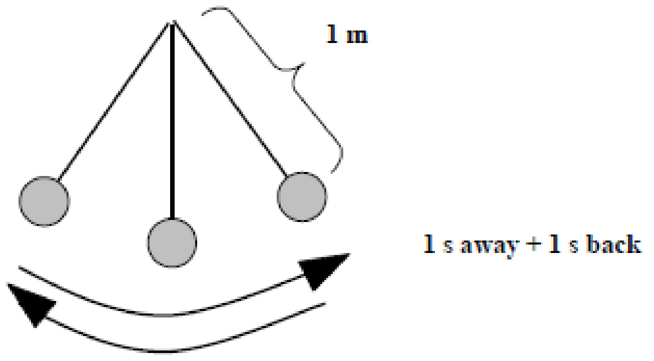
Rationale:

This lesson follows directly from the lesson on the **seconds** pendulum. The Nature of Science tenets that the students should be explicitly introduced to here are the **tentativeness** of science. What do we do when our prediction does not match our testing and observation? Is it permissible in science to change our mind? Is science always certain?

Where necessary, background knowledge of pendulum behaviour was provided in the lesson plan:

Background:

- The pendulum used for this lesson is assembled from a string with a weight at one end
- **Galileo** was the first to examine the unique characteristics of the pendulum
- Galileo stated that each pendulum has a constant period, ie the time it takes to complete a full swing away and back is always the same and unique for each different length of the pendulum
- The shorter the pendulum the faster the swing, the longer the pendulum the slower the swing.
- Christian Huygens confirmed the **isochronicity** of the pendulum.
- The **seconds pendulum** is 1 metre in length to give a swing of 1 second on each pass



This background information was also presented at the initial teacher workshops at the beginning of the PD program.

Each lesson plan was contained both teaching strategies and **explicit** (Abd-Khalick et al.,, 1998) questioning on one or more aspects of the nature of science. The following are examples of the explicit questioning proposed:

• *Should scientists be careful of being bias?*

• *Is bias a good or bad thing in science?*

• *What if a scientist is biased towards one idea that other scientist do not support and then later this idea seems to be correct?*

• *How can experiments solve the problem of bias?*

• *Why did some of us not want to change our hypothesis?*

• *Is it a good thing for scientists to change their ideas? Why?*

• *How did the measurements support your idea?*

• *How do experiments help scientists collect data (information) about their ideas?*

• *What must we keep the same when we do a test?*

All lesson plans also provided pedagogical hints (Table 3.4) for the teachers allowing for lessons both cohorts may attempt to deliver without the presence of the researcher. These hints flagged possible procedural errors by the students when conducting the investigations, provided stimulus questions and highlighted possible student questions and responses during the course of the lesson. The hints were included to support the teachers' pedagogical skills for successful science instruction:

Table 3.4

Pedagogical Hints for Teaching Strategy

Lesson	Teaching Strategy	Pedagogical Hint
Hickory Dickory Dock	Students draw nursery rhyme.	You should see at least one student drawing a grandfather clock. If no student draws the pendulum in the clock have a picture of a grandfather clock ready and question students on how their drawing differs from the picture. Students will normally point out how some drawings have the "swinging thing" inside the clock)
	Using students' drawings as a reference finish with questioning:	What time does the pendulum keep? Should it be long or short? Did you draw a clock taller than you? Why is a grandfather clock tall?

In all, twelve lesson plans were prepared and issued to both the experimental and control cohorts.

3.5.7 Pre-Intervention Trial of Lessons

During the early phase of the intervention period, a number of the volunteer teachers were asked to trial a running commentary on the effectiveness of the lesson plans and the suitability of the pendulum as the chosen context. This provided important information to the researcher for possible amendments to the complexity of the questioning and the provision of further background knowledge for the remaining teachers. The teachers completed a reflection after participating in the lesson and observing the student engagement with the concepts. These teachers agreed to the trial on the understanding that they would participate in a full PD program at a later date. **No data on these teachers is included in the quantitative analysis reported.**

The lesson reflections are summarised below (Table 3.5). They represent 15 teachers from 5 schools with classes ranging from Year 3 to Year 6. The comments by the teachers provided clear evidence to the researcher that the developed lessons and chosen context of the pendulum were effective both in engaging the teachers and students in both pendulum concepts and the targeted aspects of the nature of science.

Table 3.5

Pre-intervention teacher reflections on proposed lessons

Year	Commentary
3	A significant number of students were able to draw the pendulum inside the clock. They knew the name grandfather clock. During the tick/tock strategy, one student pointed out that the pendulum needed to swing in seconds to keep time. One Latvian student gave the Latvian version of the nursery rhyme!! Some students asked if they could draw a female scientist. Students proposed various lengths of the pendulum to swing 10 times in 10 seconds. Even when the chosen length was not correct a number of students stuck to their choice. Can I turn this into a BIAS strategy? A number of students made a hypothesis that the weight would make a difference. This class not as perceptive as the others.
4	Students proposed various lengths of the pendulum to swing 10 times in 10 seconds. Students who found their choice incorrect changed their measurement. A number of students said that the golf ball would swing differently because of its weight. Changed the lesson slightly from the other Stage 2 lessons in that I had the students draw a scientist as some of them said a scientist could wear anything and didn't need a uniform. This is the first time I have had this come up. One girl student told me that scientists could also be female. A number of students made a hypothesis that the weight and angle of release would make a difference. Some had trouble giving up on their selected length until they demonstrated to class and saw it didn't work. When asked whether a golf ball, table tennis ball or rubber ball would swing differently, the students were divided as to which one swings faster/slower. An excellent class knowing terms such as "estimate" "hypothesis"

Table Continues

Year	Commentary
5	Students proposed a range of lengths for the pendulum with the most favoured length being 100 cm. Students could note that the second hand on the wall clock and the pendulum were to keep the same time. The concept of a fair test was well understood by the students. They could point out a number of variables that needed to be controlled for the Lolly Test to be fair. NB No mention of the terms variable or control have been introduced and this will form part of the next lesson.
6	Proposed next lesson investigate weight. Proposed next lesson investigate angle of release. Students' ideas were the platform for the design of the fair test. When asked whether a golf ball, table tennis ball or rubber ball would swing differently, the students were divided as to which one swings faster/slower. Student made comment that the open window makes a difference.

Teachers have expectancy for the outcome of their teaching (Bandura, 1986) and their confidence in their required knowledge and teaching strategies to achieve those outcomes impact on that expectancy. The reflections in the commentary (Table 3.5) are indicative of a sufficient level of competency in both the teachers and the students to participate in the lessons. As a result of these early reflections, no changes were made to the lesson structure or strategies employed in the subsequent intervention period.

3.5.8 The Lessons

The classes who participated in the demonstration lessons ranged from Grade 3 to Grade 6, giving a student age range of 7 – 12 years. Grades 3 and 4 represented students at Stage 2 curriculum level with Grades 5 and 6 representing Stage 3. There were some classes in smaller schools where two grades were combined, but each combined class contained students at the same Stage. These classes had no prior introduction by the classroom teacher concerning the nature of the demonstration lesson or the pendulum concepts addressed. The equipment in the pendulum kits was presented to the students during the first lesson.

Two distinctly different introductory lessons were designed to account for the age differences between Stages 2 and 3. The younger students in Stage 2 (7 – 9 years) began with the lesson titled “Hickory, Dickory, Dock”. The rationale for this lesson was:

> This is the first lesson in this program. It is designed to introduce the pendulum through a familiar nursery rhyme. Through teacher questioning, the students should be able to recall what the clock in the nursery rhyme looks like, what sound it makes (tick tock) and (in some cases) what swings inside the clock’s cabinet.
>
> Using a familiar context and students’ prior experiences should increase student engagement in the scientific processes of observing, hypothesising, predicting and testing.

Teachers of Stage 2 classes had been introduced to the use of the nursery rhyme and pendulum timekeeping in the initial workshop. The key modelling by the principal researcher for the classroom teacher focussed on eliciting students’ prior knowledge of the grandfather clock and using this to frame appropriate questions about the relationship between time and the swinging of the pendulum.

The older students in Stage 3 (10 – 12 years) began with the lesson titled “The Lolly Test”. The rationale for this lesson was:

> What is a FAIR TEST? The Nature of Science aspect that the students should be explicitly introduced to here is that science is **empirical**. A hypothesis may be supported by the collection of data from investigations carried out in a scientific manner.

Teachers of Stage 2 and Stage 3 classes had been introduced to the concept of fair-testing and the empirical nature of science in the initial workshop. The key modelling by the principal researcher for the classroom teacher focussed on appropriate questions to elicit from the students their views on what constitutes fair-testing and its importance in the gathering of evidence. This lesson introduced the concepts of dependent and independent variables to the students, concepts also covered for the teachers in the initial workshop.

Although the choice of introductory lesson was suggested by the principal researcher, collaboration with the teachers would have allowed for the use of either lesson. All Stage 3 teachers requested the context of the “Lolly Test” as the most appropriate introductory lesson students of this age group. As some of the Stage 2 teachers expressed an interest in using this lesson **after** the introductory lesson “Hickory Dickory, Dock”, but had concerns regarding the literacy levels of Stage 2 students, the lesson contained a teaching hint for Stage 2 teachers suggesting the omission of the terminology concerning variables.

During the remaining demonstration lessons, the principal researcher modelled variations to teaching strategies according to the student age group, allowing for differing literacy levels and student responses. The teachers were encouraged to participate fully in all the demonstration lessons, especially during the conduction of the investigations and in answering student questions. Increased teacher participation was seen as crucial to teachers feeling a sense of "ownership" of the lessons and building their confidence in the teaching and learning process.

3.5.9 Researcher in Situ

On each day of the demonstration lessons the principal researcher remained at school attending staff morning teas and lunchtimes and participating in other school activities. This out of class time provided opportunities for the participating teachers to review key elements of the demonstration lessons clarify any misunderstanding or misconception regarding pendulum concepts and to discuss the nature of science aspects.

Over the ten week period, the researcher became familiar to the staff and students as an adjunct staff member. A number of extra demonstration lessons were given to staff not directly involved in the PD program, both on the pendulum and other science concepts such as weather, materials and water. The time given to be in situ was seen as an effective contributor to creating a true vicarious experience for each participating teacher.

3.6 Phase 2 The Case Studies

3.6.1 Introduction

As outlined earlier in Section 3.2, Phase 2 of the study was constructed to illustrate examples of changes to teacher practice resulting in participation in the reform-style professional development program. The case studies chosen were drawn from the quantitative results in Phase 1. The final stage in the methodological framework applied in this study (refer Figure 3.2) is the integration of the findings from the two phases. Although the study is based on an explanatory *sequential* design (refer Figure 3.1), Phase 1 and Phase 2 are interrelated so that primarily the quantitative findings in Phase 1 influenced the choices made in Phase 2 but the observations and findings in Phase 2 can be used to interpret the findings from Phase 1. As stated earlier (refer p. 82), this allows the researcher to fit together the insights from both forms of data.

The case studies are described in full in Chapter 5. Two case studies from the experimental group were conducted to account for the differing approaches that teachers took to incorporating the teaching and learning strategies into classroom practice. The most common approach employed was to incorporate the strategies directly into practice without planning a unit of work designed around a full program of lessons (Case Study 1). In a few schools, the researcher worked with the teachers as a critical friend to develop a complete unit of work prior to the teaching of the lessons (Case Study 2). The role of the researcher as critical friend was to *support classroom teachers to articulate their personal professional thinking and explore and develop personal initiatives and strategies* (Smith et al., 2012, p.131).

3.6.2 Purposive Sampling

Purposive sampling techniques involve selecting certain units or cases *based on a specific purpose rather than randomly* (Kemper et al., 2003 in Tashakkori & Teddlie, p.279). Researchers using purposive sampling seek to focus so as to select only those cases that might best illuminate and test the hypothesis.

In this study a purposive sampling technique was employed to find instances that are representative or typical of a particular type of case on a dimension of interest. (Teddlie & Tashakkori, 2009) and most likely to provide relevant and valuable information (Maxwell & Loomis, 2003 in Tashakkori & Teddlie, 2003). Since this study is sequential, a sequential MM sampling was carried out where the results from the first phase informed the sample selected in the second phase (Teddlie & Tashakkori, 2009).

A limited quantitative analysis of the SETAKIST responses was completed to identify possible divisions within the participants based on both the numerical score (/40) for each efficacy component and the corresponding difference between less and more efficacious responses (/±8). Using the Likert scale identifiers from *Strongly Disagree* to *Strongly Agree,* each response was coded as either less efficacious (LE – a negative score), uncertain (U – a zero score), or more efficacious (ME -a positive score). The difference (Δ) between less efficacious and more efficacious was recorded and tallied for all participants in each group (n=53).

A *representative sample* (Table 3.6) of the tally for teaching efficacy and knowledge efficacy are given below:

Table 3.6

Pre- and Post - Tally for teaching efficacy and knowledge efficacy

TEACHING PRE					TEACHING POST				
	LE	Uncertain	ME	Δ		LE	Uncertain	ME	Δ
16630	1	0	7	6+	220705	0	0	8	8+
220705	2	0	6	4+	16630	1	0	7	6+
AA221173	2	2	4	2+	HM	1	1	6	5+
30762	3	2	3	0	30762	2	1	5	3+
MN020761	3	2	3	0	NW121085	2	3	3	1+
SL0307	3	3	2	1-	ES040328	2	4	2	0
JE120144	5	1	2	3-	RC031250	3	3	2	1-
2209	5	2	1	4-	CW210757	5	0	3	2-
230372	6	1	1	5-	SL0307	4	4	0	4-

KNOWLEDGE PRE					KNOWLEDGE POST				
	LE	Uncertain	ME	Δ		LE	Uncertain	ME	Δ
16630	0	0	8	8+	16630	0	0	8	8+
220705	0	1	7	6+	91098	0	1	7	7+
AA221173	0	3	5	5+	230372	1	1	6	5+
MN020761	1	2	5	4+	SC170605	2	1	5	3+
2209	2	2	4	2+	LB040375	2	3	3	1+
30762	3	0	5	2+	30762	3	2	3	0
SL0307	3	1	4	1+	NW121085	3	3	2	1-
JE120144	4	0	4	0	JR281054	5	0	3	2-
230372	4	2	2	2-	RC031250	5	2	1	4-

Note: There are 8 items in each subscale

This difference (Δ) was then aligned with the corresponding total teaching and knowledge efficacy scores for both the experimental and control cohorts. A sample of this alignment (Table 3.7) is shown below:

Table 3.7

Alignment of Pre- and Post- teaching efficacy and knowledge efficacy differential with scores

TEACHING PRE versus SCORE			TEACHING POST versus SCORE		
	△	Score		△	Score
16630	8+	40	220705	8+	32
220705	6+	30	16630	6+	30
AA221173	2+	27	HM	5+	27
30762	0	28	30762	3+	32
MN020761	0	26	NW121085	1+	25
SL0307	1-	20	ES040328	0	25
JE120144	3-	21	RC031250	1-	19
2209	4-	24	CW210757	2-	22
230372	5-	20	SL0307	4-	19

KNOWLEDGE PRE versus SCORE			KNOWLEDGE POST versus SCORE		
	△	Score		△	Score
16630	8+	40	16630	8+	36
220705	6+	32	91098	7+	32
AA221173	5+	30	230372	5+	29
MN020761	4+	29	SC170605	3+	27
2209	2+	26	LB040375	1+	29
30762	2+	26	30762	0	23
SL0307	1+	25	NW121085	1-	23
JE120144	0	24	JR281054	2-	24
230372	2-	22	RC031250	4-	20

Note: Possible scores for efficacy subscales 8 - 40

The results for teaching efficacy indicate a division between participants at both a pre-test total score of 24/40. At or below 24, participants generally have teaching efficacy totals less than or equal to zero ($n_{pre\text{-}test} = 32/53$; $n_{post\text{-}test} = 19/53$). The results for knowledge efficacy indicate a division between participants at both a pre- and post-test total score of 25/40. At, or below 24, participants generally have efficacy totals less than or equal to zero ($n_{pre\text{-}test} = 13/53$; $n_{post\text{-}test} = 3/53$). The contrast in *n* numbers between teaching and knowledge efficacy indicate that the elementary teachers participating in the professional development program had a higher efficacy level for knowledge in science teaching rather than for science teaching even though the majority had no formal science discipline exposure beyond their initial teacher training course.

Therefore a key sampling criteria employed were the SETAKIST pre-test scores. The two case studies described in Chapter 5 were chosen to consist of a cohort where one teacher was from the higher score bands and one teacher from the lower score bands.

3.7 Summary

In this chapter, relevant philosophical, methodological issues and data techniques that will be used to analyze the data collected in this research were discussed. As discussed in the opening to this chapter, the use of a mixed methods research design is supported Gage's (1989) contention that studies that combine both quantitative and qualitative methods as being *more fruitful of insights, understandings, predictive power and control resulting in improvements in teaching* (Gage, 1989, p.7).

The study has a number of unique features in the use and analysis of established test instruments. Modifying the VNOS-D form for teacher use, and conducting a thematic analysis of the teachers' responses represent a new approach in the use of this instrument. As outlined in this chapter, the rationale for using and modifying this form was based on the possibility of negatively impacting on teacher confidence through completing the more complex VNOS-C form. Conducting a thematic analysis of the pre- and post-responses will allow the researcher to identify changes in teachers' NOS views that were explicitly targeted in the intervention lessons. A similar rationale was applied to the use of the SEATKIST instrument in preference to STEBI, where it was determined from the trial conducted prior to the PD program that the scientific complexity of some of the STEBI questions could possibly contribute to lower teacher efficacy for science.

Conducting case studies in Phase 2 may allow the researcher to gain some meaningful insights into how teachers who participated in a reform-style PD program on NOS attempted to incorporate new NOS teaching and learning strategies into their classroom practice. The sampling for these case studies was based on a novel treatment of the SETAKIST scores, where a determination between more efficacious and less efficacious was made based on the alignment between raw scores and overall correct responses. By assigning a cut-off score to the teachers, the case studies were then chosen to represent both more and less efficacious teachers.

In the next chapter, the results and analysis of the mainly quantitative Phase 1 are reported.

CHAPTER 4

Results and Analysis

Instruments developed to measure self-efficacy include the Teacher Efficacy Scale (TES) and the more widely used Science Teaching Efficacy Belief Instrument (STEBI) (Enochs & Riggs, 1990). The use of STEBI (Appendix 2) has been called into question by researchers, however, because 60% of the overall variance cannot be explained (Tschannen-Moran & Woolfolk Hoy, 2001, Roberts & Henson, 2001). To redress these problems, Roberts and Henson (2001) developed the Self-Efficacy Teaching and Knowledge Instrument for Science Teachers (SETAKIST) designed to measure two constructs: teaching efficacy and knowledge efficacy. The teaching efficacy construct portion of this instrument is similar to STEBI and the knowledge efficacy construct developed is based on Lee Shulman's (1986) work in pedagogical content knowledge. This instrument was piloted on a sample of 274 elementary science teachers or science specialists, and results indicated that it produced a good data fit to the hypothesized model (Roberts & Henson, 2001).

4.1 SETAKIST

The test instrument (Appendix 2) developed by Roberts and Henson consists of sixteen Likert scale items consisting of eight items designed to gather information on teachers' self efficacy for teaching in science and eight items for self-efficacy for knowledge in science teaching. The responses for each group of eight responses were tallied and recorded as a score out of 40. A number of items required reverse scoring due to the wording of the question. For example, in item 2 below, a response of *Agree* would reflect a less efficacious response whereas in item 14, a response of *Agree* would be more efficacious.

Self-efficacy for teaching in science items:

2. I do not feel I have the necessary skills to teach science.
4. Given a choice, I would not invite the principal to evaluate my science teaching.
6. Even when I try very hard, I do not teach science as well as I teach most other subjects.
8. I find science a difficult subject to teach.
10. I find it difficult to explain to students why science experiments work.
12. I generally teach science ineffectively.
15. I feel anxious when teaching science content that I have not taught before.
16. I wish I had a better understanding of the science concepts I teach.

Self-efficacy for knowledge in science teaching items:

1. When teaching science, I usually welcome student questions.
3. I am typically able to answer students' science questions.
5. I feel comfortable improvising during science lab experiments.
7. After I have taught a science concept once, I feel confident teaching it again.
9. I know the steps necessary to teach science concepts effectively.
11. I am continually finding better ways to teach science.

13. I understand science concepts well enough to teach science effectively.

14. I know how to make students interested in science.

4.1.1 Comparison of pre- and post-intervention SETAKIST mean scores

An analysis of variance (ANOVA) was conducted for the mean scores of the experimental and control cohorts for both teaching efficacy and knowledge efficacy (Tables 4.1, 4.2). ANOVA is a statistical test for heterogeneity of means by analysis of group variances (Stevens, 2009). Independent and Paired sample tests were also carried out to provide a more comprehensive statistical analysis of teaching and knowledge efficacies for both the experimental and control groups.

Table 4.1

Mean Pre- and Post-Intervention Teaching Efficacy Scores

	Group	Mean	Std. Deviation	N
Pre Teach	Exp	24.05	5.07	37
	Control	25.11	4.56	18
	Total	24.40	4.89	55
Post Teach	Exp	26.76	4.94	37
	Control	24.44	6.07	18
	Total	26.00	5.39	55

The ANOVA for time fell just outside of significance F (1, 53) = 3.813, p = 0.056. The ANOVA for group effect showed a significant effect on teaching efficacy F (1, 53) = 10.44, p = 0.002, indicating that the experimental group demonstrated significant increase in teaching efficacy over the control group. There was no significant differences between the variability of the experimental and control groups, F (1, 53) = 0.208, p = 0.651.

Table 4.2

Mean Pre- and Post-Intervention Knowledge Efficacy Scores

	Group	Mean	Std. Deviation	N
Pre Knowledge	Exp	26.84	4.58	37
	Control	27.89	3.79	18
	Total	27.18	4.33	55
Post Knowledge	Exp	30.78	3.89	37
	Control	29.83	2.87	18
	Total	30.47	3.59	55

The ANOVA for time showed a significant effect on knowledge efficacy F (1, 53) = 28.518, p < 0.001, indicating increases for both experimental and control groups. The ANOVA for group effect fell outside the level of significance for knowledge efficacy F (1, 53) = 3.293, p = 0.075. As for the ANOVA for teaching efficacy, there was no significant differences between the variability of the experimental and control groups, F (1, 53) = 0.003, p = 0.960.

The effect sizes of the intervention on knowledge efficacy and teaching efficacy were determined using Cohen's test (1988). The effect sizes for knowledge efficacy (d = 0.26) and teaching efficacy (d = 0.44) indicate that there was a greater impact by the intervention on the teaching efficacy between the two groups of the test group than on knowledge efficacy.

An ANOVA is based on a number of assumptions (Howell, 2002): data is numerical data representing samples from normally distributed populations, the variances of the groups are homogenous (similar), the sizes of the groups are similar and the groups should be independent. Therefore further testing was conducted to provide a more comprehensive statistical analysis of teaching and knowledge efficacies for both the experimental and control groups.

A description of the results of this testing is provided in Appendix 5, but in summary:

- the assumption of homogeneity of variance was tested using Levene's Test and found to hold
- the assumption of normally distributed populations was tested using a Wlilks-Shapiro Test analysis and found to hold in all variables except for the control group post-test knowledge efficacy.

Although there was one variable that was not distributed normally (control group's knowledge efficacy post-test (See Appendix 4), parametric testing procedures are still used. Even though the small and unequal sample size in some cases may tend to exacerbate the problem for violations in the assumption of normality (Lix et al.,1996) parametric tests are considered robust to small departures from the normality assumption (Howell, 2002).

4.1.2 Paired sample test for pre- and post- intervention teaching and knowledge efficacy mean scores

Having established normality and similarity of distribution, a paired sample test was conducted (Table 4.3) to compare the mean scores for teaching and knowledge efficacies at pre- and post-test for the both the experimental and control groups individually.

Table 4.3.

Paired sample test for pre- and post-intervention teaching and knowledge efficacy means scores

	Pre-test Mean	*SD*	Post-test Mean	*SD*	*t*	*p*
Exp Group Teaching Efficacy	24.05	5.07	26.76	4.94	-4.485	.000
Exp Group Knowledge Efficacy	26.84	4.58	30.78	3.89	-6.075	.000
Control Group Teaching Efficacy	25.11	4.56	24.44	6.07	.797	.436
Control Group Knowledge Efficacy	27.89	3.79	29.83	2.87	-2.299	.034

There was a significant difference in the pre- and post-test mean scores for both teaching efficacy and knowledge efficacy in the test group. There was a significant difference in the pre- and post-test mean scores for knowledge efficacy in the control group but no significant difference in the pre- and post-test mean scores for teaching efficacy.

Finally, the SETAKIST test instrument was completed by 57 high school science teachers at a subsequent science teacher professional development day. The completion of the survey was voluntary and no names or pseudonyms were recorded on the survey. This was performed by the researcher to ascertain the mean pre-test score for science-trained teachers, and this was compared (Table 4.4) to the pre-test mean score for the elementary school experimental group:

Table 4.4

Pre-Test Mean Scores for Efficacy in High School Science Teachers

	Group	Mean	Std. Deviation	N
Teaching	Experimental group	26.84	4.60	37
	High School group	32.58	4.48	57
Knowledge	Experimental group	30.78	3.89	37
	High School group	33.63	3.08	57

The differences in the mean scores between the elementary and high school teachers would be expected given the high school teachers' specific science discipline training and mandated teaching and learning experiences of the high school syllabus.

4.1.2 SETAKIST Results Summary

The applied tests and analysis indicate a positive effect on knowledge efficacy for both the experimental and control groups as a result of participation in either the full PD program (inclusive of specialist-delivered lessons) or the more traditional program where workshops and support materials were provided without specialist-delivered lessons. Both groups had access to new curriculum materials for science subject knowledge including pendulum studies and nature of science with the experimental group exhibiting a more significant increase in efficacy for this construct than the control group. Since the experimental group had the specialist researcher in situ for five days over the ten week period of the program there were more opportunities for discussion between the participants and the specialist on these science subject areas.

Teacher efficacy for the control group has not been impacted significantly through participation in a traditional PD program. Participants in this style of program did not observe any specialist-delivered lessons in their own classroom nor were they instructed to incorporate the provided lessons into their teaching as a requirement of participation in the PD program. Teaching strategies aimed at instructing students in aspects of nature of science were demonstrated at a single workshop. Although the control group were provided with the full suite of lesson plans for the subsequent specialist-delivered lessons, few members of this group when later contacted incorporated any of these lessons into their teaching practice.

4.2 VNOS Form D (Modified)

The theoretical framework outlined in Chapter 1 proposes that a teacher's views on the nature of science can contribute significantly to the development of their pedagogical knowledge for science teaching. The VNOS-D form allowed participants a free response to questions about the nature of science. Analysis of these responses can be aided by follow-up interviews that may assist in the interpretation of the responses. This is usually performed for assigning a NOS status to the respondent which could be classified as ranging from naive to expert. However, it is not always required that interviews be conducted when using the VNOS forms (Abd-El-Khalick, 2001; Lederman et. al., 2002) and assigning a status to the participants was not an objective of this study. The VNOS-D form was utilised to allow participants to express a view about the NOS question posed and these views were analysed as written in the text,

Contextual analysis was conducted on the participants' responses to this test instrument to determine the stability of these views as a consequence of participation in either the reform or standard type PD program. Content analysis can be utilised in both quantitative and qualitative research:

- Quantitative – content analysis, ie counting in terms of researchers' categories
- Qualitative – interpreting participants' categories

Although content analysis is less common in qualitative research, mixed-method studies allow a researcher to engage in a qualitative study which uses quantitative data to locate the results in broader context (Silverman, 2006; Spicer, 2004). The combination of methods could be seen as utilising the quantitative data to establish patterns of behaviour and utilising the qualitative method to interpret these patterns (Spicer, 2004).

4.2.1 Coding of Themes

The VNOS-D form consisted of seven questions requiring written responses to either a single item or a number of sub-items:

1. What is science?
2. How is science different from the other KLA subjects you are teaching?

3. Scientists produce scientific knowledge. Some of this knowledge is found in your science books. Do you think this knowledge may change in the future? Explain your answer and give an example.

4. (a) How do scientists know that dinosaurs really existed?

(b) How certain are scientists about the way dinosaurs looked?

(c) Scientists agree that about 65 millions of years ago the dinosaurs became extinct (all died away). However, scientists disagree about what had caused this to happen. Why do you think they disagree even though they all have the same information?

5. In order to predict the weather, weather persons collect different types of information. Often they produce computer models of different weather patterns.

(a) Do you think weather persons are certain (sure) about these weather patterns?

(b) Why or why not?

6. What do you think a scientific model is?

7. Scientists try to find answers to their questions by doing investigations / experiments. Do you think that scientists use their imaginations and creativity when they do these investigations / experiments? **YES** **NO**

a. If **NO**, explain why?

b. If **YES**, in what part(s) of their investigations (planning, experimenting, making observations, analysis of data, interpretation, reporting results, etc.) do you think they use their imagination and creativity? Give examples if you can.

The participants' textual responses were treated as *data consisting of words and/or images which have become recorded without the intervention of a researcher* (Silverman, 2006, p.153). Pre- and post- test responses to each individual question item and sub-item were collated from the experimental and control groups. These responses were then randomised onto a spreadsheet without respondents' identification code. The theme(s) contained in each response were coded and recorded.

The categorisation themes created for the responses were not pre-determined by the researcher but were drawn from the texts. However, Lederman and colleagues provided "descriptors" (Lederman et al., 2002), adapted here for use with teachers, for each question of what is being assessed and what is considered to be an answer consistent with reform documents and contemporary views about science. The descriptor for Question 1 is shown below:

Question 1: What is Science?

RESPONSE SHOULD INCLUDE REFERENCES TO A BODY OF KNOWLEDGE (OFTEN THE SCIENCE CONTENT TEACHERS ARE CURRENTLY TEACHING) AND PROCESSES (OBSERVING, EXPERIMENTING, ETC.) FOR THE DEVELOPMENT OF THE KNOWLEDGE.

TEACHERS MAY NOT REFER TO ANYTHING RELATED TO EPISTEMOLOGY OR CHARACTERISITICS OF THE KNOWLEDGE THAT RESULTS FROM THE PROCESSES RARELY DO THE TEACHERS REFER TO SCIENCE AS A "WAY OF KNOWING".

The researcher was aware of the descriptors and used them as themes for coding but also developed themes *directly* from participants' responses that were outside these descriptors. This was done in an attempt to address one of the disadvantages of pre-determined categories of deflecting attention away from uncategorised activities (Silverman, 2006).

It should also be noted that the descriptors assigned to each question by Lederman and colleagues for VNOS-D (Lederman et al., 2002) and adapted here for use with teachers (Appendix 2) were to be used to assign not a numerical score to the respondent but a description of whether the respondent has a desired view of science (Lederman, 1998). This purpose of utilisation of this test instrument in this thesis is not in the assignation of a level on nature of science understanding for each individual respondent but in providing a limited quantification of an overall qualitative study (Spicer, 2004). The frequencies of pre- and identified themes will be analysed for any emerging patterns within and between the responses from the experimental and control groups as a whole. This will be followed by interpretation of these patterns and how these are used in concrete activities (Silverman, 2006). These activities will be described in a later chapter on the case studies.

In assigning a theme to the responses, an interpretation was required of the longer phrases or sentences employed by the respondents. An example of responses and categorised themes for Question 1 is shown below in Table 4.5:

Table 4.5

Responses and categorised themes for Question 1

Theme	Example
Study of phenomena	The study of animals, plants, (biology) physics and chemistry
Investigating	The process of investigating ideas
Role of science in explaining phenomena	The explanation and discovery of our world and why things happen.
How things are connected	The study of the impact of one or more element on others
A body of knowledge	Geology, Biology, chemistry, Physics.
Hypothesising	Ask a question
Changeable	Facts that can change

From participants' responses, 23 themes were determined and each given a code number (Table 4.6):

Table 4.6

Code numbers for themes for Question 1

Theme	CODE
Role of science in explaining phenomena	1
Role of science in providing proof	2
Technology	3
A process	4
Using and gaining knowledge	5
Study of phenomena	6
Testing hypotheses and theories	7
Systemic process	8
A body of knowledge	9
How things are connected	10
A way of knowing	11
Involves fair-testing	12
Changeable	13
Real and imaginary	14

Table continues

Theme	CODE
Unbiased	15
Hypothesising	16
Experimenting	17
Investigating	18
Reasoning	19
Inferring	20
Analysis	21
Observing	22
Predicting	23

The purpose of the assigning code numbers was to allow the researcher to do a simple tabulation (Silverman, 2006) within a qualitative study and apply multiple coding to the interpretation of participant responses that were more complex than a single phrase or sentence. Examples of more complex responses are shown below:

Table 4.7

Interpreted codes for extended responses

Response	Interpreted codes
Answers to questions about the environment, how things work, the universe Questions about investigating and finding answers to what is around us	1,7,18
It's a way to look at something and try to explain why it is so. Ask a question, find a fair test, observe, record, results	1,11,12,16,22

Table continues

Response	Interpreted codes
It is an inquiry or investigation about an aspect of science that begins in most instances with a hypothesis. This can then be tested and questioned in order to rearrange thoughts/ideas	7, 13, 16, 18
Investigation of anything, using a process to ask questions, hypothesise, record results, draw conclusions, research	4,16,18, 20
Investigating, thinking, testing….theories and ideas	7, 16, 18
The study of phenomena through hypothesising applying fair tests and reaching informed decisions	6,12, 16, 19

The interpretation of the themes within the textual responses and the assignation of codes were conducted solely by the researcher. In an effort to investigate the applicability of the coding process, the responses for the VNOS questions were coded by a colleague of the researcher familiar in the area on NOS studies and VNOS questionnaire (Krippendorf, 2004).

On completion, this second coding was compared to the researcher-produced coding (Table 4.8) and a average correlation of approximately 85% was determined. The outliers in interpretation were predominantly in the different interpretation of responses that related to the term "study" and descriptions of science inquiry or science as "proof". In a number of coded responses, the colleague added the code for '*A Process*' (Code 4) and/or '*Role of science in providing proof* ' *(Code 2)* as additional to the researcher coding. Below are examples of the different interpretation for the same response:

Table 4.8

Differences in Interpretation

Response	Researcher Interpreted codes	Colleague
Science is investigating (experimenting) designing and making and using technology	3,17,18	3, 4, 17,18
Finding out how things work through knowledge and experiments. Why is it so?	1, 17	1, 2, 17
The study of why and how our universe works the way it does	6	2, 6

It was decided to proceed with the established coding scheme for the pre- and post-test responses for all VNOS questions. The codes were applied to the collated and randomised pre- and post-test responses before the rearrangement of responses into the cohort groups. Table 4.9 below is a *representative* sample of coding:

Table 4.9

Coding of pre- and post-test responses

Respondent	Pre-Test Response	Code	Post-Test Response	Code
ST171290	An understanding and manipulation of forces of nature	1	A method of thinking whereby information is gathered, and given additional meaning.	1, 5, 11

Table continues

Respondent	Pre-Test Response	Code	Post-Test Response	Code
RPA2502	The explanation and discovery of our world and why things happen.	1	Science is the understanding and workings of our world and outer world	1
KM1710	The study of physical phenomenons (sic) and their relationship to each other and the environments in which they are found	6, 10	The investigation of how and/or why things happen in our world. It is the search for answers about events that occur naturally or how to alter these events	1, 6

The number of coded interpreted themes for each question item is shown below in Table 4.10:

Table 4.10

Number of coded themes for each NOS question

Question Item	Number of Coded Themes
Question 1	23
Question 2	25
Question 3	14
Question 4 (b)	16
Question 4 (c)	17
Question 5 (a) and (b)	16
Question 6	18
Question 7	18

Note: The responses to Question 4 (a) *How do scientists know that dinosaurs really existed?* were almost exclusively referencing fossils finds in both the pre- and post- test.

The number of themes was rationalised (Table 4.11) by tallying only those themes that had a more than one instance either at pre- or post-test for the experimental group (Table 4.12) and then tallying the matching themes in the control group even at only one instance. This was done to account for the smaller numbers in the control group.

Table 4.11

Rationalised number of themes

Question Item	Number of Coded Themes	Code Themes > 2
Question 1	23	16
Question 2	25	20
Question 3	14	12
Question 4 (b)	16	15
Question 4 (c)	17	17
Question 5 (a) and (b)	16	16
Question 6	18	16
Question 7	18	15

Table 4.12

Frequency of themes pre- and post-test Question 1

Question 1. Experimental Group		
Theme	PRE	POST
Study of phenomena	20	21
Role of science in explaining phenomena	19	14
Investigating	8	8
How things are connected	6	2
Experimenting	6	6
Technology	3	2
Reasoning	3	1
Analysis	2	1

Table continues

Question 1. Experimental Group	PRE	POST
Testing hypotheses and theories	1	10
Hypothesising	1	7
A body of knowledge	1	1
A way of knowing	1	2
Involves fair-testing	1	4
Observing	1	3
Changeable	0	3
Inferring	0	2

4.2.1 Frequency Charts

A frequency chart was constructed for the percentage occurrences for each coded theme for each group's response to the question item. A frequency chart is used to graphically summarize and display the relative importance of the differences between groups of data. The charts produced display both the differences of tallied themes within a group as well as the differences **between** groups at pre- and post-test.

Each chart represents interpreted themes in teachers' responses to questions on their views on aspects of the nature of science. Shifts in the distribution of those themes were analysed with reference to the different professional development activities experienced by the experimental and control groups. As each group was involved in the same initial workshop, key differences between the two groups were the classroom observations of the five researcher-delivered lessons and the in situ opportunities for questioning and clarification afforded to the experimental group.

The principal nature of science aspects addressed by the five lessons were the role of developing and testing of hypotheses and the notion of fair-testing in experimentation.

Other aspects addressed to a lesser degree were the tentativeness of science and subjectivity and/or bias. Although both the experimental and control were introduced to aspects of the nature of science in the common initial workshops, the aspects outlined above were reinforced to the experimental group through the lessons and informal discussion.

In attempting to develop elementary teacher's confidence to teach science, the lessons and their delivery in situ were designed to demonstrate a pedagogical approach based on scientific inquiry incorporating aspects on the nature of science. In the process of adding to a teacher's pedagogical repertoire, did the lessons contribute a greater knowledge of aspects of the nature of science as evidenced by shifts (if any) in response themes?

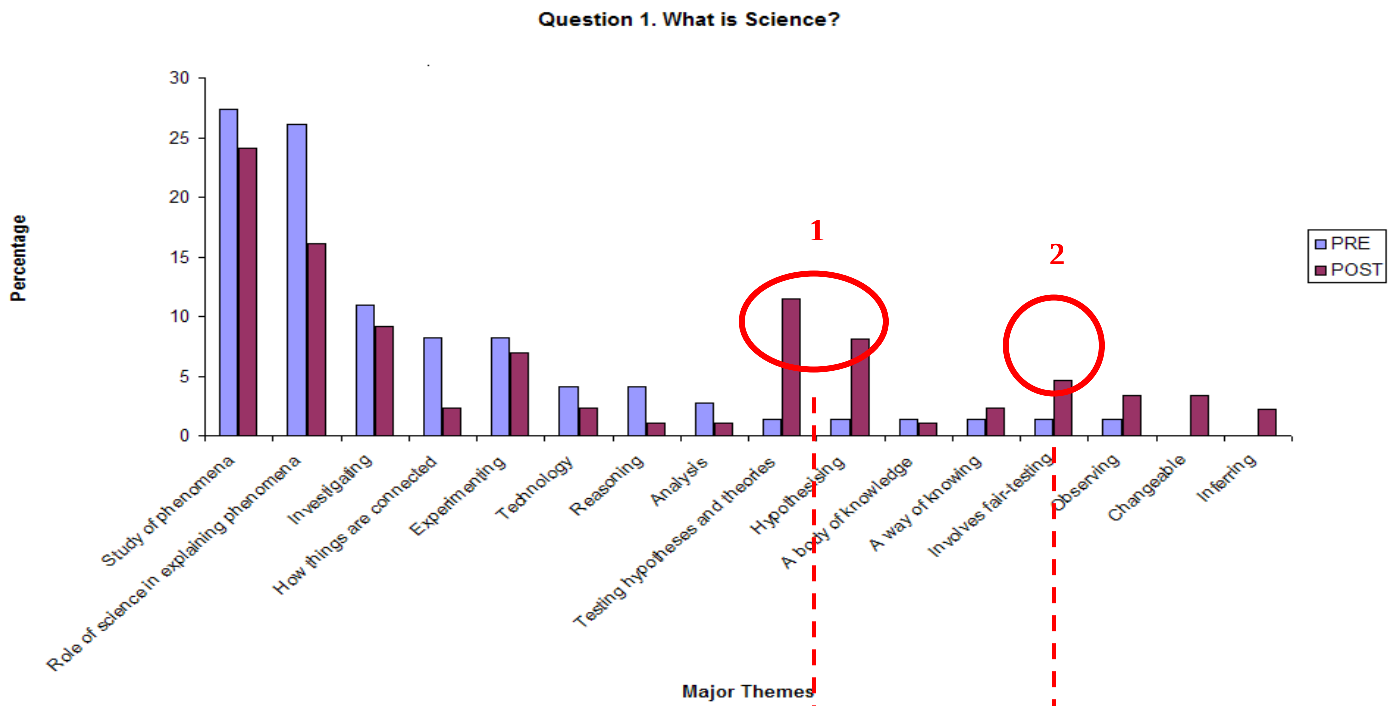
Analysis of the charts begins with a general overview of distribution patterns followed by analysis of highlighted differences within and between the two groups that may be due to some component of the observed lessons. *Where there were no instances of a theme in the responses from either group, these are not recorded on each chart*. Each question in the VNOS-D form has descriptors recommended by Lederman and colleagues (Lederman et al., 2002). As described earlier in Section 4.2.1, these descriptors *and* the teachers' responses were used to identify emergent themes. A abbreviated descriptor is provided at the beginning of each chart and for full descriptors refer to *Views of Nature of Science Teacher Version (VNOS D) (Annotated Scoring Guide)* (Appendix 2).

4.2.1.1 Question 1 What is Science?

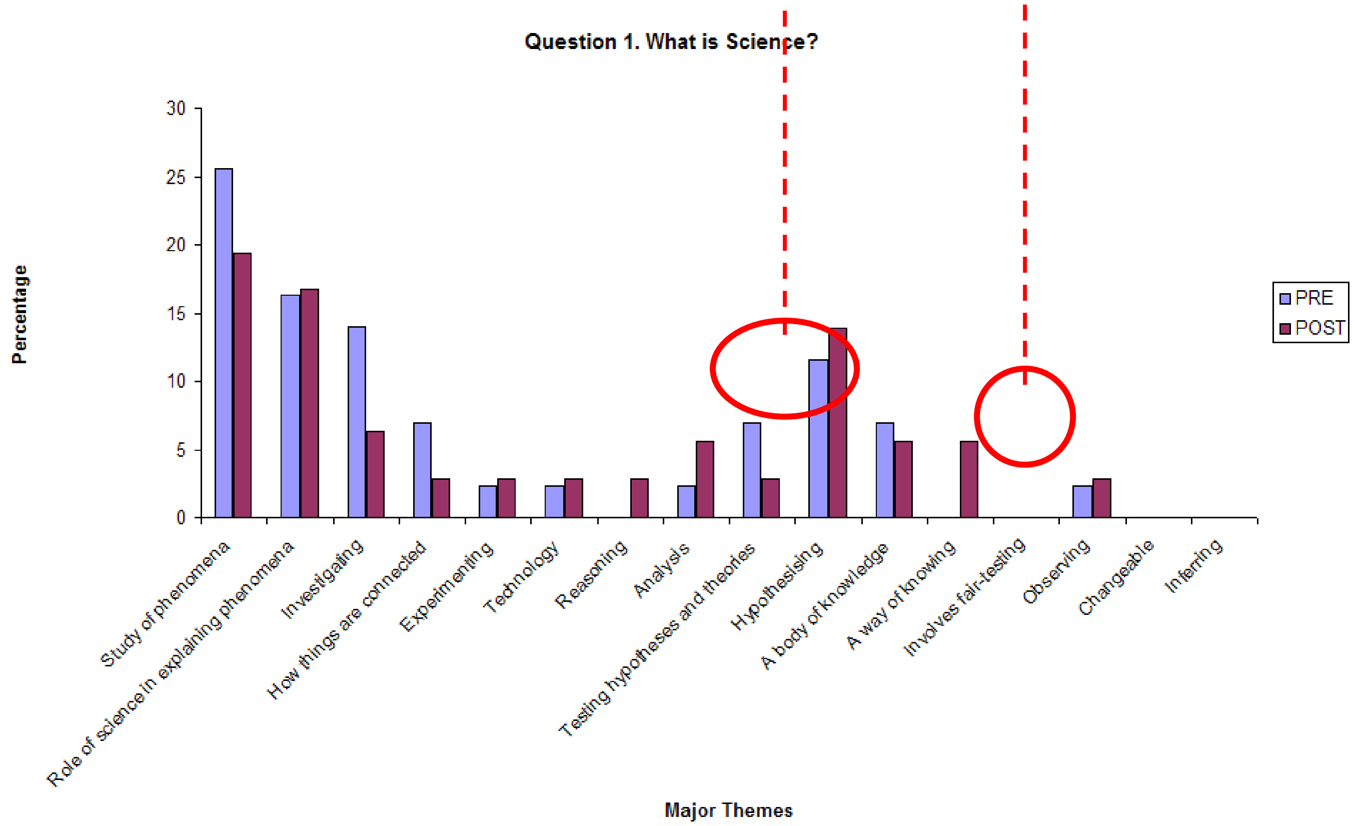
RESPONSE SHOULD INCLUDE REFERENCES TO A BODY OF KNOWLEDGE (OFTEN THE SCIENCE CONTENT TEACHERS ARE CURRENTLY TEACHING) AND PROCESSES (OBSERVING, EXPERINMENTING, ETC.) FOR THE DEVELOPMENT OF THE KNOWLEDGE

Chart 4.1

Experimental Group (n =37)



Control Group (n = 18)



The charts for Question 1 (Chart 4.1) *"What is Science?,* show a similar pre-distribution in both groups for the themes concerning study and explanation of phenomena, investigating and experimenting. These themes are the most popular for both groups although the control group chart shows a higher relative percentage for hypothesising. The responses by those teachers within the control group that made reference to hypothesising also contain the more popular themes as identified in the chart, e.g.

Science is knowledge, learning and understanding about the universe. It's about knowing about all physical aspects of our world/nature. Science is about investigating, researching, questioning, hypothesising, observing etc things in the world. It's about experimenting/testing/making predictions (any more adjectives I can think of?)

The pre- and post-responses in the control group for hypothesising are from the same respondents. There is no new inclusion for this theme in the post-responses:

Table 4.13

Control group example for 'What is Science'

	Pre	Post
HM260475	Good question! The study of how and why things work or happen. Chemistry/physics/biology. Its theory, testing, analyzing and deducing	Investigating, theory, testing and annalising(sic)

There is a marked difference in the post-distribution for hypothesising in the experimental group (Highlight 1). The increased references to creating and testing hypotheses are contained in more complex answers (Table 4.14):

Table 4.14

Test group examples for hypothesising

	Pre	Post
RM0004	Science is the understanding of how the biology, physics and chemistry work connected to the physical world as it is known. My understanding of science is HS (high school) science, 30+ years ago when you worked out of a textbook	It is an inquiry or investigation about an aspect of science that begins in most instances with a hypothesis. This can then be tested and questioned in order to rearrange thoughts/ideas
MF070526	The study of why and how our universe works the way it does	The study of phenomena through hypothesising applying fair tests and reaching informed decisions

Although an outcome for Stage 3 in the NSW syllabus, fair-testing is referenced only by the experimental group. The lessons delivered for observation by this group contained specific strategies to address fair-testing in the design and conduction of investigations. There was no exposition or discussion of fair-testing in the initial teacher workshops.

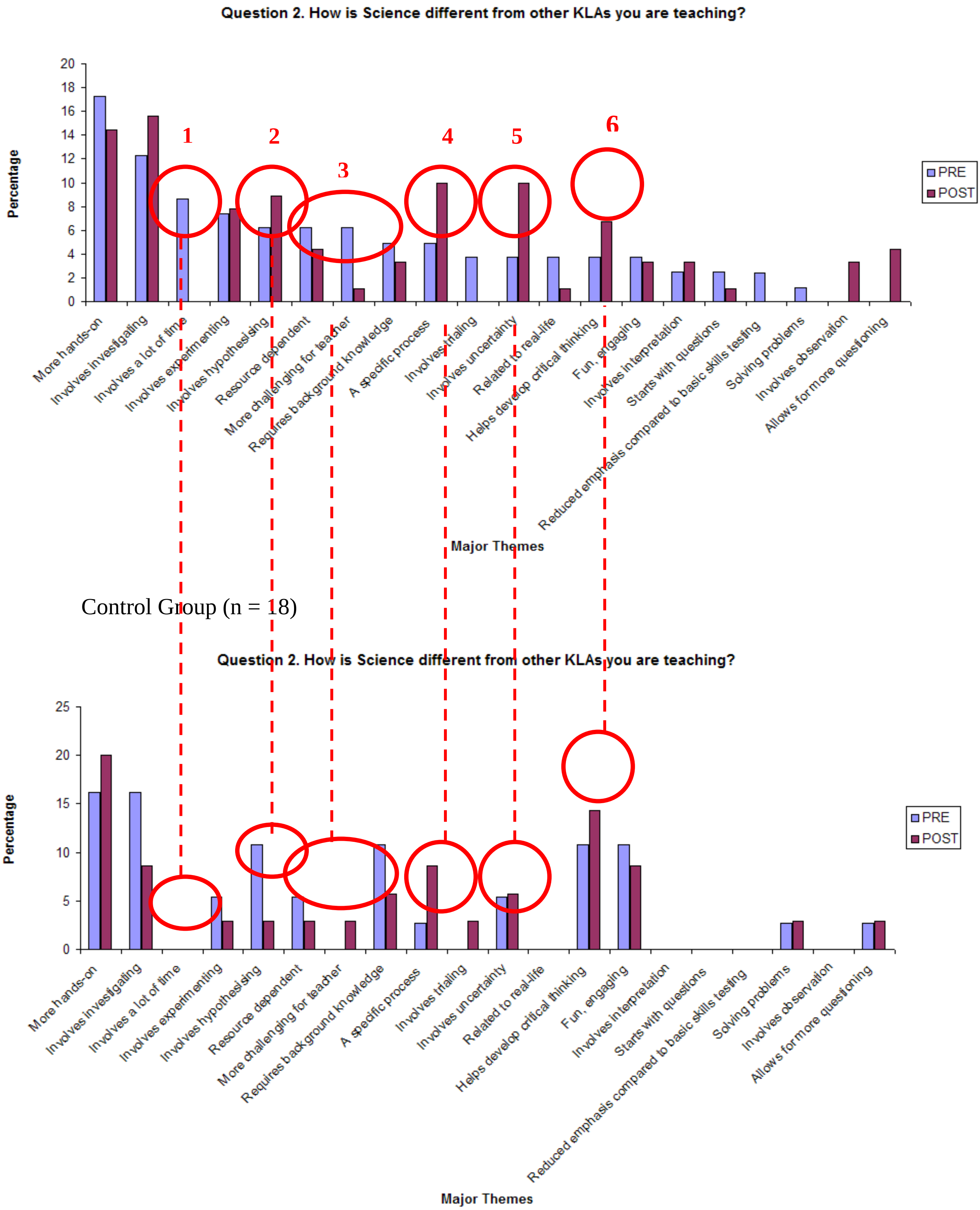
4.2.1.2 Question 2 How is Science different from other KLAs you are teaching?

THE DESIRED RESPONSE SHOULD REFER TO RELIANCE ON DATA FROM THE NATURAL WORLD (EMPIRICAL BASIS), SYSTEMATIC OR ORGANIZED APPROACH TO COLLECTION OF DATA. IT IS ALSO COMMON FOR TEACHERS TO FOCUS ON THE SPECIFIC SUBJECT MATTER OR OBJECTS OF SCIENCE'S ATTENTION.

TEACHERS MAY INCORRECTLY STATE THAT SCIENCE FOLLOWS A SINGLE METHOD (THE SCIENTIFIC METHOD)

Chart 4.2

Experimental Group (n = 37)



The responses indicated by Highlight 5 in the charts for Question 2, *"How is Science different from other KLAs you are teaching?"* make reference to the NOS aspect of tentativeness. Specific questioning in the lesson plans and utilised during the demonstration lessons observed by the experimental group included:

Do scientists sometimes have to change their ideas? Why?

What happens to an idea when scientists do more experiments and find new information that doesn't fit that idea?

This particular NOS aspect was addressed only in the lessons observed by the experimental group. The increased percentages for this group represent responses from 12 individuals, almost 1 in 3 for this group. The percentages for the control group represent responses from 2 individuals, 1 in 10 for this group. There is also a corresponding post-test increase in the experimental group for the theme of *Allows for more questioning.* This may refer only to a pedagogical approach rather than a NOS aspect but taken in tandem with the increases for the theme *Involves uncertainty* may also indicate the importance for teachers to experience the classroom strategies that enhance NOS aspects.

Highlights 1 (experimental group only) and 3 in the pre-test distribution are indicative of the perceived barriers to the teaching of science in elementary school. Teachers' insufficient science background knowledge, dependence on appropriate resources and the time required for preparation and conduction of investigations are three of the major restraints identified by elementary classroom teachers in the teaching of science:

> The knowledge needed is more specific which makes me feel less qualified. It takes more time to gather resources and set up lessons for hands on experiments.

Although not addressing aspects of the nature of science, the experimental group's post-distributions for time and teacher demands indicate of a shift in the experimental group's attitudes to these barriers.

Both the experimental and control groups demonstrate a higher post-test view of science as *A specific process* (Highlight 4). This indicates that future studies be modified to instruct teachers that the pedagogical approach being modelled in both the workshops and lessons is not **the** scientific method but rather a specific approach to scientific inquiry in their classrooms. As part of a future professional development package, some discussion on the role of thought experiments in science could be included.

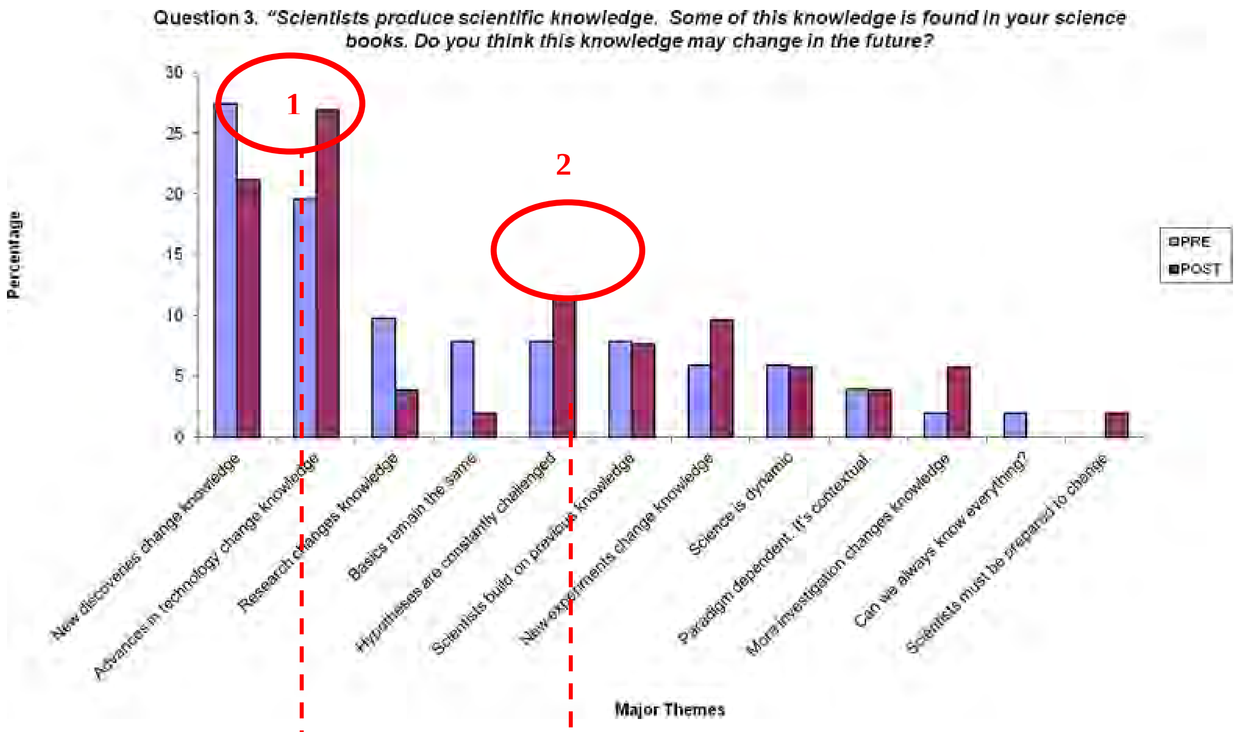
There is a decrease in the control group post-test for the theme *Involves hypothesis* (Highlight 2) with corresponding increase in the theme of science as a specific process. The experimental group maintains the percentage for hypothesis at post-test. Without the experience of the observed lessons in which questioning and generating ideas are significant strategies, the control group may have taken from the initial workshop a mechanistic view of the demonstrated strategies.

4.2.1.3 Question 3 Scientists produce scientific knowledge. Some of this knowledge is found in your science books. Do you think this knowledge may change in the future?

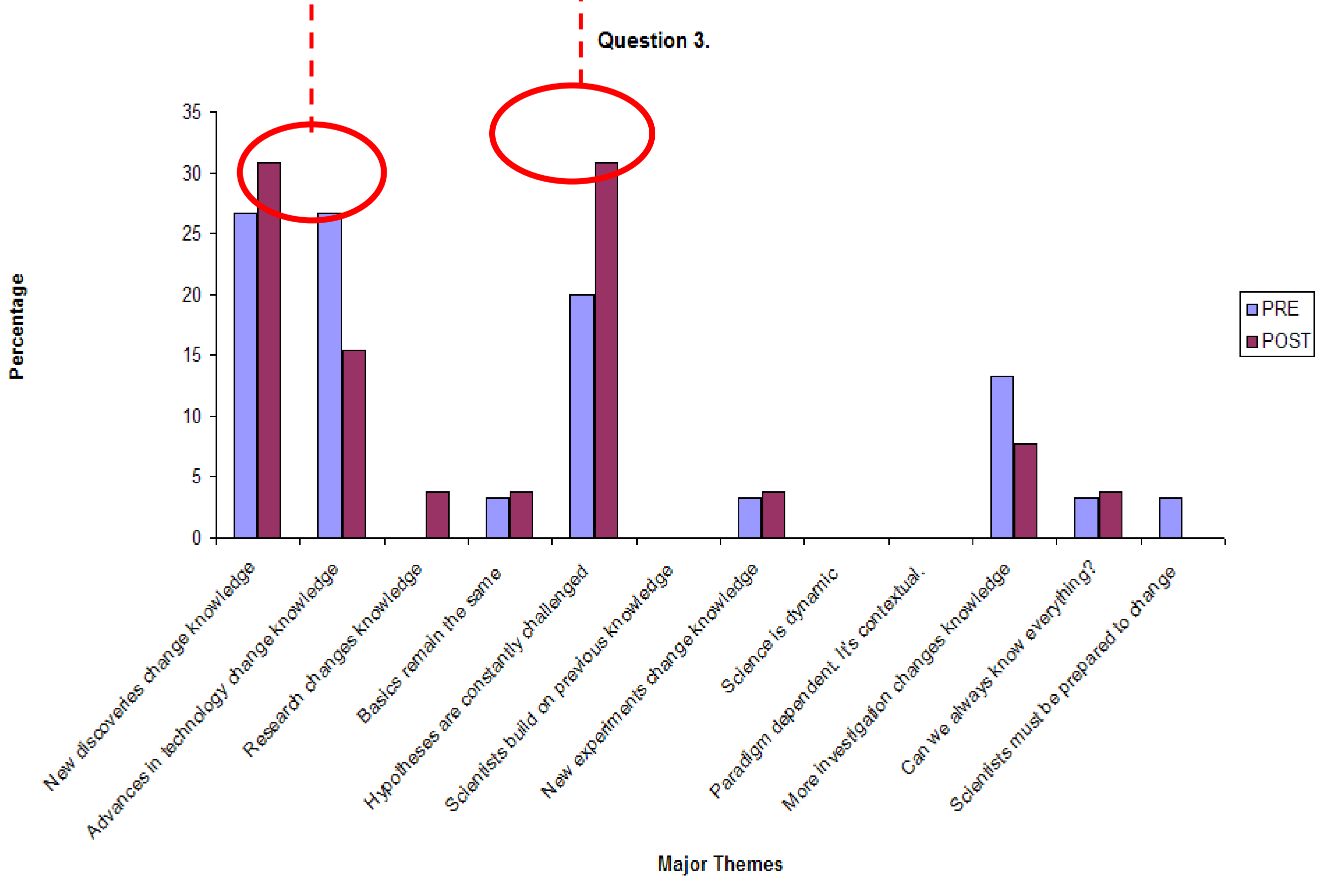
THIS QUESTION FOCUSES ON THE IDEA THAT ALL SCIENTIFIC KNOWLEDGE IS TENTATIVE OR SUBJECT TO CHANGE. SO, YOU ARE LOOKING FOR THE TEACHER TO AGREE THAT THE KNOWLEDGE IN THE TEXT WILL POSSIBLY CHANGE.

Chart 4.3

Experimental Group (n = 37)



Control Group (n = 18)



The two themes on changing knowledge (Highlight 1) in both charts for Question 3, *"Scientists produce scientific knowledge. Some of this knowledge is found in your science books. Do you think this knowledge may change in the future? Explain your answer and give an example."* may be indicative of the combination of science and technology in the NSW K-6 syllabus. Both groups see technology as playing an important role in building science knowledge, a theme that may not be as prominent in responses by teachers using a science-specific syllabus.

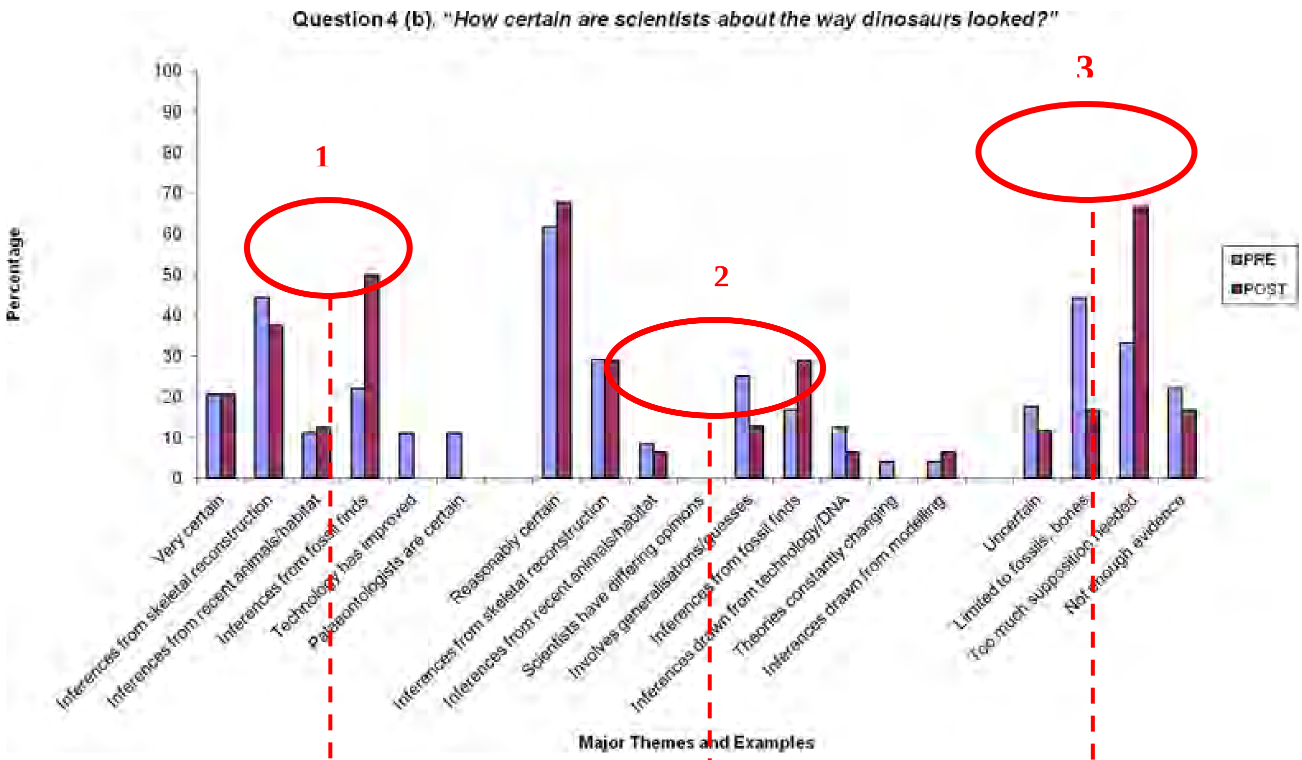
Although there is a broader range of themes from the experimental group, both groups indicate an awareness of the dynamic nature of science knowledge. Referring back to the responses for Question 2 referencing tentativeness, the experimental group show a shift away from the constancy of knowledge (Highlight 2) as knowledge is revised rather than simply added to by new discoveries.

4.2.1.4 Question 4 (b) How certain are scientists about the way dinosaurs looked?

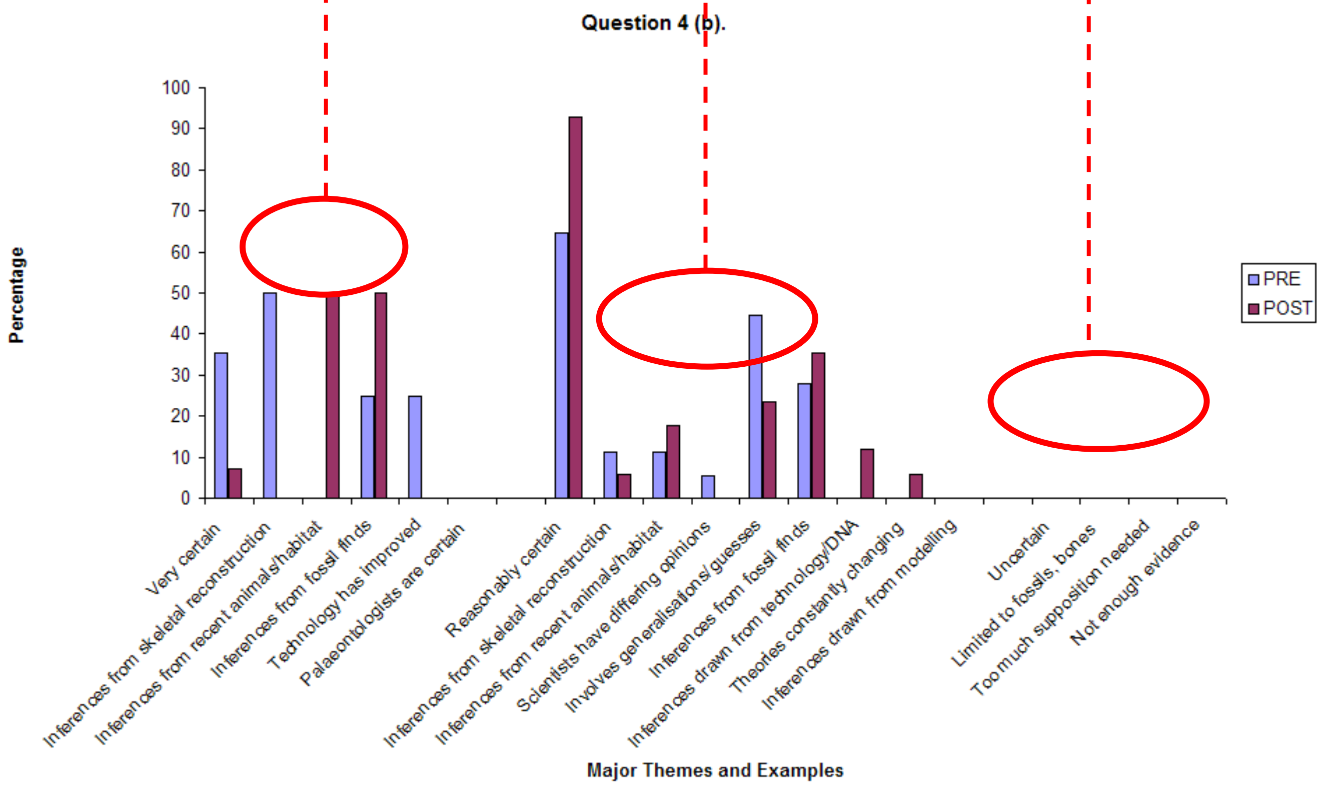
THE FOCUS HERE IS ON OBSERVATION AND INFERENCE AND EMPHERICAL NATURE OFF SCIENCE. A SOPHISTICATED, BUT UNCOMON ANSWER WOULD INCLUDE THAT SCIENTISTS HAVE SOME DATA ABOUT DINOSAURS AND HAVE INFERRED FROM THIS DATA THAT CREATURES DEFINED AS "DINOSAURS" EXISTED.

Chart 4.4

Experimental Group (n – 37)



Control Group (n = 18)



Although no charts were created for Question 4(a), “*How do scientists know that dinosaurs really existed?”* the overwhelming theme of fossil evidence can be combined with both groups responses to Question 4(b), “*How certain are scientists about the way dinosaurs looked?”*

Combining the percentages for the themes for inference (Highlights 1 and 2) in both charts for Question 4(b) indicate similar awareness in both groups of the importance of inference in interpreting appearance from fossil finds.. Many teachers in both groups also referred to the role of inferring from the appearance and behaviour of modern animals:

> Not very - can only go by skeleton remains and what they deduce from like animals today.
>
> Fairly, using present day biological knowledge, physiology of present day animals, habitat, eating habits etc, fossil reconstruction.

The NSW K-6 syllabus makes reference to inference in the Learning Processes strand:

> Students will be required to propose explanations for discoveries they have made.
>
> A proposed explanation or inference involves providing a tentative explanation for an observation or set of observations.

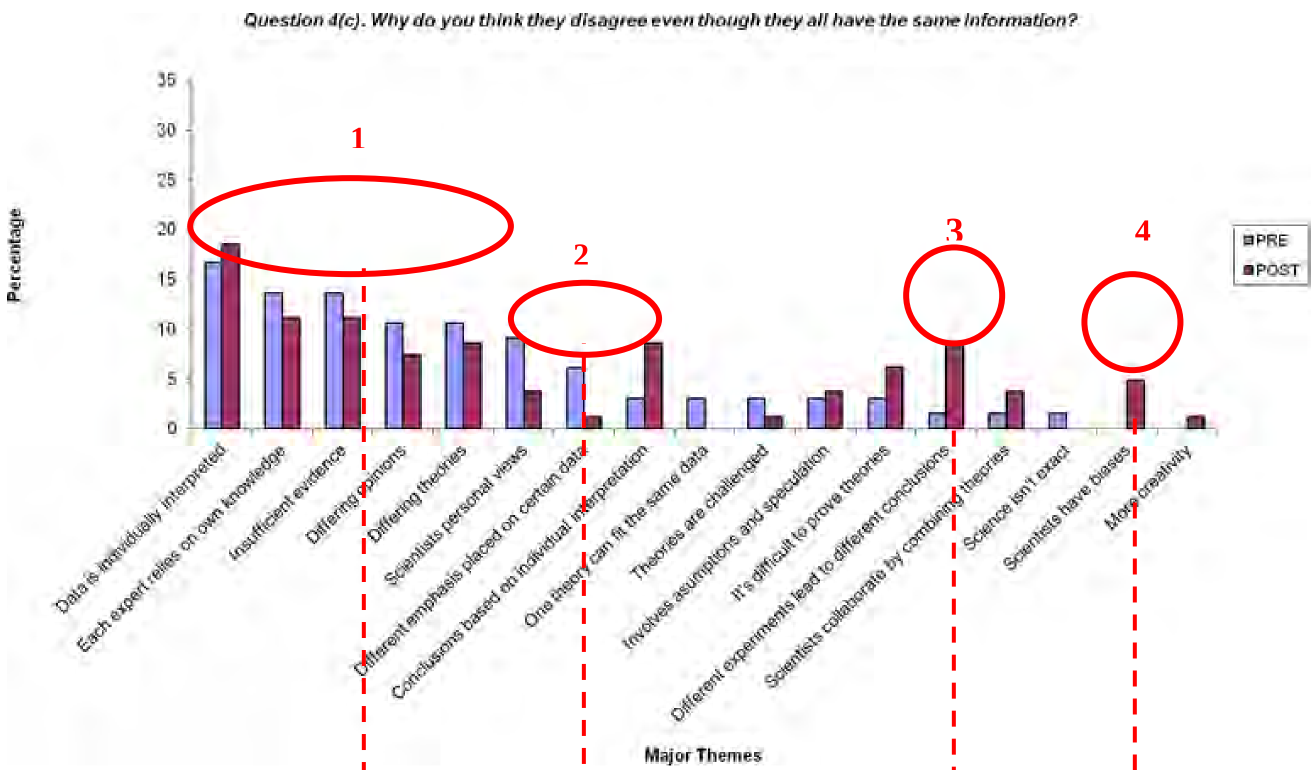
There are no specific skill or investigation outcomes for inference in any of the three Stages across K – 6. Even without this specific attention in the syllabus, this NOS aspect was evident at both the pre- and post-test for both groups. As well, the post-test responses show an absence of *Uncertain* response themes for both groups. The only supporting theme that may explain this distribution could be the idea both groups hold that science develops critical thinking (Highlight 6, Chart 4.2).

4.2.1.4 Question 4 (c) Why do you think they disagree even though they all have the same information?

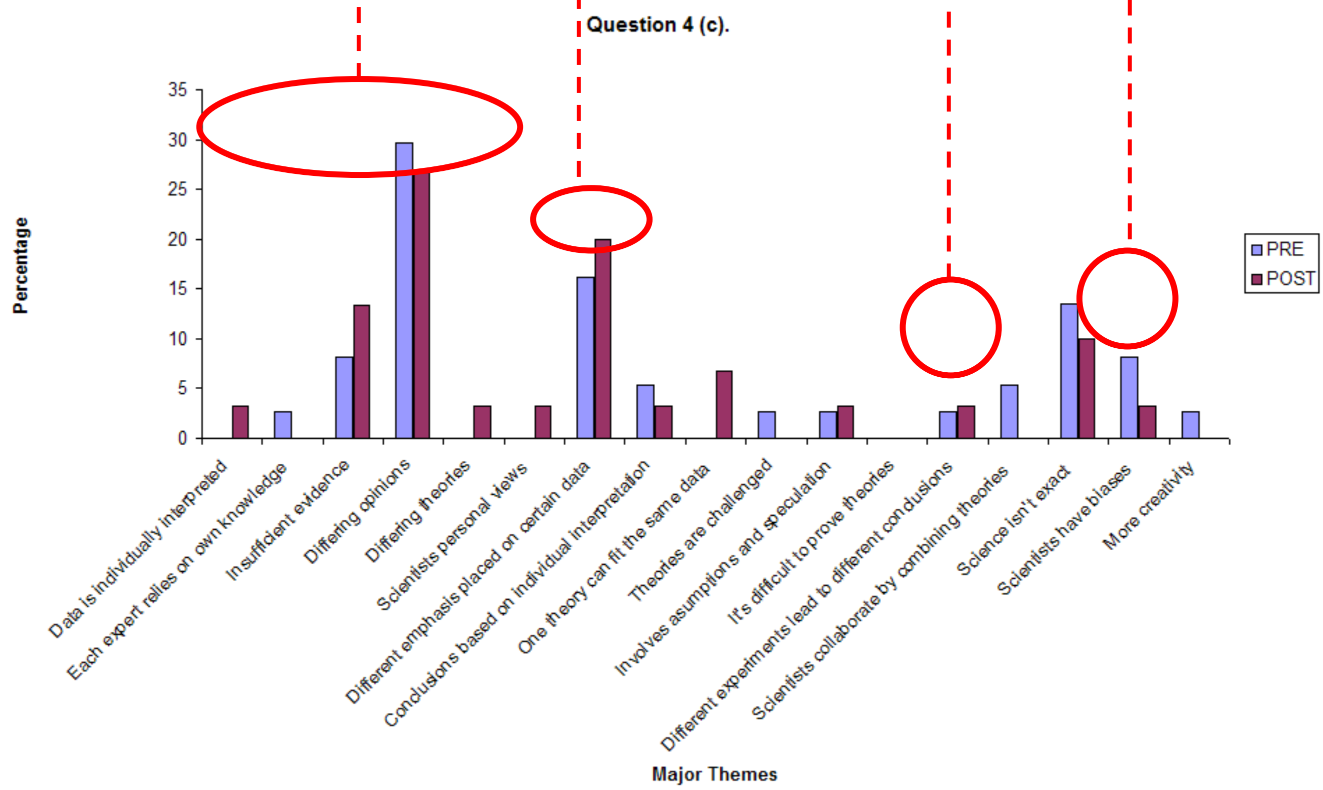
THIS QUESTION REFLECTS TEACHERS' VIEWS ABOUT THE SUBJECTIVE AND TENTATIVE NATURE OF SCIENCE. THE DESIRED RESPONSE WOULD BE THAT DIFFERENT SCIENTISTS BRING DIFFERENT BACKGROUNDS AND DIFFERENT BIASES TO THE INTERPRETATION OF DATA.

Chart 4.5

Experimental Group (n =37)



Control Group (n = 18)



The observed lessons delivered to the experimental group made specific references to subjectivity and bias. The specific questions on subjectivity utilized in the lessons were:

Why did some of us not want to change our hypothesis?

Did some of you see what you only wanted to see?

Can what we believe affect how we observe things?

Can scientist be biased about their ideas?

Is this a good thing?

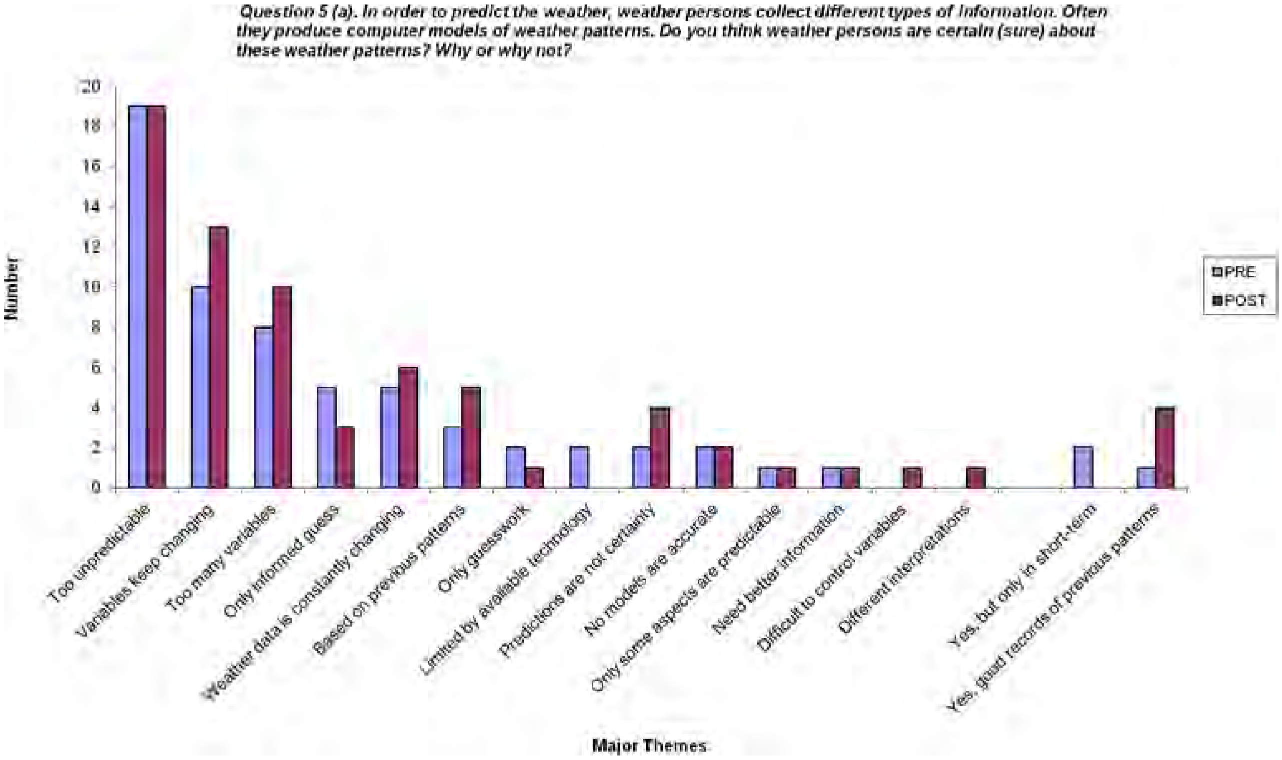
The workshops attended by both groups made no mention of these NOS aspects. The chart highlights for Question 4(c), "*Why do you think they disagree even though they all have the same information?*" show clear differences between the groups in the both distribution and ranked (percentage) importance of themes addressing these NOS aspects at pre-and post-test, but in general, the experimental and control groups have maintained their pre-test ideas

4.2.1.5 Question 5 In order to predict the weather, weather persons collect different types of information. Often they produce computer models of weather patterns. Do you think weather persons are certain (sure) about these weather patterns? Why or why not?

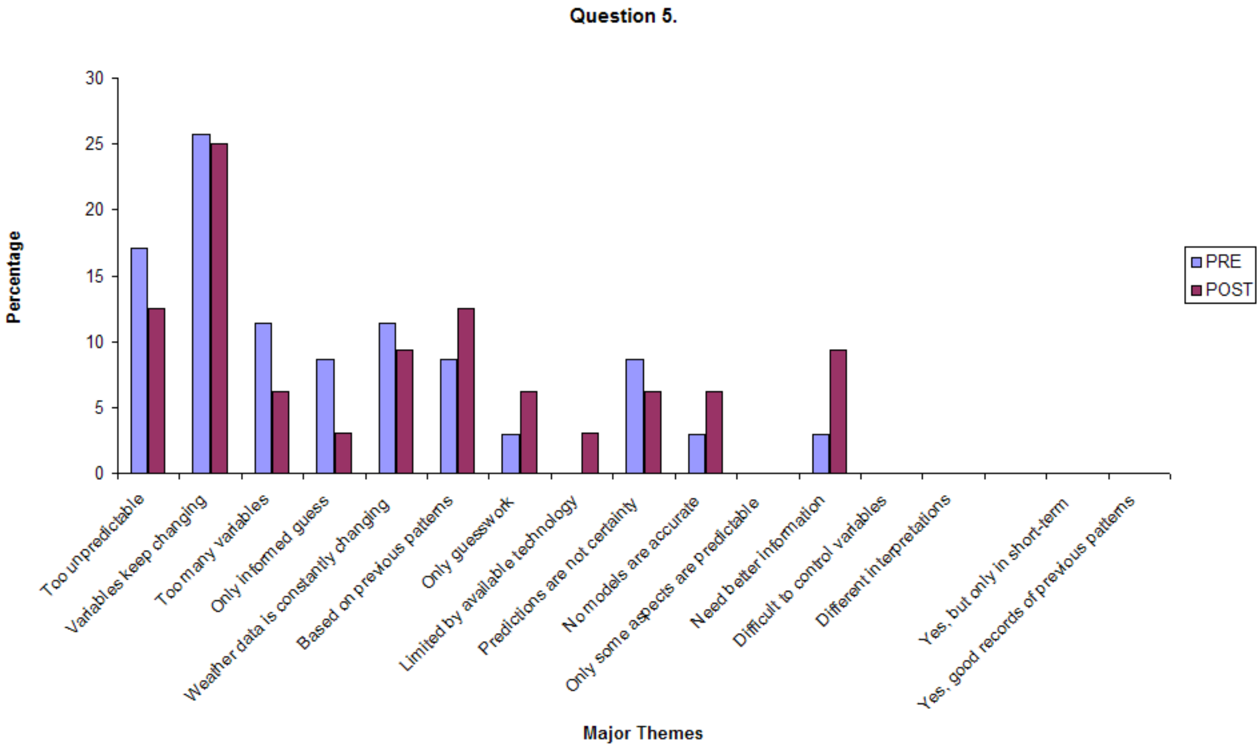
THIS QUESTION IS LOOKING FOR IDEAS ABOUT OBSERVATION AND INFERENCE AND TENTATIVENESS. AGAIN AND YOU WOULD BE LOOKING FOR ANSWERS SIMILAR TO THOSE IN QUESTION #4. ONLY THE CONTEXT OF THE QUESTION IS DIFFERENT.

Chart 4.6

Experimental Group (n =37)



Control Group (n = 18)



The charts for both groups for Question 5, "*Do you think weather persons are certain (sure) about these weather patterns? (b) Why or why not?*" show few differences in distribution and ranked (percentage) importance of themes at pre-and post-test. There appears to be a good understanding in both groups of weather forecasts being prediction-based, requiring knowledge of previous weather events and limited by the large numbers of impacting variables.

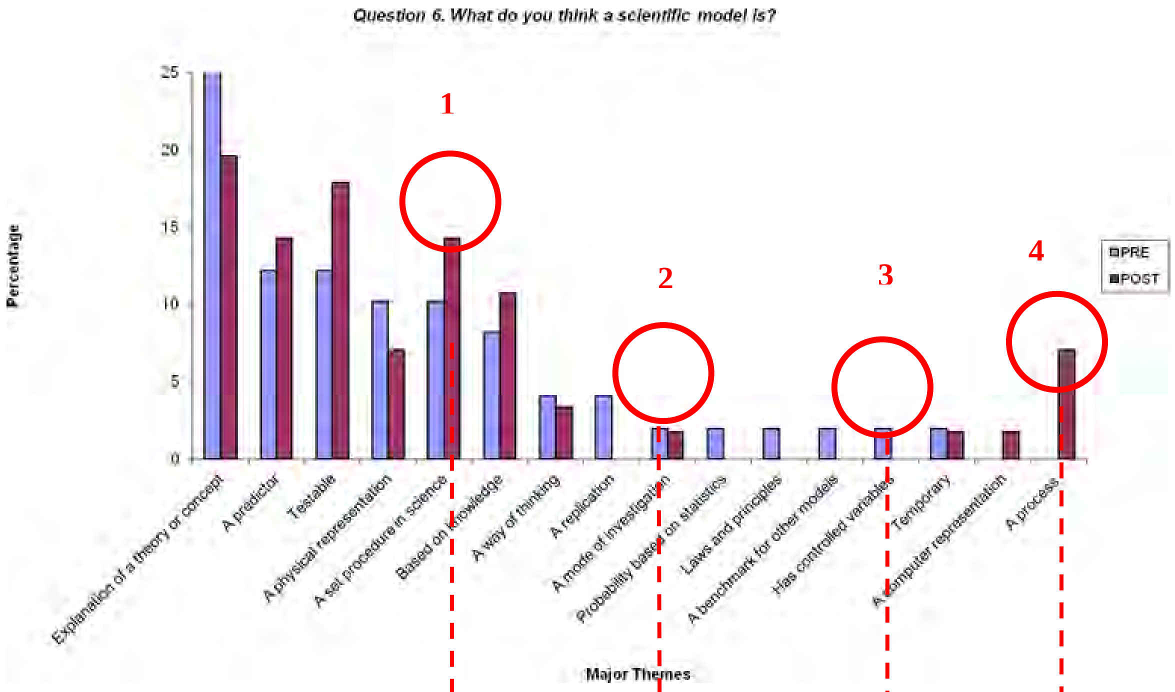
This question is intended to elicit ideas about inference and tentativeness and is a companion to Question 4. The high occurrences for inference themes in the responses to Question 4 (b) are supported here but the responses on the aspect of tentativeness relate more to the uncertainty of the available data rather than the challenging of existing ideas by new interpretations or development in technology.

4.2.1.6 Question 6 What do you think a scientific model is?

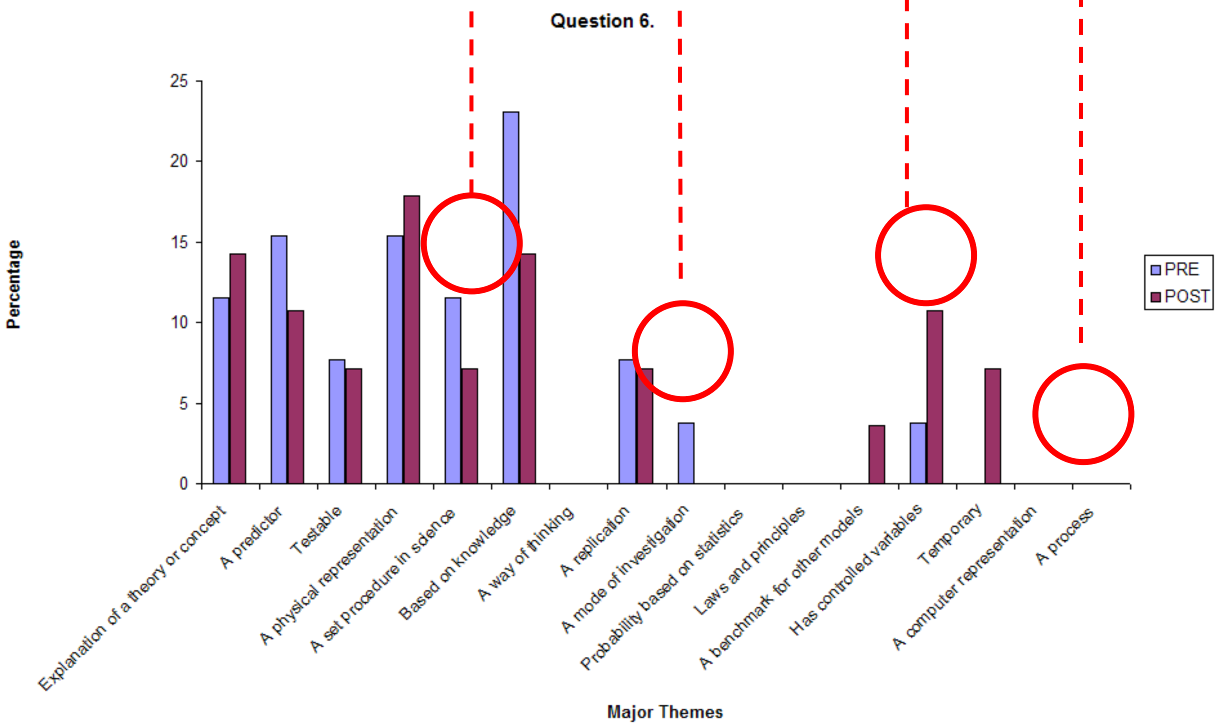
THIS QUESTION FOCUSES ON THE ROLE OF OBSERVATION AND INFERENCE, BUT ALSO MAY PERMIT YOU TO GATHER DATA ON TEACHERS' UNDERSTADNING THAT A MODEL IS AN INFERENCE THAT IS NOT "REAL" OR NOT AN EXACT COPY OF NATURE

Chart 4.7

Experimental Group (n =37)



Control Group (n = 18)



The charts for Question *6. What do you think a scientific model is?* Demonstrate commonality across both groups for the main interpreted themes. Models are seen as explanatory and predictive. Both groups describe models as largely physical constructs in either materials or 3D computer generation:

> Something in 3D that is able to demonstrate an idea/theory/occurrence visually.
>
> A 3D representation to explain/describe something. Could be 3D but on computer as well.
> A physical representation of a phenomenon from our world.

The written responses from which the themes of *Testable, A Set Procedure in Science and A Process* were interpreted indicate that teachers also equate models with scientific inquiry. This involves a step by step process of hypothesising, experimentation, fair-testing (Highlight 2) and formulating conclusions:

> Hypothesis → experiments → conclusion
>
> Begins with a hypothesis, 10,000+ controlled experiments - a scientific model
>
> Idea/Theory - hypothesise - investigate - test - analyse - report. The process of 'learning'. (Hands on)

The increased post-test occurrences for the procedural nature of models (Highlights 1 and 4) may indicate some confusion within the experimental group between scientific models and the modelling of a pedagogical approach. This follows the same pattern for this group’s increased responses in the charts for Question 2 for science having *A set process* (Highlight 4, Question 2)

The Lederman descriptors provided for this VNOS question state that responses should refer to the role of observation and inference and that models are not “real”. Deeper responses should refer to the role of creativity and subjectivity in creating models; that models are tentative.

Whilst there is support in both group responses for models being “not real”, there was only one response that made reference to both the subjectivity and hence tentativeness of models:

> A scientific model is an explanation of how something works. It is supported by "information and opinion", which can change the model as "it" changes.

There was no instruction or materials provided to either group on the creation and role of models in science. This particular aspect of the nature of science was not addressed in the workshops or lessons in this study. The charts show little to no shift in either group towards the deeper responses sought for by the descriptors for this VNOS question.

Whilst there is support in both group responses for models being “not real”, there was only one response that made reference to both the subjectivity and hence tentativeness of models:

4.2.1.7 Question 7 Scientists try to find answers to their questions by doing investigations/experiments. Do you think that scientists use their imagination and creativity when they do these investigations/experiments?

THIS QUESTION RELATES BACK TO TEACHERS’ UNDERSTADNING OF WHY SCIENCE IS TENTATIVE AND HOW CREATIVITY, SUBJECTIVITY, AND INFERENCE PERMEATE ALL OF SCIENCE.

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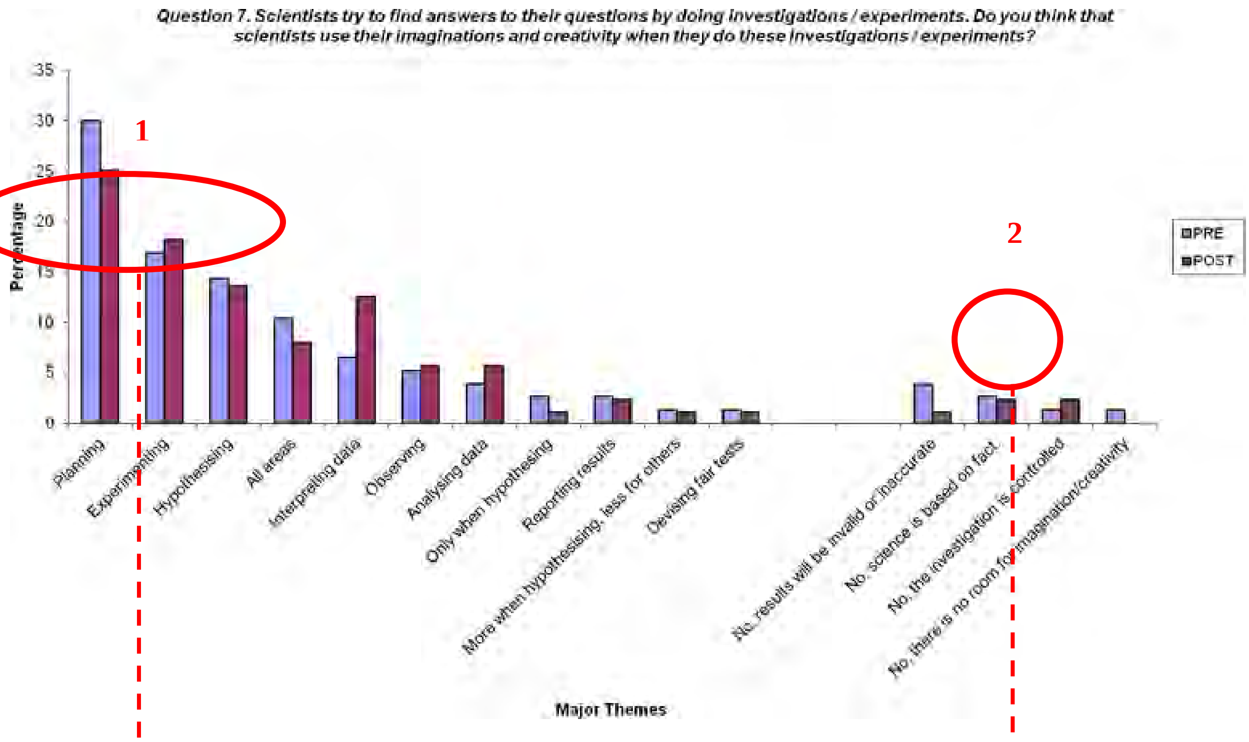
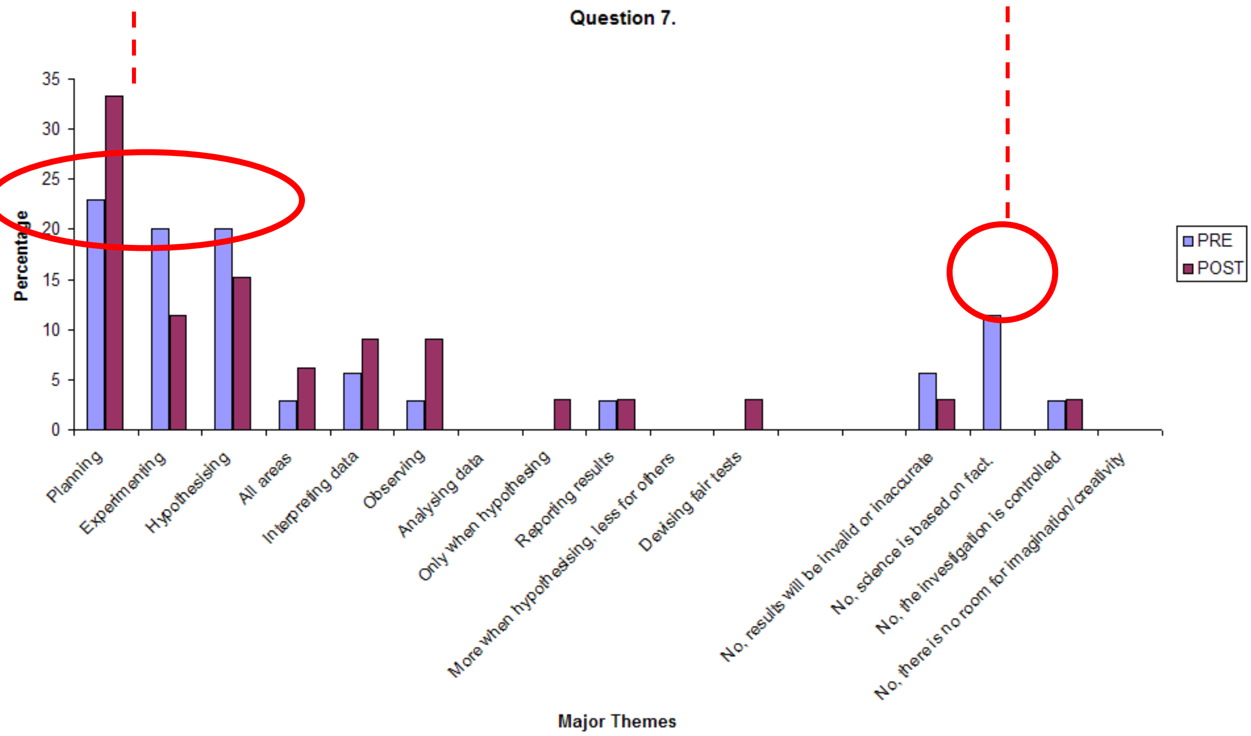
Chart 4.8

Experimental Group (n =37)



Control Group (n = 18)



The high percentage of responses for *Planning* in Highlight 1 in both charts reflect the expected less-developed understanding as outlined in the descriptors for Question 6*: Most will only understand, or at least say, that scientists use their creativity and imagination in the planning of investigations.* But the percentages for the themes of *Experimenting* and *Interpreting Data* indicate that teachers in this study have a more developed awareness of the role of creativity and imagination than that provided in the descriptors: *Few will tell you that scientists use creativity and imagination during an experiment/investigation and in the interpretation of data and reporting of results.*

The post-test results for both groups show a small increase for *Interpreting Data* and *Observing*, but overall the teachers' responses for Highlight 1 are relatively stable. These NOS aspects were not specifically targeted by the workshops or lessons.

Highlight 2 shows a shift for *No* respondents in the control group away from a fact-based driven investigative approach towards greater use of creativity and imagination. The decrease in percentages for the *No* theme of *No, science is based on fact*, is matched by increases in the themes for creativity and imagination use in *Planning, Interpreting Data* and *Observing.* As there were no specific strategies for any group to elicit ideas on creativity and imagination, the decrease in a fact-based view may be related to a shift in the control group's view on the challenging of hypotheses as shown in the charts for Question 3.

4.3 Summary of Charts

The purpose of constructing frequency charts to the VNOS-D form was to investigate and identify *emergent* themes in teachers' responses. A quantitative analysis of the themes was limited by the small number of responses to some themes. However, this limited quantitative analysis may provide trends in themes that can be explored in later professional development programs.

From the charts reproduced here, there are some emergent themes worth commenting on. Both the experimental and control group demonstrate an awareness that science is the study and explanation of phenomena (Chart 4.1), involving experimentation/investigation (Chart 4.2) and hypothesising (Chart 4.1). An interesting theme for both groups is the notion that science is a specific process (Highlight 4, Chart 4.2). It is possible that the teachers may think the structure of the lessons both at the initial workshop and then in the intervention phase is *the* and *only* scientific method involving a hands-on investigative process. The idea of a process driven approach is also present in the experimental groups' responses for a scientific model (Highlights 1 and 4, Chart 4.7).

Themes from both groups on the tentativeness of scientific knowledge (Highlights 1 and 2, Chart 4.3) are strongly present both at pre- and post-test and the notion of bias has only limited reference. Although specifically targettted in the intervention lesson, the experimental teachers in general show no real increased awareness of this NOS tenet over the control group.

A number of NOS ideas that do appear to show some impact by the intervention lessons for the experimental group are: *Testing hypotheses and theories* (Highlight 1, Chart 4.1), *Allows for more questioning* (Highlight 5, Chart 4.2) and *Different experiments lead to different conclusions* (Highlight 3, Chart 4.5). At post-test the trend for the frequency of the theme for science as being more challenging for the teacher (Highlight 3, Chart 4.2) shows a marked drop. There is also an increase in their overall mean for the SETAKIST questions on teaching efficacy that include:

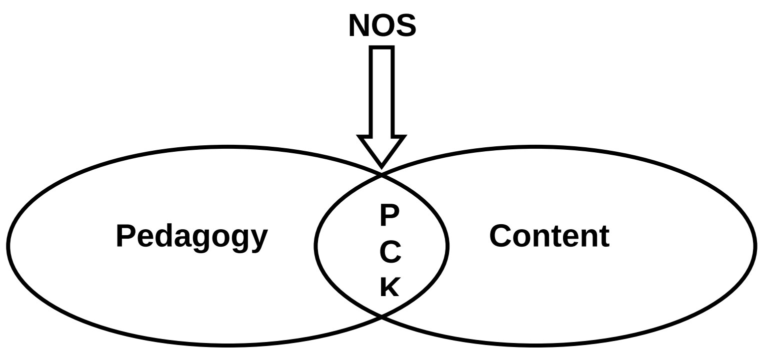
1. When teaching science, I usually welcome student questions.

3. I am typically able to answer students' science questions

This may indicate that the experimental group have identified questioning during science lessons playing an important role and their confidence in asking questions have increased. Further statistical analysis on the individual SETAKIST questions could give supporting evidence to this contention.

4.4 Pendulum Knowledge and Understanding

Recalling the theoretical framework on which this study is based, a teacher's pedagogical content knowledge is the integration of pedagogical practice and subject matter knowledge:



A contention of this thesis is that situating science matter knowledge in a pedagogical approach focussing on aspects of the nature of science will contribute to increased teacher efficacy for science knowledge. The lessons presented as researcher-delivered (reform) and workshop-delivered (standard) in the PD program were designed to address teachers' NOS understanding as a critical component of their scientific literacy. The context within which this understanding was to be developed was based on concepts of pendulum motion. Therefore, a measure of teacher knowledge of this particular area of science subject matter knowledge may indicate differences between the outcomes of the two professional development approaches.

Concepts addressed in the pendulum questionnaire are shown below (Table 4.15) along with the section of the PD program where they were presented to participants:

Table 4.15

Concept covered by Question and Lesson

Pendulum Concept	Questions	Lesson	Workshop	Factsheet
Mass, Air Resistance	1, 8	Yes	Yes	No
Gravity	2, 3, 4, 6, 7	Yes	Yes	No
Length	5	Yes	Yes	No
Angle of Release	9	Yes	No	No
Energy	10	Yes	No	No
Early Greeks, Galileo	11, 12	No	No	Yes
Pendulum and Sea Voyages	13, 14	No	No	Yes

As part of the mixed-method approach taken for this thesis, quantitative methods were applied to the participants' responses to the developed questionnaire. Interpretation of the quantitative results was then conducted to determine patterns (if any) between the responses from the two groups. A limited quantification (raw percentages) was conducted and presented for each question, combined with statistical analysis of the total questionnaire and the individual concepts by question(s).

4.4.1 Quantitative analysis and Interpretation

An analysis of variance (ANOVA) was conducted for the mean scores of the experimental and control groups for a) correct responses (Table 4.16), b) incorrect responses (Table 4.17), c) difference between correct and incorrect (Table 4.18), and d) unsure (Table 4.19). There are three less respondents from the experimental group (N = 34) due to incomplete and/or non-submission at the post-test.

4.4.1.1 Overall Responses

Table 4.16

Overall Correct Responses to Pendulum Questionnaire

	Group	Mean	SD	N
Correct Pre	Exp	6.26	5.72	34
	Control	8.89	4.61	18
	Total	7.17	5.47	52
Correct Post	Exp	13.15	3.29	34
	Control	10.89	4.14	18
	Total	12.37	3.73	52

The ANOVA for time showed a significant effect on correct responses $F\ (1, 50) = 35.671$, $p < 0.001$, indicating increases for both test and control groups. The ANOVA for group effect showed a significant effect $F\ (1, 50) = 10.78$, $p = 0.002$, indicating that the experimental group demonstrated significant increase in correct responses over the control group. There was no significant differences between the variability of the test and control groups, $F\ (1, 50) = 0.027$, $p = 0.869$.

Table 4.17

Overall Incorrect Responses to Pendulum Questionnaire

	Group	Mean	SD	N
Incorrect Pre	Exp	4.09	4.07	34
	Control	5.78	4.11	18
	Total	4.63	4.13	52
Incorrect Post	Exp	8.03	2.96	34
	Control	7.33	4.38	18
	Total	7.79	3.49	52

The ANOVA for time showed a significant effect on incorrect responses F (1, 50) = 14.502, p < 0.001, indicating increases for both test and control groups. The ANOVA for group effect fell outside the level of significance F (1, 50) = 2.808, p = 0.100. There was no significant differences between the variability of the test and control groups, F (1, 50) = 0.396, p = 0.532.

Table 4.18

Differences between Correct and Incorrect Responses

	Group	Mean	SD	N
Difference Pre	Exp	2.47	4.84	34
	Control	3.06	4.76	18
	Total	2.67	4.77	52
Difference Post				
	Exp	5.12	5.03	34
	Control	3.50	6.51	18
	Total	4.56	5.58	52

The ANOVA for time showed no significant effect on differences between correct and incorrect responses F (1, 50) = 2.422, p = 0.126. The ANOVA for group effect showed no significant effect F (1, 50) = 1.229, p = 0.273. There was no significant differences between the variability of the test and control groups, F (1, 50) = 0.202, p = 0.655.

Table 4.19

Changes in total Unsure Responses

	Group	Mean	SD	N
Unsure Pre	Exp	14.71	8.54	34
	Control	9.67	7.13	18
	Total	12.96	8.36	52
Unsure Post	Exp	3.71	3.82	34
	Control	6.06	5.20	18
	Total	4.52	4.44	52

The ANOVA for time showed a significant effect on the number of unsure responses F (1, 50) = 44.481, $p < 0.001$, indicating decreases for both test and control groups. The ANOVA for group effect showed a significant effect F (1, 50) = 11.375, p = 0.001, indicating that the experimental group demonstrated significant decrease in the number of unsure responses over the control group. There was no significant differences between the variability of the test and control groups, F (1, 50) = 0.761, p = 0.387.

The significant reduction in the number of unsure responses (Table 4.19) for both groups reflects the increased knowledge efficacy scores (from the SETAKIST instrument (See section 4.1.2).

Both groups demonstrate an increased preparedness (confidence) to choose a position on the pendulum concepts addressed in the pendulum questionnaire. There is no way of determining from the SETAKIST scores whether the increased efficacy for knowledge in due to increased knowledge of NOS aspects or pendulum aspects or a combination of both.

Table 4.20

p-values for Correct, Incorrect and Unsure Responses

Variable	Time	Group effect
Correct Responses	< 0.001	0.002
Incorrect Responses	< 0.001	0.100
Changes in total Unsure Responses	< 0.001	0.001

The results of STEAKIST, VNOS-D and the pendulum questionnaire test instruments appear to suggest some consistency in the trend towards increased teacher knowledge and hence teacher knowledge efficacy. An interesting result from this early analysis is then increase in the means for ***both*** incorrect and correct answers within each group, and to identify where the distribution occurred, the questionnaire was further analysed according to the major concepts addressed. This is described below.

4.4.1.2 Overall Responses by Question Theme

In producing the descriptive statistics for each of the experimental and control groups for each theme, the responses were assigned a numerical value of:

- +1 (Correct)
- 0 (Don't Know)
- -1(Incorrect)

For each concept, the percentages of each question and sub-set question (where present) are shown in their relevant tables with an associated table of the mean scores to allow for interpretation of any patterns in participants' responses. *Correct responses in each of the percentage response tables are indicated with an asterisk (*).* The mean scores of the experimental and control cohorts for each concept were determined as the addition of the Correct and Incorrect responses.

4.4.1.2.1 Length

The effect of length on a pendulum's period was a key first lesson at the initial workshop attended by both groups. Teachers were posed the problem of designing a pendulum of a length that would give ten swings in ten seconds (a swing being one pass across). Teachers were given the opportunity to predict a length and then perform the experiment.

The experimental group then observed lessons (See Appendix 3) that directly targeted this relationship. A single question (Question 5) was included in the questionnaire.

Table 4.25

Percentage Responses for Length Question 5

		PRE-TEST			POST-TEST		
		FALSE	DON'T KNOW	TRUE	FALSE	DON'T KNOW	TRUE
5. A metre-long pendulum takes approximately one second to swing away and approximately one second to swing back	***control***	**19.4**	**58.8**	***23.5**	***29.4***	***5.9***	****64.7***
	exp	**11.8**	**64.7**	***23.5**	***8.8***	***2.9***	****88.2***

Table 4.26

Means for Length Question 5

	Group	N	Mean
Total Pre	Exp	34	.12
	Control	17	.06
Total Post	Exp	34	.79
	Control	17	.35

The means demonstrate that the relationship between length and period is well understood by both groups at the post-test. As described in the methodology, this concept was used in the lesson **Hickory, Dickory, Dock** to model for the teachers the pedagogical approach to be used in the subsequent intervention. A substantial portion of the initial workshop was devoted to Galileo's study of the influence of length and the origins of the pendulum clock.

The decision to include *approximately* in the question was taken to account for the quality of the timing devices to be used in the teacher's classroom. All timing was done using the wall clock found in school classrooms. Students were allowed to use personal watches (even utilising the stopwatch function) but only following discussion with the students about the benefits of better technology. Teachers quickly identified the limitations of the wall clock from the initial workshop but this was then used by the researcher to introduce the investigations on mass and the effects of air resistance.

4.4.1.2.2 Mass and Air Resistance

During the initial teacher workshops, teachers investigated various pendulum bob masses using a controlled pendulum length. When limited to timing ten swings only, both heavy and light pendulums were observed to have identical swings. The effect of air resistance was studied by allowing the pendulum to swing until any change in swing was identifiable. A heavy-mass pendulum was able to complete more than fifty swings whereas a light pendulum demonstrated a clear change after twenty swings, and it some cases were allowed to come to rest well before fifty swings.

Each investigation was followed by instruction by the researcher on the pendulum studies conducted by Galileo with reference to the concept of idealisation (See 3.5.4 Initial Workshop).

The first questions discussed with the teachers were *What did happen?* and *What would cause the change in the light-mass pendulum's swing?* The teachers were able to use appropriate terminology such as "friction", "air resistance" to explain their observations but were then asked *What would happen if all impediments were removed?* The researcher described Galileo's observations and explanations in their historical context explaining the use of the term "impediment" rather than "friction" and "air resistance". Two main questions in the questionnaire (Table 4.21) targeted mass and air resistance, with sub-set questions, where relevant, designed to investigate consistency of responses:

Table 4.21

Percentage Responses for Mass and Air Resistance Questions 1, 8

Q 1 Two pendulums have the same shape and size but one had a light mass and the other a heavy mass		PRE-TEST FALSE	PRE-TEST DON'T KNOW	PRE-TEST TRUE	POST-TEST FALSE	POST-TEST DON'T KNOW	POST-TEST TRUE
(i) When released from the same height the pendulums stop swinging at the same time	*control*	***41.2**	**5.9**	**52.9**	****29.4***	***11.8***	***58.8***
	exp	***35.3**	**47**	**17.6**	****55.9***	***0***	***44.1***
(ii) The light-mass pendulum stops swinging earlier than the heavy-mass pendulum because of air resistance	*control*	**64.7**	**11.8**	***23.5**	***52.9***	***5.9***	****41.2***
	exp	**38.2**	**32.4**	***29.4**	***47***	***5.9***	****47***

Table continues

(iii) The heavy-mass pendulum stops swinging earlier than the light-mass pendulum because of air resistance	*control*	***82.3**	**11.8**	**5.9**	****82.3***	***11.8***	***5.9***
	exp	***50**	**38.2**	**11.8**	****82.4***	***8.8***	***8.8***
(iv) Air resistance has no effect on the swing of a pendulum	*control*	***52.9**	**5.9**	**41.2**	****64.7***	***17.6***	***17.6***
	exp	***41.2**	**38.2**	**20.6**	****73.5***	***2.9***	***23.5***
Q8. The shape and size of the bob (the mass hanging on the end of the pendulum) has no effect on the swing of the pendulum	*control*	***52.9**	**29.4**	**17.6**	****47***	***0***	***52.9***
	exp	***32.3**	**44.1**	**23.5**	****47***	***11.8***	***41.2***

Table 4.22

Means for Mass and Air Resistance Questions 1, 8

	Group	N	Mean
Total Pre	Exp	170	0.15
	Control	85	.14
Total Post	Exp	170	.28
	Control	85	-.55

Overall, the mean scores indicate a better understanding in the experimental group that air resistance has an effect on the swing of the pendulum. Analysing the responses by question parts shows that both groups have identified that air resistance has an effect on the swing of the pendulum (Q1 iv), a concept covered for both groups in the initial teacher workshops. But the consequence of this effect on different pendulum masses, sizes and shapes (Q1 i; Q1 ii; Q8) is not well understood. Although both groups are confident (~ 84%) that a heavy-mass pendulum **will not** stop swinging earlier than a light-mass pendulum (Q1 iii), the corollary for the light-mass pendulum indicates some ambiguity in the effect (~45% T/F).

The control group responses for the "ideal" observation expected between a heavy- and light-mass pendulum (Q1 i,) shows a slight variation towards a correct response but the experimental group demonstrates ambiguity in an understanding of the "ideal". This is repeated for the experimental group for the expected observation for a light-mass pendulum (Q1 ii). Some teachers in the experimental group may be responding to the question (Q1 ii) in the post-test as an "expected" Galilean observation, having observed and participated in the Phase 1 intervention lessons where this was specifically included and the concept of idealisation was revisited. It may be possible to account for this by modifying the questionnaire in future studies to include specific questioning on the consequences of removal of impediments on the resultant pendulum swing.

The distribution of responses within each group for the concepts of *Length* and *Mass and Air Resistance* at the post-test is in general quite similar. Both concepts formed the basis of the initial workshops, so in effect, the control group was exposed to an example of the intervention lessons that were to follow for the experimental group. But one of the intervention lessons (not observed by the control group) expanded the investigation of the effect of mass by allowing pendulums of different masses to continue beyond ten swings until they came to rest (See Appendix 3 – *What Makes It Go? V What Holds It Back?*).

.

The control group's workshop investigation was limited to ten swings of differing masses followed by discussion on Galileo's "idealisation" of pendulum behaviour. The experimental group observed an intervention lesson that allowed differing masses to swing until they came to rest. A heavy-mass pendulum (golf ball) took more than fifty swings to come to rest compared to approximately twenty swings for a light-mass pendulum (ping-pong ball). The distribution of responses indicates a negligible change in the control group but a rise in ambiguity in the experimental group.

There is a change in conceptual understanding in the experimental group but this has been accompanied in an increase in conceptual dissonance. As stated earlier, the questionnaire may need to be modified to explore teachers' understanding of the difference between the real-world experience and the "idealised" expectation as proposed by Galileo.

4.4.1.2.3 Gravity

The effect of gravity on the period of a pendulum was not introduced in the initial workshop. Only the experimental group were given any instruction on the effect of gravity in the intervention lesson **What Makes it Go? V What Holds it Back?**

Reference to gravity was made in the lesson questions:

"Is there gravity on the moon?"

"Is there air on the moon?"

"Would a pendulum swing on the moon?"

. The questionnaire contains five questions related to

Table 4.23

Percentage Responses for Gravity Questions 2, 3, 4, 6, 7

2. A pendulum of given mass and length was taken on a trip to Mars		PRE-TEST FALSE	PRE-TEST DON'T KNOW	PRE-TEST TRUE	POST-TEST FALSE	POST-TEST DON'T KNOW	POST-TEST TRUE
(i) As the spacecraft orbited the Earth before leaving for Mars, this pendulum would swing normally	*control*	*11.8	47	41.2	**11.8*	*41.2*	*47*
	exp	*23.5	61.8	14.7	**20.6*	*26.5*	*52.9*
(ii) As the spacecraft orbited the Earth before leaving for Mars, this pendulum would not swing	*control*	41.2	17.6	*41.2	*64.7*	*17.6*	**17.6*
	exp	17.6	70.6	*11.8	*61.8*	*23.5*	**14.7*
(iii)After the spacecraft landed on Mars, this pendulum would swing slower when compared to its swing on Earth	*control*	23.5	29.4	*47	*23.5*	*52.9*	**23.5*
	exp	11.8	64.7	*23.5	*23.5*	*26.5*	**50*
(iv)After the spacecraft landed on Mars, this pendulum would swing faster when compared to its swing on Earth	*control*	*52.9	35.3	11.8	**47*	*35.3*	*15.8*
	exp	*20.6	67.6	11.8	**50*	*35.3*	*14.7*
(v)After the spacecraft landed on Mars, this pendulum would swing the same as when compared to its swing on Earth	*control*	*52.9	35.3	11.8	**52.9*	*23.5*	*23.6*
	exp	*44.1	55.9	0	**64.7*	*28.4*	*5.9*

3. The period of a pendulum's swing depends on gravity	*control*	35.3	23.5	*41.2	35.3	17.6	*47
	exp	2.9	44.1	*52.9	23.5	5.9	*70.6

4. (i)A pendulum of given mass and length swings with the same period (time to make one complete swing) at the Equator as it has at the North or South Pole	*control*	*29.4	29.4	41.2	*23.5	23.5	52.9
	exp	*8.8	67.6	23.5	*41.2	17.6	41.2
(ii)A pendulum of given mass and length swings faster at the Equator than it does at the North or South Pole	*control*	*47	35.3	17.6	*47	58.8	5.9
	exp	*26.5	70.6	2.9	*55.9	38.2	5.8
(iii)A pendulum of given mass and length swings slower at the Equator than it does at the North or South Pole	*control*	64.7	35.3	*0	47	41.2	*11.8
	exp	23.5	73.5	*2.9	38.2	38.2	*23.5
6. A pendulum can be used to determine a value for gravity	*control*	0	76.5	*23.5	5.9	52.9	*41.2
	exp	2.9	67.6	*28.4	8.8	26.5	*64.7

		PRE-TEST			POST-TEST		
		False	Don't Know	True	False	Don't Know	True
7. A pendulum swings slow as it swings up and swings fast as it swings down	*control*	*52.9	23.5	23.5	*82.3	11.8	5.9
	exp	*35.3	44.1	20.6	*58.8	5.8	35.3

Table 4.24

Means for Gravity Questions 2, 3, 4, 6, 7

	Group	N	Mean
Total Pre	Exp	373	0.10
	Control	85	.09
Total Post	Exp	373	.08
	Control	85	-.06

There is a clear difference between the stability of both groups' *Don't Know* responses within most questions on the effect of gravity. The experimental group demonstrate a greater readiness compared to the control group to take a position for each question. No reference to gravity was made by the researcher (other than in the issued lesson plans) at the initial workshops but was included in specific teaching and learning strategies in the intervention lessons.

The experimental group distribution demonstrates a better understanding of the role of gravity in a pendulum's period (Q3; Q6) at post-test. Information on the role of gravity was provided to the control group **only** in the issued lesson plans. The experimental group however also observed an intervention lesson **What makes it go, what holds in back** that made specific reference to this role. The presence of the researcher in situ allowed the researcher to clarify questions and explain in more detail the equation for pendulum period provided in the lesson plan for another intervention lesson **Weight v Period**.

The intervention lesson **What makes it go, what holds in back** also introduced questions concerning a pendulum's behaviour under different gravity values. Specific teaching strategies were included in the lesson to elicit student ideas on the moon's gravity and how a pendulum would behave on the moon *Is there gravity on the moon? Would it (pendulum) swing differently?*

Although the majority of experimental group teachers were clear that the value of gravity on the moon was less than that on Earth, it was evident during the discussions after this intervention lesson, that in general, the reference to Mars in the pre-test questionnaire had proved problematic. A number of teachers commented that they actually had posters in their classrooms comparing gravity values on planets in our solar system but were unable to recall the comparison between Mars and Earth. Other teachers had no prior knowledge of this comparison but were able to link the Apollo astronaut moon walk action to lower gravity.

The experimental group post-test distribution indicates an increased awareness that gravity is an important factor but demonstrates the importance of further professional development to clarify the correct effect. The control group distribution, in general, indicates little to no change in teacher knowledge and understanding of this particular concept.

There was no reference during the initial workshops to the use of the pendulum in determining the shape of the Earth. Both groups were issued the factsheets (Appendix 4) after the workshops without instruction from the researcher as to the applicability to any of the corresponding lesson plans.

The experimental group distribution for each question demonstrates an increased understanding of the gravity concepts treated in the factsheets concerning the use of the pendulum in the determination of the shape of the earth. It was clear from discussions with the experimental group teachers that they had not referred to the issued factsheets at any time following the initial workshops. It was only subsequent to the intervention lesson **What makes it go, what holds in back** that the information in the factsheets was used by the researcher in post-class feedback. Again, the equation provided in the lesson plan **Weight v Period** was highlighted for the experimental group teachers to explain the significance of the value of ‘g’ on the period of a pendulum

4.4.1.2.4 Energy

This concept was not aligned with any of the originally distributed lesson plans or addressed in the workshop delivered to both groups. The inclusion of this question was to address a lesson that the researcher had trialled with a number of trial schools (who did not participate in the study) prior to the PD program.

The lesson involved swinging a pendulum across a large grid panel so that release and obtained height could be measured. It was determined from this trial that a lesson on energy was worth including as a researcher demonstration lesson *only* at each experimental group school but included in the set of extra lessons distributed to each group after the conclusion of the professional development program. The rationale for inclusion as a demonstration lesson only at the conclusion of the PD program was the difficulty of obtaining the required large grid panel at each school and the limits of time in delivering other lessons over the intervention period with the experimental group.

Table 4.27

Percentage Responses for Energy Question 10

		PRE-TEST			POST-TEST		
		FALSE	DON'T KNOW	TRUE	FALSE	DON'T KNOW	TRUE
10.(i) A pendulum bob at the end of the first swing will return to the release height on most occasions	*control*	29.4	52.9	*17.6	*47*	*11.8*	**41.2*
	exp	38.2	55.9	*5.8	*52.9*	*5.8*	**41.2*
(ii)A pendulum bob at the end of the first swing will return higher than the release height on most occasions	*control*	*47	52.9	0	**82.3*	*17.6*	*0*
	exp	*38.2	55.9	5.8	**91.2*	*8.8*	*0*
(iii)A pendulum bob at the end of the first swing will return lower than the release height on most occasions	*control*	*17.6	52.9	29.4	**41.2*	*17.6*	*41.2*
	exp	*5.8	55.9	38.2	**29.5*	*5.8*	*64.7*

Table 4.28

Means for Energy Question 10

	Group	N	Mean
Total Pre	Exp	102	.32
	Control	51	.24
Total Post	Exp	102	.46
	Control	51	-.12

The differences in the post means between the groups suggest that the demonstration lesson delivered for the experimental group has had some impact on their understanding of energy losses during the pendulum's swing. However, this would need to be investigated further as the changes to the number of unsure responses is marked for *both* groups. A possible explanation is that either the control group or both groups are answering this question *not* from an energy perspective but rather from a purely observational one without reference to energy losses.

This question may need to be rewritten to explicitly reference energy losses/gains for a more definitive analysis to be conducted.

4.4.1.2.5 Angle of Release

This concept was covered only very briefly in the initial two hour workshop for both groups and no observation or comment was made by any participating teacher on where a pendulum should be released from:

Table 4.29

Percentage Responses for Angle of Release Question 9

		PRE-TEST			POST-TEST		
		FALSE	**DON'T KNOW**	**TRUE**	**FALSE**	**DON'T KNOW**	**TRUE**
9. To obtain accurate measurements of a pendulum's period it is better to release the pendulum from small angles only	***control***	**29.4**	**52.9**	***23.5**	***23.5***	***23.5***	****52.9***
	exp	**23.6**	**67.6**	***8.8**	***47.1***	***20.6***	****32.3***

Table 4.30

Means for Angle of Release Question 9

	Group	N	Mean
Total Pre	Exp	34	-.15
	Control	17	-.12
Total Post	Exp	34	-.15
	Control	17	.24

As with the other questions, the percentages of *Don't Know* have decreased for both the control and experimental groups. Unusually, the mean for the experimental group has remained unchanged. A possible explanation is that in observing and practicing the pendulum experiments, the experimental group saw numerous releases of the pendulum from various release positions. As the experimental results appeared to be consistent with whatever release point was chosen, the angle of release seemed to be irrelevant for a successful pendulum activity.

For future lesson plans and a revised PD program, the angle of release will need to be explicitly highlighted in the lesson procedure and explicitly introduced to the teacher instructions in the classroom.

4.4.1.2.5 Early Greeks, Galileo

At the initial workshops, the researcher presented the case for the use of the pendulum as the context for the PD program. As well as highlighting the pendulum's applicability to elementary school classes due to the simplicity of the resources required and potential motivational qualities for the students, the researcher outlined the significance of Galileo's pendulum studies on the conduct of science.

The importance of Galileo's view of 'idealisation' in describing and explaining phenomena as distinct from an Aristotelian view was covered in the workshop delivery.

Table 4.31

Percentage Responses for Early Greeks, Galileo Question 11, 12

		PRE-TEST			POST-TEST		
		FALSE	DON'T KNOW	TRUE	FALSE	DON'T KNOW	TRUE
11.The early Greeks were the first to realise that the pendulum could be used measure time	***control***	***5.9**	**76.5**	**17.6**	***11.8***	****47***	***41.2***
	exp	***5.8**	**76.5**	**17.6**	***23.5***	****41.1***	***35.3***
12.Galileo's use of mathematics to analyse the swing of a pendulum was a common method of science inquiry at that time	***control***	***11.8**	**76.5**	**11.8**	****52.9***	***29.4***	***17.6***
	****exp***	**8.8**	**76.5**	**14.7**	****41.1***	***23.5***	***35.3***

Table 4.32

Means for Early Greeks, Galileo Question 11, 12

	Group	N	Mean
Total Pre	Exp	68	-.09
	Control	34	-.12
Total Post	Exp	68	-.06
	Control	34	.03

Both groups exhibit similar distributions indicating some increased knowledge of Galileo's work gained from participation in the initial workshops. A reference was made to Galileo's concept of 'idealisation' during the intervention lessons with the experimental group but the distributions of responses for question 12 are comparable for each group. The percentage of unsure responses in question 12 has markedly declined indicating an increased awareness of the Galileo's contribution to the development of science. Further development of the concept of idealisation could be pursued in further PD.

4.4.1.2.6 Pendulum and Sea Voyages

Another key historical feature of the pendulum was presented to both groups at the initial workshops. The development of the early pendulum clocks and the subsequent chronometer was described to the teachers and then further supported by factsheets. This was seen as important to encourage teachers to realise how science concepts may be incorporated into cross-curricular teaching programs.

Table 4.33

Percentage Responses for Pendulum and Sea Voyages Question 13, 14

		PRE-TEST			POST-TEST		
		FALSE	DON'T KNOW	TRUE	FALSE	DON'T KNOW	TRUE
13. The early pendulum clocks used on long sea voyages remained accurate even during bad weather and rough seas	***control***	***23.5**	**64.7**	**11.8**	****35.3***	***41.2***	***23.5***
	exp	***14.7**	**70.6**	**14.7**	****47***	***20.6***	***32.4***

14.The early pendulum clocks used on long sea voyages could help navigators determine a ship's position	***control***	**29.4**	**70.6**	***0**	***11.8***	***47***	****41.2***
	exp	**11.8**	**70.6**	***17.6**	***20.6***	***23.5***	****55.9***

Table 4.34

Means for Pendulum and Sea Voyages Question 13, 14

	Group	N	Mean
Total Pre	Exp	68	.03
	Control	34	-.12
Total Post	Exp	68	-.09
	Control	34	.26

Most teachers indicated that they had developed programs in another key learning area on Australia's early colonial history from the time of Captain Cook's discovery but had been unaware of his role in testing of sea clocks for improved navigation. No further reference was made this feature of the pendulum in the intervention lessons but as stated previously, the in situ position of the researcher allowed post-class discussion with the experimental group.

Therefore the distribution for the experimental group towards a correct response indicates a slightly better understanding over the control group concerning the role of the pendulum in navigation during sea voyages.

4.5 Summary

Participation in a reform-style PD program has resulted in positive changes to teachers' self-efficacy for teaching and knowledge in science, knowledge of aspects of the nature of science and pendulum concepts. For teachers participating in the standard PD program, there has been a positive change to knowledge self-efficacy and some improved understanding in pendulum concepts. The analysis of the responses in the VNOS-D survey and pendulum questionnaire indicate that changes in teachers' knowledge and understanding are most pronounced when items within each test instrument were explicitly targeted in both types of PD program. The most significant changes in these test instruments occur when the PD program is based on a reform-style approach.

The reform-style PD program was designed around providing vicarious experiences in the teaching of VNOS and pendulum concepts in situ of the teachers' classrooms, with time available for lesson debriefs and general discussion between the teachers and the researcher. The results within the three test instruments (Table 4.35) indicate teachers participating in this type of PD program have not only developed a deeper understanding and broader knowledge of the targeted concepts compared to the control group, but have also increased self-efficacy for the teaching of science, a change not reflected in the control group.

Table 4.35

Summary of Test Instruments Outcomes/Interpretations

<table>
<tr><th>Variable</th><th>Outcome/Interpretation</th></tr>
<tr><td>Knowledge Efficacy</td><td>Significant improvement for both groups (p < 0.001)

No significant difference between groups (p = 0.075)</td></tr>
<tr><td>Teaching Efficacy</td><td>Improvement for both groups just outside significance (p = 0.056)

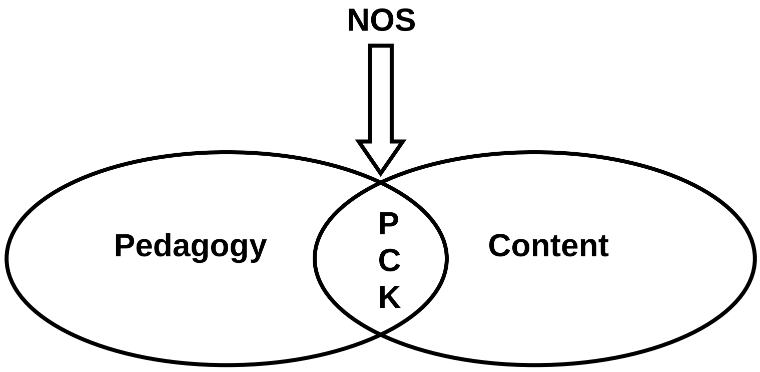
Significant difference between groups (p = 0.002)</td></tr>
<tr><td>VNOS Themes</td><td>Both the experimental and control group demonstrate an awareness that science is the study and explanation of phenomena, involving experimentation/investigation and hypothesising.

Both groups have a notion that science is a specific process involving a hands-on investigation.

Tentativeness of scientific knowledge are strongly present for both groups at pre- and post-test and the notion of bias has only limited increased reference.

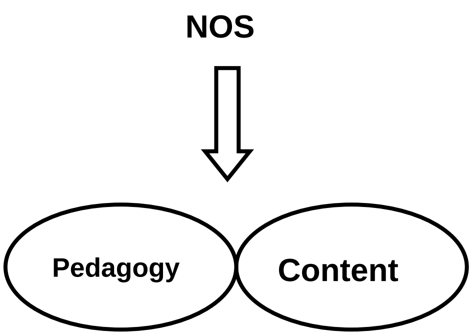
The ideas of testing hypotheses and theories, allowing for more questioning and different experiments leading to different conclusions appear to be positively impacted for the experimental group.</td></tr>
<tr><td>Pendulum Knowledge</td><td>Understanding of the following concepts improved for both groups:
Length V Period
A metre pendulum swings 1 second each way
Air resistance affects the period
A pendulum can be used to determine a value for gravity
A pendulum should be released from small angles
Galileo’s pendulum investigations were unique for science
Better understanding for the experimental group of the following concepts:
A pendulum’s swing depends on gravity
A pendulum would swing slower on Mars
A pendulum can be used to determine a value for gravity
Galileo’s pendulum investigations were unique for science</td></tr>
</table>

PCK is the integration of both pedagogical (teaching) and content (knowledge) that ultimately influences classroom practice (Parker, 2004). The differences in the results of the test instruments between the two groups may be represented by referring to the graphical representation (Figure 1.1) described in Chapter 1:



Using the assumptions that the groups were homogenous with a normal distribution (See Section 4.1.1), the groups would have the same initial graph (Figure 4.1) (drawn using the scale of the ideal graph above) as:

Figure 4.1 Initial graphical representations of Experimental and Control groups

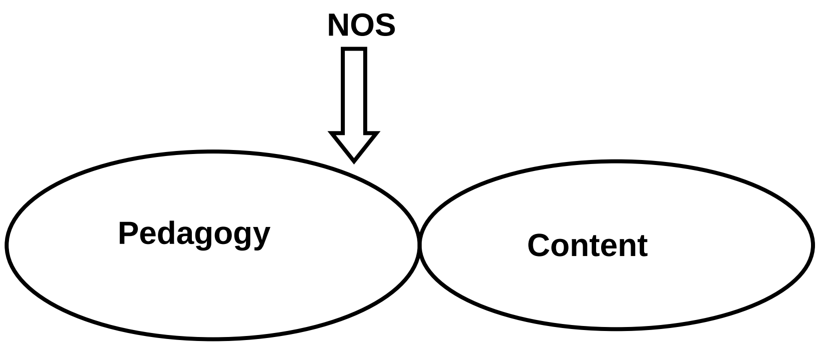


Within each group there were teachers whose test results would give a different component size for either pedagogy, content or both. No integration of pedagogy and content is shown in this graph as data on the teachers' current teaching practice with respect to nature of science was not gathered.

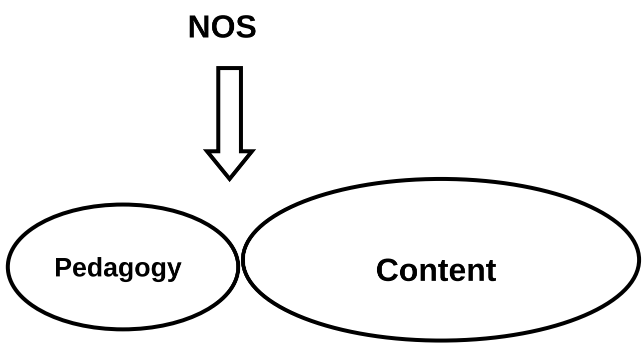
Using this ideal representation and its scale, the graphical representations below (Figure 4.2) attempt to illustrate a generalised view of the changes to each group as analysed from the three test instruments.

Figure 4.2   Graphical representations of changes to Experimental and Control groups

Experimental Group



Control Group



In Phase 2 of this study, an investigation was conducted into how teachers in the experimental group attempted to incorporate new NOS teaching and learning strategies into classroom practice. This investigation involved case studies of teacher lesson planning and classroom practice. Teachers in the control group were provided with lesson plans but no follow up assistance or advice from the researcher.

In the next chapter, the case studies are described and results discussed. At the end of that chapter, updated graphical representations showing any observed integration of pedagogy and content will be presented.

CHAPTER 5

Case Studies and Teacher Reflections

5.1 Introduction

Returning to the theoretical framework outlined in Chapter 1, the degree of integration of the pedagogical and content components of teacher NOS knowledge will be reflected in their classroom practice. The contention of this study is that classroom practice is influenced by teacher self-efficacy beliefs, content knowledge for NOS, general science content knowledge and pedagogical knowledge for NOS instruction.

In Phase 1 of the study, changes to teacher self-efficacy beliefs, NOS content knowledge and general science content knowledge on a specific science concept were studied. The purpose of conducting case studies in Phase 2 was to obtain information on how practicing elementary teachers attempted to integrate these components into their classroom practice. From this information, the degree of integration for a teacher may be represented as the amount of overlap of the components (Refer Figure 1.1).

This chapter describes two case studies for the purpose of illumination of the results from Phase 1 as part of a mixed methods study. Situating Phase 2 of the study in a real-world context favours the collection of data in natural settings and may help in better understanding the responses to the quantitative instruments utilised in Phase 1 (Yin, 2011).The case studies were conducted at the conclusion of the PD program and the cases were selected on the principles of purposive sampling as outlined in Chapter 3.

The mixed methods design chosen for this study was an explanatory sequential design (see Chapter 3). Since the two phases occur sequentially, the design it may be represented pictorially as QUAN $\longrightarrow$ QUAL (Teddlie and Tashakkori, 2009) where the two phases are treated as being of equal importance to answering the research questions. The rationale for employing this design was to:

- use quantitative results about participant characteristics to inform the purposive sampling for the qualitative Phase 2 case studies
- investigate the quantitative data in more depth through the interpretation of qualitative results to *explain or provide insight into the quantitative results and what overall is learned in response to the study's purpose* (Creswell & Plano Clark, 2011, p83).

In this chapter, the first analysis conducted was on the teacher questioning in the case studies and how the questioning might reflect teacher efficacy and increased VNOS understanding. This analysis is described in the relevant sections below.

An analysis of the debrief question responses from all teachers in the experimental group completed at the end of Phase 2 was then conducted to investigate if there is alignment with their responses for VNOS questions 1 and 2 from Phase 1. The aim here is to arrive at some *generalisable* understanding of how teachers' NOS understanding was impacted by participation in the program. Then the incorporation of NOS teaching and learning strategies in classroom practice by the teachers in the case studies may be represented as a multifaceted phenomenom (relying on teacher efficacy, vicarious experiences and NOS understanding), but also a unitary thing achievable across local contexts (Fisher & Stenner, 2010).

The first case study investigates teachers' immediate attempts to modify their teaching practice for explicit instruction in nature of science. In this case study, the teachers attempted to adapt existing lessons into a NOS framework through the inclusion of new questioning techniques. The second case study investigates teachers' intentions to modify their teaching practice through redesigning existing curriculum by writing new lesson plans incorporating nature of science teaching and learning strategies and then enacting these in their classrooms through expanded NOS questioning.

At the conclusion of the PD program, all of the experimental group attended a two hour debrief session. A series of questions regarding the structure and outcomes of the PD program were posed and responses recorded for analysis. This debrief and the teacher reflections are described in the last sections of this chapter.

5.2 Case Study 1 Lessons without specific Nature of Science questions in lesson plans

The first case study describes two teachers who were attempting to incorporate explicit questioning on nature of science aspects into their teaching was conducted. This approach of trailing first was common to about two thirds of the experiment group schools. The teachers had chosen to trial the nature of science lesson strategies prior to developing a unit work. Having observed the researcher conduct lessons with their students, the teachers felt that they needed to assess their own experiences with nature of science questioning before developing a complete series of lessons

5.2.1 Case Study 1 - The teachers and their school

The school was a medium sized suburban primary school with a Principal supportive of the PD program. The school was involved in the first stages of assessment of their current teaching programs for the current NSW K – 6 Science and Technology Syllabus.

The two teachers involved in this case study were female with 20+ years of teaching experience and could recall receiving only minimal science instruction during their teacher preparation course. None of the teachers had any instruction in or knowledge of nature of science aspects prior to participation in the PD program. They were co-teachers of two classes in stage 1 (year 2). Based on the primary sampling criteria of pre-test efficacy scores (Table 5.1), the case study consisted of one more efficacious and one less efficacious teacher:

Table 5.1

Case Study 1 Teacher Efficacy Scores

Pre/Post Efficacy Scores				
Teacher	Teaching Years	Knowledge	Teaching	Case Study 1 Efficacy Rank
Wendy	20+	29/32	26/29	More efficacious
Bridget	20+	23/29	23/26	Less efficacious

Although not the primary criteria used in choosing the teachers for each case study, the pre/post responses to the VNOS-D form are given below and will be discussed later in the chapter. The questions chosen from VNOS-D are used to give an overview of each teacher's development in NOS understanding:

Table 5.2 Case Study 1 pre/post response Question 1 VNOS-D

Teacher	**Question 1. What is Science?**			
Wendy	The way things work in the world. What things are, how they react to other things and where they fit in the total or overall picture. How things change and the factors that contribute to change in the physical world.	**1, 6, 10**	It is the study of how things occur in the world, the interaction of these things and what occurs as a result of these interactions. It is based on observation, experimentation which leads to a body of knowledge	**1, 6, 10, 9, 17, 22**
Bridget	It is the study of the world in which we live, including living and non-living things	**6**	Is the study of living and non-living things and phenomenon in the world.	**6**

Question 2. How is Science different to other KLAs subjects you are teaching?

Wendy	I don't think it is any different to other KLAs. It is part of the total syllabus - with its own knowledge and skills.	**24**	They are all different - in the time you allocate, the processes involved and the skills you are developing in students. Science is usually a once -a-week subject, taught in isolation.	**24**
Bridget	It is often neglected because of the constraints of time and space (there is little room to spread out for some things). It is easier to teach "natural science " than things like physics.	**10.13**	There is a requirement for lots of equipment to allow for students to experiment or make observations.	**4,7,10**

Question 6. What do you think a scientific model is?

Wendy	It is a way of showing how something happens, or works.	**1**	I think…….a scientific model is something that attempts to replicate a component of a theory or hypothesis, to make it easier to understand or study.	**1**
Bridget	An explanation of a given thing that explains how something occurs.	**1**	One of those girls on "Brainiac" It is a set of steps that produce a predictable outcome eg the water cycle	**5, 13**

Table 5.3

Case Study 1 Teacher Pendulum Scores		
	Difference Correct/Incorrect	Unsure
	Pre/Post	Pre/Post
Wendy	5/14	10/1
Bridget	7/1	12/6
Experimental Group (Mean)	2.47/5.12	14.7/3.7

.

Wendy as the more efficacious teacher of the two, exhibits a broader understanding of *What is Science?* in her response at post-test than Bridget. Neither teacher in their response to Question 6 on 'models', mention drawing inferences from models (see Appendix 2) but Wendy's response indicates some understanding of the explanatory nature of models rather than as a procedure . She also is well above the experimental group mean for the difference between correct and incorrect responses and has only one unsure response. Bridget has improved her difference result but still is above the experimental group mean for number of unsure responses. Her VNOS-D responses are at the lower descriptor level for these questions.

5.2.2 Case Study 1 – Lesson observations and intervention

Prior to the first lesson, both teachers' intended questioning on aspects of the nature of science was shown to researcher but no alteration of or addition to the questions was conducted. The researcher observed lessons delivered by the two teachers with the understanding that the researcher could make suggestions for further teacher questioning during the lesson where appropriate. As the researcher had already delivered lessons to the students as part of the PD program, the teachers where confident that the students would accept the presence of the researcher in a team-teaching role.

The context for the lessons was Communication and for the first lesson, the students were to make a model stethoscope. Leading into this first lesson, the teacher who was to be the first to trial the questions had already had their class make a model telephone. This teacher confirmed that she had used the term ‘model’ with the students. In the teaching and learning activities and questions shown to the researcher, no explicit attention to nature of science aspects was evident, except for a possible opportunity for students to hypothesise on the last question:

> “*What ways can you use parts of your body to make a sound?*”
>
> “*How was sound made?*”
>
> “*How does the sound alter when the top is spinning quickly and slowly?*”
>
> “*Why does it work?*”

So, although the teacher had indicated that there were specific nature of science questions, no explicit questions on hypothesising or models were evident. There was a student activity where they were to investigate design alternatives and discuss their findings but this was without explicit reference to the use and improvements on models.

5.2.2.1 Bridget Lesson 1 Stage 1 (Year 2)   class 2B1 The Stethoscope

This was a mastery experience lesson for Bridget that was the second in a series of lessons on Communications. The students had already constructed a model telephone in the previous lesson. The lesson began with extensive initial questioning of the class:

> *What did we make last week?*
>
> *Did we have to change our design?*
>
> *Did the changes make it work better or worse?*

Students were able to recall the lesson and there was some class debate on which constructed telephone worked best at first attempt and which telephones had to be altered in design.

Lesson continued with Bridget showing the students a stethoscope and asking students who and/or jobs might use a stethoscope. The contexts she chose included doctors, vets and rescue workers at disaster sites.

She then held up a stethoscope constructed from cardboard paper and paper rolls and had volunteer students try to hear each other's heart beat. The lesson then proceeded with the students working in pairs to construct their own cardboard stethoscope. Each pair then exhibited their stethoscope to the class. She then questioned the students on how effective they thought their design might be to make it work better.

What things were important to think about when you were designing your stethoscope

What about the shape? (Reference here to the cup shape of the earpiece and mouth piece.)

What could you change to make it work better?

The students were sent back to work on their design

During this time, the researcher made suggestion for further questioning:

"Talk to the students about how scientists sometimes use models in their investigations."

The students then reported back on their changed design. Bridget then continued with the following questions:

Is this a real stethoscope?

Student: It's a pretend one.

Is it a puzzle or model?

Student: A model.

(Student were able to recall word from previous lesson)

How do we get from our model to a real stethoscope?

Student: They improve it.

Who would do this?

Student: Scientists.

Were our telephones last week real?

Student: No, they were models.

Do all models work?

Student: No.

How do you know they don't work?

Student: We test them!

When a scientist comes to test their new model they have to test the same way as their model. Why should you test your new stethoscope the same way?

Student: To prove it to people.

After the class had ended, Bridget had the opportunity to reflect on her questioning. She stated that she as soon as the researcher made the suggestion about including some questioning on models she realised she had originally intended to do so and would ensure to include such questions with the next class. Bridget was to teach a second Stage 1 class (2B2) the following week.

Bridget commented on the help that questioning gave her in engaging the students in not only the concept but also scientific process and recalled how models had been mentioned in the pendulum lessons she observed during the PD program.

5.2.2.2 Bridget Lesson 2 Stage 1 (Year 2) class 2B2 The Stethoscope

Bridget had a second stage 1 class who were also conducting investigations into communication. This second class was conducted in the afternoon following the debrief with the researcher on the first lesson.

Bridget began the class with similar initial questioning used in lesson 1 on the previously constructed telephone and the introduction to the stethoscope. She held up a doctor's stethoscope and a model constructed by the previous class:

Is this a real stethoscope? (holds up the model)

Student: No, someone made it.

Would it work?

Student: We could try it on someone.

Bridget then chose some students to try out the model stethoscope. She explained that the students in the other class had constructed a "model" of a real stethoscope. This term had not been used with these students.

How do we could get our model to be more like a real stethoscope?

Student: Make it better/Change it.

Were our telephones last week real?

Student: No, they were models.

Do all models work?

Student: No.

How do you know they don't work?

Student: We tested them!

What do we call people who make models and test things?

Student: Scientists.

When a scientist changes their model, is it important to test the new model the same way their first model?

Student: Yes.

Why should you test your new model the same way?

Student: It wouldn't be fair would it?

(Students were able to recall of the concept of fair-testing from pendulum lessons)

Bridget then spent some time talking about an Australian invention, the Cochlea ear. She talked about ear trumpets and hearing aids. She then made the following statements:

They had to make lots of models to get to this stage.

Because we're going to be working like scientists today, we will be making a model and then see if we can make it better.

You try out your model by testing it.

The lesson then proceeded similarly to the first class with student working in pairs and reporting back. Bridget then asked for suggestions in how to make a better model. A sample of student response included:

Student: Try a double one (two rolls).

Student: Take some of the paper off.

Student: Use ice cream cone shapes.

Why?

Student: It covers your ear.

The lesson concluded with the following questions:

Is it normal for scientists to make lots of models to get better and better at things?

Another scientist would have thought I can make a better model than this?

Student: They keep trying don't they?

Bridget expressed increased satisfaction with the lesson outcomes. She held the view that the students can some understanding of the usefulness of models in investigations. Bridget commented that the reporting back by the students allowed other students to critique a design. Bridget was able to incorporate quite good questioning on models after prompting from the researcher. She was more confident in her delivery of the second lesson

The researcher made suggestions for further questioning:

"Ask the students at the next lesson if scientists make models of things they cannot see."

The idea here was to use the ideas behind the popular television program "Walking with Dinosaurs" as a basis for class discussion on the use of models.

The researcher referred Bridget to the questions in the VNOS (D) form concerning dinosaurs and fossils."

5.2.2.3 Wendy Lesson 3 Stage 1 (Year 2) classes 2B1 and 2B2 Sound Vibration

Wendy had been present during the researcher's debrief of Bridget's lesson 2. This was conducted informally during the student recess period after Bridget's observed lesson and continued during lunchtime. Wendy indicated that she would include specific questioning on the use of models for the next class delivered to both of Bridget's two cohorts. These classes would be focussing on sound vibrations.

Each lesson began with Wendy questioning the students on the model telephone and stethoscopes they had constructed. She then began a series of questions referencing scientists' use of models in representing dinosaurs:

Who can tell me what a scientist does?

Student: They do experiments

They find things out

They know what we don't know.

Wendy then held up some toy dinosaurs:

Do you think they know a lot about dinosaurs?

Student: They're smart.

But they haven't seen a real dinosaur have they?

Student: They use computers.

They find bones.

How do the bones help?

Student: They try different things to fit the bones.

Gives size.

At this point Wendy held up a dinosaur model kit:

If we put all these pieces together, is it a real dinosaur?

Student: It's a toy one.

It looks like one.

Remember our telephones and stethoscopes? They weren't real!

Student: They were models.

Wendy then proceeded to explain that even though dinosaurs are no longer around we can still get an idea of what they were like by making models of them. She stressed to the students that we can make models of things we can't see.

She then turned the ceiling fans on to high speed to generate a loud noise in the room.

How does the sound get from the fan to your ear? It's a long distance!

How does the sound get one end of the stethoscope to your ear?

Wendy had the students line up side-by-side with their shoulders touching and explained that sound can travel as "push" of the air. She then had one student gently push the end of the line and the students saw the movement of the next students:

So even though you cannot see the sound you can model how it travels!

5.2.3. Debrief of Case Study 1 teachers

At the conclusion of the lessons, both Wendy and Bridget attended the debrief session. They commented that without the knowledge gained from both the PD program and the comments and discussions during the observation lessons and debriefing, they would have simply conducted what they called “design and make” activities with some minimal science explanation.

Both commented that in the mechanics of conducting a lesson, it was difficult to remember to be explicit about nature of science concepts. The researcher suggested that it may be advantageous to design lesson plans using the template they had been given for the pendulum lessons. In these lesson plans, they would include their intended questioning at each relevant point in the lesson. Working with Wendy and Bridget, the researcher then acted as an academic friend by assisting them in the design of a series of lessons for a unit of work on the human body:

Table 5.4

Case Study 1 Proposed Units of Work

	Stage 2 UNIT	**Human Body**
Lesson	**Focus**	**Title**
1	Digestion	Food on the Move
2	Breathing	Lung Capacity
3	Bones	This is My Skeleton
4	Bones	Moving My Skeleton
5	Bones	Whose Skeleton is That

The researcher was to produce a lesson plan for each lesson with the inclusion of prompts for the teachers where explicit nature of science questioning would be appropriate. To ensure the researcher did not produce complete lessons, the lesson template required the teachers to insert their own questioning. It was agreed that the researcher would assess the questioning prior to the teachers conducting a lesson. An example of a lesson template is shown below:

Figure 5.1

Example of lesson template used in case study 1

A Look Inside	
Lesson Plan Title:	FOOD ON THE MOVE
Grade Levels:	2
Outcomes: **Stage Two** • INVS 2.7 Conducts investigations by observing, questioning, predicting, testing, collecting, recording and analysing data, and drawing conclusions. • VA2 Exhibits curiosity and responsiveness to scientific and technological ideas and evidence. • VA45 Works cooperatively with others in groups on scientific and technological tasks and challenges.	
Rationale: This lesson has students investigating the muscle action that moves food through he body. Most students will think that gravity causes the food to move through the body so the activity specifically addresses this conception. This lesson would follow the lesson where students created a model digestive system.	
Background: • In this lesson students should hypothesise how food moves through the body • The questioning involved should include discussion on how astronauts eat in space. • Science knowledge is tentative. • Scientists make use of models.	
Materials needed: Stocking/pantyhose Tennis balls	

Time Allotted: 35 - 40 minutes	
Teaching and Learning Activities:	
Teacher Strategy	**Student Activity**
1. ***YOUR INITIAL QUESTIONING HERE*** Have students suggest their idea. 2. Refer back to students' drawing and/or cut and paste of the human digestive system ***YOUR QUESTIONING HERE***	1. Students answer questions. 2. Students answer questions
3. Question students on whether a person can eat while upside down ***YOUR QUESTIONING HERE***	3. Students split into two groups: YES/NO
4. Conduct demonstration where a student stands on their head and drinks through a straw ***YOUR QUESTIONING HERE***	4. Students watch demonstration and propose an idea as to how the drink made its way to the stomach. .
5. Ask the question: **"Can we make a model for what's happening?"** **"Do scientist use models?"** ***YOUR QUESTIONING HERE***	5. Students debate whether scientists ever use models when doing investigations..
6. Hand out the stocking/pantyhose and tennis. Have students attempt to move the tennis ball from top to bottom and then bottom to top. ***YOUR QUESTIONING HERE***	6. Students perform activity and report back. **Students should note that only by SQUEEZING the stocking/pantyhose does the ball move through.**

7. Ask students now how they think this model may show what's happening when they swallow food. ***YOUR QUESTIONING HERE***	7. Students share ideas about how food moves.
8. Refer back to the initial question about how food moves. Spend time discussing how ideas have to change based on experiments and observations. **"Do scientists also have to change their ideas?"** ***YOUR QUESTIONING HERE***	

At the time of writing this study, the completed lessons from the teachers were still in production but could form the basis of an extended study to investigate the enacted lessons.

5.3 Case Study 2 Lessons with specific Nature of Science questions in lesson plans

In case study 2, the researcher's role in this case study was also as an academic/critical friend, giving advice during the initial development of lesson plans for a unit of work on the context of Matter. This advice suggested practical experiences for the students and questions that the teachers may consider to explicitly address nature of science aspects.

5.3.1 Case Study 2 - The teachers and their school

The school was a large sized suburban elementary school, again with a Principal supportive of the PD program. The teachers involved in the PD program were female, with teaching experience ranging from 10+ to 20+ years. The two most senior (in teaching years) teachers could recall receiving only minimal science instruction during their teacher preparation course whereas he most recent teacher graduate had science instruction across the years of her preparation course. None of the teachers had any instruction in or knowledge of nature of science aspects prior to participation in the PD program. As with case study 1, the cohort consisted of at least one more and one less efficacious teacher:

Table 5.5

Case Study 2 Teacher Efficacy Scores

		Pre/Post Efficacy Scores		
Teacher	Teaching Years	Knowledge	Teaching	Case Study 2 Efficacy Rank
Suzanne	20+	33/36	30/35	More efficacious
Judith	10+	22/27	23/27	Less efficacious
Margaret	20+	26/29	25/29	More efficacious

Their pre/post responses to the VNOS-D form are given below are will discussed later in the chapter:

Table 5.6 Case Study 2 pre/post response Question 1 VNOS-D

Teacher	**Question 1. What is Science?**			
Suzanne	The study of natural or physical phenomenon in the universe	**6**	Science is something that is forever changing, not stagnant. It is enquiry, testing, retesting, hypothesising, questioning, intriguing.	**13, 16, 7, 20, 22, 14**

Table continues

			Something that makes you think and re-think what you believe in or thought you believed in. It is simple and complex. It is real and it is your imagination	
Judith	The study of the impact of one or more element on others	**10**	Observation and understanding of the natural world and its relationships/interactions between its parts. Experimentation to explain/discover the relationships/interactions.	**1, 6, 10, 17**
Margaret	Study of natural phenomena and processes.	**6**	Investigation of phenomenon	**6**

Question 2. How is Science different to other KLAs subjects you are teaching?

Suzanne	You don't always know the outcome at the beginning - you use different thinking skills - eg analysis and hypothesis, synthesis. - it can involve higher thinking skills.	**3,8,11,15**	It is exact and not exact - there can be one or many answers - it is enquiring, challenging - thought provoking. It is simple and complex. It is changing in some areas and remains the the same in other areas. It involves skills such as enquiry, questioning, reasoning, organising, hypothesising, analysing, synthesising, testing, fairness of testing, scientific language.	**2,3, 4,8,11,25,15,19**
Judith	Technical. More specific content (less easy to fudge)	**no code**	Requires more specific knowledge of subject content. A specific technical vocabulary needs to be taught. Compared to some KLAs more/different use of handson.	**1,14,19**
Margaret	Hands-on activities are vital to learning.It is 'ranked' not as 'important ' as Maths and English. It is easy to incorporate both Maths and Englsh into many learning activities.	**1, 24**	Science is learning by investigating, testing, hypothesis and repeating this process! Other KLAs more 'book' based learning.	**2,3,4,24**

Question 6. What do you think a scientific model is?

Suzanne	It is a way of showing how something happens, or works.	**1**	Something that explains phenomenon. It shows how things work, or occur as a result of all the factors involved.	**1**
Judith	Average of what happens based on an extensive number of similar experiments (can show variable change)	**18**	A generalised explanation that shows how things are most likely to occur. (average scenario)	**13**
Margaret	A diagram, program, model supporting a theory or occurrence.	**1**	Idea/Theory - hypothesise - investigate - test - analyse - report. The process of 'learning'. (Hands on)	**8, 18**

Table 5.7

Case Study 2 Teacher Pendulum Scores

	Difference Correct/Incorrect	Unsure
	Pre/Post	Pre/Post
Suzanne	4/6	21/3
Judith	- 2/13	13/8
Margaret	12/5	11/4
Experimental Group (Mean)	2.47/5.12	14.7/3.7

Suzanne, one of the most efficacious teachers involved in this study, exhibits the most expansive responses to questions 1 and 2, especially in her post-test response for *What is Science?"* In terms of Lederman's descriptors (see Appendix 2), Suzanne's response comes closest to the notion that science is a way of thinking. Judith, the less efficacious teacher in this case study, showed marked improvement in her post-test *Difference* score and a broader response to *What is Science?"*

As with case study 1, no teacher in their response to Question 6 on ‘models’ mention drawing inferences (see Appendix 2) although Judith’s comment *shows how things are most likely to occur* demonstrates some predictive quality to the use of models rather than for explanation as in Suzanne’s and Margaret’s response.

5.3.2.Case Study 2 Developing Units of Work with specific Nature of Science questions

An initial meeting was held with the three teachers during the intervention period of the PD program. They were about to develop a unit of work on Matter for the Stage 2 classes (Years 3/4). The researcher, acting as academic friend, conducted a brainstorm activity with the teachers eliciting their prior knowledge on the concepts of states of matter, change of state, refrigeration and the water cycle.

Below are the notes kept by the teachers during this brainstorm activity representing the proposed structure of the lessons and suggested teacher questioning. The main focus of this stage of the unit writing was to expand the teachers’ content knowledge on Matter as well as giving suggested contexts for the lessons. The researcher’s additions to the lesson plan are in bold:

Table 5.8 Teacher/Researcher brainstorm summary

Teacher/Researcher Brainstorm

Suggested Lesson	Questioning and Contexts
Dry/Wet Ice	What will happen when I pour water onto the ice **(both)**? After they watch – Can you explain what happened? What do you think will happen when I do this **(put a piece of each type of ice into a balloon and seal it)**? Why did the balloon blow up? Is this the same as me blowing up a balloon? **(Carbon dioxide)**
Melting Ice	Which colour will melt first? **(put coloured ice cubes in the sunlight)** **Do we need to use the same size ice cubes and why? (Fair testing concept)** We need to keep everything the same - measurements- for fair testing and controlling) Talk about colours of cars, clothing etc. What colour would you want your car or clothes to be in Australia?
Coolgardie Safe	How do we protect the ice from melting? What materials will keep things cool? Need hessian and/or muslin.
Evaporation and Chill Factor	What do we have to do to cool? (take heat out) **(Evaporation)** What is the best way to take heat out? Which thermometer is going to cool down the fastest when I put the fan on them? Wind chill factor. Why does one thermometer have no cotton wool or water around it? **(Control)** Use air through wet towel (air conditioner). **Use the concept of being cool at the beach when you come out of the water.** Dogs panting (don't sweat like us). We cool by sweating. Animals in cold environments or in winter.
Popcorn Experiment	How do we change the state of things? (Can put heat in) Does adding energy change state?

As with the first case study, much of the questioning was eliciting factual or explanatory responses from the students. But the brainstorming allowed the teachers to bring their prior knowledge and understanding to the intended lessons. In many cases they commented that they were familiar with the observations the students would make but had not made the link to the science involved. This brainstorming gave the teachers increased confidence in being able to bring their own experiences to a science lesson.

The researcher then reiterated the nature of science aspects demonstrated in the intervention lessons. Following the brainstorm the teachers were asked to develop the lesson plans and where appropriate include **explicit** questioning and reference to nature of science aspects.

From this brainstorm, the researcher and teachers outlined a possible six lesson (Table 5.5) unit of work for Matter:

Table 5.9

Units of work on Matter

Stage 2 UNIT		**MATTER**
Lesson	**Focus**	**Title**
1	States of Matter	Wet Ice
2	States of Matter	Wet Ice v Dry Ice (Universal Indicator)
3	States of Matter	Wet Ice v Dry Ice (The Balloon)
4	Keeping Cold	Keeping Things Cold (Without Refrigeration)
5	Change of State	Change of State in Matter
6	Getting Hot	Melting Ice

Each lesson contained teaching and learning activities based on a template developed by the teachers and using equipment more readily available to elementary teachers. An example of the redesigned lessons can be shown by comparing a previous utilised lesson plan (Figure 5.2) with the teacher-developed lesson plan (Figure 5.3):

Figure 5.2 Original lesson plan Coolgardie Safe

20 Making a Coolgardie Safe

Here are a set of **instructions** on how to make a place which kept things cool. Such a place was called a 'Coolgardie Safe'. Many people used Coolgardie Safes before refrigerators were invented. It was a 'safe' because it kept the meat and other things cool and safely away from the flies.

Before you read.

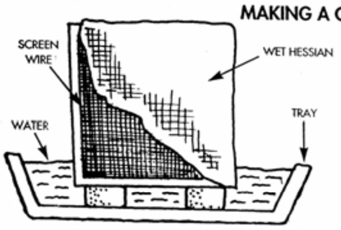
1. Why would you need a Coolgardie Safe?

2. If you had electricity, what would you use in place of a Coolgardie Safe?

3. What food would you store in a Coolgardie Safe?

Read through the materials you need for the safe and the set of instruction on how to make it.

MAKING A COOLGARDIE SAFE



YOU WILL NEED:
timber for the frame of the safe
flyscreen wire
a metal tray
hessian bags
bricks

INSTRUCTIONS FOR MAKING THE SAFE.
1. Build wooden frame for safe.
2. Fit door.
3. Cover frame and door with fly screen wire.
4. Make tray out of sheet metal.
5. Place safe on bricks in metal tray.
6. Hang hessian bags over safe so they completely cover it.
7. Fill tray with water.

Note: The Coolgardie Safe should be placed in a cool, shady position where a breeze can move the air around it. As the water soaks into the hessian bags, it rises around the safe. As the air moves around the safe, the water in the hessian evaporates and as it does, it cools the air inside the safe.

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Reading Focus
• **Literal** comprehension: 2
• **Inferential** comprehension: 1, 4
• **Critical/creative** comprehension: 3, 5, 6
• **Language/genre**: Omission of articles (determiners) from the instruction: 7
Verbs (processes) in the imperative mood: 8

Re-read the instructions or any part of the instructions so you can answer the following questions.

1. Circle the modern object which does a job like a Coolgardie Safe.
   gas stove: refrigerator: washing machine: dishwasher: clothes drier
2. With what do you build the frame of the safe? ____________________
3. Why is fly-screen wire used when building the safe?
   ____
4. Why do you need a metal tray?
   ____
5. Why would the safe need to be placed on bricks in the tray?
   ____
6. Circle those foods that would be better if they were kept in a Coolgardie Safe.
   leg of lamb: butter: tomato sauce: water: eggs: plain flour: tea: celery: plain biscuits: salt: sugar: tomatoes
7. In the instructions, there are words left out of the sentences. Re-write this sentence to include all the words that are left out.
   5. Place safe on bricks in metal tray. ____________________
8. Every sentence in the instructions begins with a verb (process) like *build, fit, cover.* Write down the other verbs (process words) that tell what to do.
   ____
9. Sentences used in instructions are commands. *Place safe on bricks in metal tray* is a command. Write down any other command from the instructions.
   ____
10. Here are a set of instructions for cooking a leg of lamb. Arrange them in the best order.
    - Place in baking dish with dripping.
    - Remove leg of lamb from Coolgardie Safe.
    - Cook 2 hours.
    - Place lamb in moderate oven.
    - Serve with potatoes and beans.

    1. ____________________
    2. ____________________
    3. ____________________
    4. ____________________
    5. ____________________

More things to do Imagine you were alive in the time when you had to use a Coolgardie Safe. Think about what you would do in a day. Fill in the information on a time line showing the important things you would do.

Structure of commands *Build wooden frame for safe* 9, 10
Ordering in a set of instructions 10

• **Discuss**: What was life like in the days when families used Coolgardie Safes? What has changed most in modern homes?

This lesson plan followed the design-and-make style of science lesson found in many of the current elementary resource books designed for the current syllabus. There is no explicit referencing in the plan to nature of science aspects. The principal questioning style is again factual and/or explanatory. Following the brainstorm activity, the teachers developed the following lesson plan on the same theme of keeping cool:

Figure 5.3 Teacher-developed lesson plan

MATTER LESSON 4

Lesson Plan Title: KEEPING THINGS COLD (WITHOUT REFRIGERATION)

Grade Levels: Stage 2

Materials needed: Hessian or muslin – wet and dry
6 cans of drink at room temperature
Thermometers
A windy day (if possible)

Teaching and Learning Activities:

TEACHER PRIOR KNOWLEDGE: Evaporation process
Refrigerator
Coolgardie safe (ref. folder)

PROBLEM: How can we cool a can of drink on a hot day?

T – Explain to students that the experiment will be set up as follows:

- 2 cans to be used as controls – 1 in sun, 1 in shade
- 1 can wrapped in wet Hessian in the shade
- 1 can wrapped in wet Hessian in the sun
- 1 can wrapped in dry Hessian in the shade
- 1 can wrapped in dry Hessian in the sun

T- Why do we need to have 2 cans to be used as 'controls' in the test? (fair testing)
Why do cans need to be exposed for equal amounts of time?

MAKE OBSERVATIONS:

Student – observe weather factors – wind, sun, shade

FORM A HYPOTHESIS:

T – What do you think will happen to the temperature of the liquid inside each of the cans?
S – Predict 'The can that………because……………….'
Or 'Wrapping cans in……………will………because………………'

`DO THE EXPERIMENT:

T – open the cans at start of experiment, then set up the experiment in the morning, leave several hours.

S – Record temperatures of liquid in each cans at commencement of experiment and after several hours. Compare temperatures between cans and between time periods. Record changes to the external appearance of any of the cans.

DRAW A CONCLUSION:

S – Describe what has happened to the liquid in each of the cans.

T – What caused the change in temperature of the liquid in the cans?
Why did some cans have a greater change in temperature?
What caused the drop in temperature in some of the liquids?
Where did the heat go?
Did the experiment support your hypothesis?

ASSESSMENT:

Accurately graph the changes in temperature in the cans.
Did the children participate in the post-activity discussion?

EXTENSION ACTIVITIES:

- What is a Koolgardie safe? How does it work? Research.
- Identify the role the evaporation process has in the water cycle.
- How would you keep a can of drink cool at the beach?

Although many of the questions are still factual and/or explanatory, the teachers have included explicit questioning and reference to nature of science aspects. As well, they have contextualised the lesson to include students' life experience with the beach and cooling drinks.

5.3.2.1. Case Study 2 Judith Lesson 1 Stage 2 (Year 4) class 4J Coolgardie Safe

The lesson on the Coolgardie Safe was conducted by Judith with her Year 4 class (4J). Judith was beginning her tenth year of teaching and admitted that she felt less confident in teaching science compared to the teaching literacy and numeracy. She had been given what she considered a good amount of science instruction in her teacher preparation course. This instruction had been included in each year of her teacher education course and had focussed on conducting practical-based lessons. Judith indicated she would use the teacher-developed lesson plan.

Unlike the lessons conducted by Suzanne and Margaret described later, Judith began the lesson by almost outlining in full for her students the lesson topic and the concept to be investigated:

Today we are going to find out what happens when we wrap a soft drink can in hessian and leave it out in the sun.

Note that although the opening question, *How can we cool a can of drink on a hot day?* was included in the lesson plan, and students were to be encouraged to suggest conditions that might influence the experiment, Judith's lesson opening was very teacher-centred. She limited her opening questions and provided a great deal of instruction:

We'll wrap some cans up in dry hessian and some in wet hessian.

We'll take the temperature of the can now and then every 10 minutes in the sun.

It was not until the equipment had been issued to the students that Judith began incorporating some of the lesson plan questioning:

Hands up who think the dry hessian will get hotter? Who thinks the wet hessian one?

She then asked a student for each of dry and wet:

Why do think that?

Two examples of student ideas are given below:

Student 1:

The can that is in the sun with the dry hessian will heat up because if it is in the sun the towel can heat up and heat up the drink.

Student 2:

The can that is in the sun and is in the wet hessian, it will change more because I think the sun will dry the wet hessian and the can will get warmer.

Judith did not continue questioning the students on these ideas but made the statement:

These ideas are called hypothesis (sic). When a scientist has an idea it's called a hypothesis.

She then introduced the concept of a 'control':

I'm going to put some cans out in the sun with no hessian.

Why would I do that?

One student was able to offer an answer:

Student 3:

The can that is not wrapped with anything in the sun will change most because it has nothing wrapped around it and that way the sun can get on more easily and make it much more hotter.

Judith went straight to the comment:

The can with nothing is called a control. We measure the others cans against it.

No further questioning on the use of control or hypothesising was conducted and the investigation was completed by the students. In wrapping up the lesson, Judith introduced the term ‘observation’ in her final question:

Did you observation support you hypothesis?

Student 1:

It turns out that the control in the sun, it heated the most.

Student 2:

No my observation didn’t support my idea because the control can was the hottest.

Student 3:

It did because the control in the sun was the hottest of all.

Judith was the least experienced of the three teachers and also had the lowest efficacy scores. Interestingly her post score for pendulum concept questionnaire was one of the highest in the whole of the study’s experimental group. When questioned by the researcher as to why she had departed from the questioning in the lesson plan and limited her questions overall, Judith commented that she lacked confidence in her ability to ask and answer more complex questions. She was more with the original lesson where she would have gone through the design-and-make process with a minimal explanation of how the Coolgardie safe works and the need for student to hypothesis and certainly no reference to the need for a control.

It is evident from the use of terms such ‘hypothesising’, ‘observation, and ‘control’ that some key aspects of scientific inquiry had been added to Judith’s nature of science knowledge but her pedagogical knowledge of how to elicit these from students was still underdeveloped.

5.3.2.2. Case Study 2 Suzanne Lesson 2 Stage 2 (Year 4)   class 4M/S Wet and Dry Ice

Suzanne, who was the most experienced teacher in this case study and who had a had been the school’s key promoter of science in the classrooms, asked the researcher to observe the first lesson of the series, Wet Ice versus Dry Ice. She was to deliver this lesson to the second (4M/S) of the two Year 4 classes at the school. Suzanne had always had a deep interest in science as her father was an engineer and had encouraged her to take science subjects in high school. Science instruction in her teacher preparation course had been minimal. Throughout her teaching career (20+ years) she had taken a leading role in developing and seeking out science curriculum resources. She was keen to have comments from the researcher on her questioning techniques for the lesson plan below (Figure 5.4):

Figure 5.4 Teacher questioning in lesson plan on Wet and Dry Ice

MATTER LESSON 1

Lesson Plan Title: WET and DRY ICE

Grade Levels: Stage 2

Materials needed: Ice cubes (wet ice)
Dry ice
Containers
Water
Tongs (for handling dry ice)

Teaching and Learning Activities:
TEACHER PRIOR KNOWLEDGE: Dry ice facts (see resource notes)
PROBLEM: How can matter change state?
TEACHER – Place each type of ice into separate containers.
MAKE OBSERVATIONS:
STUDENTS – Observe differences between each type of ice.
T – Tell students that water will be poured into each container. Ask :
Look at the ice: What shape, colour, size are the pieces? Is there anything surrounding the ice?
FORM A HYPOTHESIS:
What do you think will happen to each piece of ice when I pour the water on to it?
S – Predict what will happen to each piece of ice.
DO THE EXPERIMENT:
T – Pour water over each piece of ice (separately)
S – Observe the reaction in each container.
T – What happened to each piece of ice? Did the experiment confirm your predictions?
DRAW A CONCLUSION:
S - Describe what has happened in each container.
T – Did the experiment support your hypothesis? What did you learn about changes in matter?
- Relate the results of the experiment to the states of the particles in each matter form.

EXTENSION ACTIVITIES:

- How can you slow down the melting process?
- Investigate dry ice. What are the uses of dry ice? What is the temperature of dry ice?

ASSESSMENT:
Were all the children engaged in the activity?
Were all the children able to record changes in the matter?

A transcript of the lesson is given below:

The lesson began with Suzanne following the introduction as outlined in lesson 1 by showing the students ice-cream and asking:

How did I keep my ice-cream from melting between the shop and the school?

The students suggested a range of cooler bags, ice packs and wrapping paper. She then showed them a cooler bag with dry ice packed in it.

Does this look like normal ice?

Students commented on the 'smoke' (sic) coming out of the bag and that it looked different. One student was able to identify the ice as 'dry-ice'.

We're going to find out the difference between dry ice and wet ice.

But before we start, we will be doing science!

What sort of person does science?

Students: A scientist!

What does a scientist do?

Students: Experiments!

What are they trying to find out?

Students: They find out whether things do or don't work.

Suzanne explained to the class that scientists have thoughts in their head before they start.

What are they trying to do by doing an experiment? It's a word starting with 'P'.

Students: Prove.

Predict

Prepare

Suzanne then asked the students if they remembered a word they had used in an earlier science lesson. As an enthusiast for science in the school, Suzanne had developed lessons based on an inquiry approach so had introduced terms to the students.

So a scientist has in their head that something might happen. What word did we use for that?

Students: They had a hypothesis.

We are going to watch what happens. Do you remember a better word for watching in a science experiment?

Students: Observe.

If things don't work out scientists have to change.........

Students: Change their mind

Change their idea

Change their hypothesis

Now just because your idea doesn't work out, that's ok. As long as you can make a hypothesis, that's what's important.

What does a scientist make at the end of an experiment when the thoughts and ideas are put together?

Students: They make conclusions.

Suzanne then returned to the question of the differences between dry and wet ice. She placed a small amount of dry ice and wet ice in separate dishes.

I'm going to add water to each dish now. Let's see what happens after a few minutes. I'll put the dry ice in the fridge. Is that ok?

Students: No, they should both be in the fridge or on the bench.

Suzanne then introduced the term 'fair test' to the students with a simple explanation of what makes a test fair:

When you are doing an experiment, the test is meant to be fair.

So when we are comparing dry ice to wet ice, what would make our test fair?

Why should they be in the same place?

Students: Something is different.

Such as?

Students: It might be hotter outside.

Atmosphere.

The weather's not the same.

Different temperature.

To be a fair test the conditions must be the same.

Some students thought that the experiment still wasn't fair because the amount of dry and wet ice was not the same.

5.3.2.4. Case Study 2 Margaret Lesson 3 Stage 2 (Year 4) class 4M/S Melting Ice

Margaret was the next most experienced teacher in this case study and had formed a close relationship with Suzanne in promoting science in the school. She also had a science subject in her senior high school years and like Suzanne had minimal science instruction on her teaching preparation course. Margaret was to follow Suzanne's lesson with the same class (4M/S) on the concept of melting ice (Figure 5.5):

Figure 5.5 Teacher questioning in lesson plan on Melting Ice

MATTER LESSON 6

Lesson Plan Title: MELTING ICE

Grade Levels: Stage 2
Materials needed: Ice cubes – plain, coloured red, black, yellow Clear observation containers.

Teaching and Learning Activities:
TEACHER PRIOR KNOWLEDGE: Heating and insulation properties
PROBLEM: Which coloured ice will melt the fastest?
MAKE OBSERVATIONS:
S – Observe the ice cubes noting colour, shape and size
T – Why do we need to have the ice cubes all the same size and shape?
FORM A HYPOTHESIS:
Will any of the ice cubes melt at a faster rate than the others?
S – Predict what will happen to the ice cubes.
DO THE EXPERIMENT:
T – Set up the experiment and allow the children to make observations at regular intervals over a period of time.
T – What happened to each ice cube over the time period? Did the experiment confirm your predictions?
DRAW A CONCLUSION:
S – Describe the changes that occurred to the ice cubes.
T- Did the experiment support your hypothesis?
ASSESSMENT:
Simple written activity describing and illustrating the changes that took place.
EXTENSION ACTIVITIES:
Does the colour of a car affect its inside temperature? What colour car would be the best for Australian summers?
Can the colour of clothing affect the temperature of the person wearing it?

A transcript of the lesson is given below.

The lesson began with Margaret following up on Suzanne's lesson:

Who can tell me what you learned in the last lesson?

Students: Dry ice is carbon dioxide.

There are three states of matter.

You can change matter into another form.

Wet ice melts, dry ice doesn't.

Ice melts when you put heat in.

Margaret used the final answer to set up the lesson:

If we put ice in the sun, is that putting heat in?

Students: The sun has solar energy miss. That's heat isn't it?

Margaret spent a few minutes discussing heat from the sun to the students and then continued:

What do think would happen to the ice if we put colour in it?

Students: The colour might catch the heat?

Maybe we could use cold colours and hot colours.

What is a cold colour? Can you give me an example?

Students: Green

White

Blue

Why do you think blue is cold?

Students: Because on a cold day your lips turn blue.

And the sun's colour is yellow and red and that's hot

Margaret then spent a few minutes telling the students about how scientists can tell from the colour of stars what temperature they are.

So, what colours should we try?
 	
Students: Red
 	
        Clear
 	
        Blue
 	
        Yellow
 	
Write down what colour will melt fastest, but more importantly write down why you think it will.

Margaret had already made ice cubes of various colours so the students could have a range of choice. She then instructed the students to put an ice cube into a small clear plastic cup.

Now we will put the ice out in the sun and check every five minutes. How will we tell which one is melting the fastest?
 	
Students: Just look at what one is smaller
 	
        How much water there is.
 	
        We need to measure.

Margaret then told the students that she had made the ice cubes in a tray so they would be the same size. She did not explain to the students why this is important. She did however start a few questions on the ice without colour:

Remember we will be having some ice cubes without colour.

Which one was that?

Students: The clear one.

The normal one.

We will be comparing the clear ice to ice cubes without colour. This is called using a control.

The control is what you compare something to.

So let's check what you thought about which colour would melt first. When you chose your colour that is a prediction. But when you try to explain why your colour melts first, that's an idea or what scientists call a hypothesis.

So why does your colour work best?

Students: It's the colour of the sun.

There are chemicals in the colour.

Blue ice absorbs heat faster.

Red ice because red is a hot colour and absorbs the sun fast.

Margaret and the class completed the experiment but the students found measuring the water produced difficult to measure so Margaret was unable to conclude the lesson with further questioning.

5.3.3. Debrief of Case Study 2 teachers

Suzanne commented that she felt she had a reasonable understanding of the science inquiry process but was surprised how quickly the class picked up on the notion of fair testing. She commented that alerting students to this concept was not addressed in her previous lessons. Also, she believed that explicit questioning on fair testing and ideas changing in science were crucial elements in the new lesson plans.

Margaret commented how surprised she felt that she had remembered the colour of stars but felt it was valuable to be able to include that discussion in this lesson. She stated she would have never talked about this in any other previous lesson as those lessons were more technology based or science in application type.

When asked by the researcher why she had mentioned the ice cubes having to be the same size, Margaret were able to link this to the notion of fair-testing. The researcher pointed out that this was a part of the new lesson plan:

MAKE OBSERVATIONS:
S – Observe the ice cubes noting colour, shape and size
T – Why do we need to have the ice cubes all the same size and shape?

She commented that she had missed this as an explicit question as she concentrated on the student predictions of colour and heat absorption.

5.4 Summary of Case Studies

A number of key observations can be made from the two cases. Both case studies provide evidence of how teachers in the cases have made purposeful attempts to include explicit questioning on aspects of nature of science. In the context of the lessons taught, the teachers have developed their questioning around the importance of hypothesising, fair-testing, modelling and the tentativeness of science.

The NOS questioning was most thorough in case study 2 where the teachers pre-planned the lessons with explicit attention to the questions to be asked. In case study 2 lessons, the teachers for the main part covered the intended NOS questions and had a greater scope of nature of science aspects addressed. The teachers in case study 1 who had not developed a lesson plan with intended explicit NOS questioning required prompts from the researcher during the lesson and/or at a debrief session.

Below (Table 5.10) are comparisons between the questioning utilised in case study 1 classroom lesson transcripts and the intended questioning in a case study 2 teacher-developed lesson plan:

Table 5.10

Comparison of intended NOS questions of Case Study teachers with low SETAKIST pre-test scores (<24)

Case Study 1 (Bridget)	Case Study 2 (Questions in Lesson Plan)
What ways can you use parts of your body to make a sound?	How can we cool a can of drink on a hot day?
How was sound made?	Why do we need to have 2 cans to be used as 'controls' in the test? (fair testing)
How does the sound alter when you clap quickly then slowly?	Why do cans need to be exposed for equal amounts of time?
Why does it work?	What caused the change in temperature of the liquid in the cans?
What things were important to think about when you were designing your stethoscope?	Why did some cans have a greater change in temperature?
What about the shape?	What caused the drop in temperature in some of the liquids?
What could you change to make it work better?	Where did the heat go?
	Did the experiment support your hypothesis?

Case study 2 intended questioning explicitly includes reference to the notion of use of a *'control'*, the need for *'fair-testing'* and the term *'hypothesis'*.

Below (Table 5.11) are comparisons between the actual questioning utilised in both case study classrooms, with case study 1 questioning **after** prompting from the researcher:

Table 5.11

Comparison of ***actual*** classroom NOS questions of Case Study teachers with low SETAKIST pre-test scores (<24)

Case Study 1 (Bridget, after prompting)	Case Study 2 (Judith)
Is this a real stethoscope?	Today we are going to find out what happens when we wrap a soft drink can in hessian and leave it out in the sun.
Is it a puzzle or model?	We'll wrap some cans up in dry hessian and some in wet hessian. We'll take the temperature of the can now and then every 10 minutes in the sun.
How do we get form our model to a real stethoscope?	Hands up who think the dry hessian will get hotter? Who thinks the wet hessian one?
Were our telephones last week real?	Why do you think that?
Do all models work?	These ideas are called hypothesis (sic). When a scientist has an idea it's called a hypothesis.
How do you know they don't work?	I'm going to put some cans out in the sun with no hessian. Why would I do that?
When a scientist comes to test their new model they have to test them the same way as their first model. Why should you test your new stethoscope the same way?	The can with nothing is called a control. We measure the other cans against it.
	Did the experiment support your hypothesis?

In both examples above, the researcher had a role as an academic friend, intervening either at the lesson delivery (case study 1) or prior to the lesson during the lesson plan construction (case study 2). As a result of the researcher input, the explicit questioning on NOS aspects and the instances of NOS terms has increased. In case 1, however, the researcher had to intervene during the lesson to prompt the teacher on the NOS aspects discussed prior to the lesson.

The questions (Tables 5.10/5.11) were from lessons taught by the teacher in each case study that had the lowest SETAKIST pre-test score (Bridget, Judith). Referring back in the chapter to the description of this case study 1 lesson, Bridget commented that in the everyday pressure of delivering a science lesson, she found it difficult to remember to explicitly include NOS questioning and terms. Bridget commented on the help that questioning gave her in engaging the students in not only the concept but also scientific process and recalled how models had been mentioned in the pendulum lessons she observed during the PD program.

In the case study 2 lesson, Judith had a lesson plan to guide her but still omitted some of the explicit NOS questioning or introduced NOS terms without questioning. Judith was the least experienced of the three teachers in case study 2 and also had the lowest efficacy scores. Interestingly her post score for pendulum concept questionnaire was one of the highest in the whole of the study's experimental group. When questioned by the researcher as to why she had departed from the questioning in the lesson plan and limited her questions overall, Judith commented that she lacked confidence in her ability to ask and answer more complex questions. She was more comfortable with the original lesson where she would have gone through the design-and-make process. This would have required minimal explanation of how the Coolgardie safe works and the need for student to hypothesis and certainly no reference to the need for a control.

It is evident from the use of terms such 'hypothesising', 'observation, and 'control' that some key aspects of scientific inquiry had been added to Judith's nature of science knowledge but her pedagogical knowledge of how to elicit these from students was still underdeveloped.

However, case study 2 shows a more planned questioning approach that was reproduced in the actual lesson. Lessons delivered by the teacher in each case study with the higher pre-test SETAKIST scores (>24) (Wendy, Suzanne) were then observed and analysed for NOS questioning and terms. Although the SETAKIST scores were the determinant for selection of the case studies, it is worth noting the post-test responses (Table 5.12) to question 1 of the VNOS-D form for each of the teachers:

Table 5.12

Comparison of Case Study teachers' VNOS-D Question 1 pre- and post- responses

Question 1. What is Science?					
Case Study 1	Wendy	The way things work in the world. What things are, how they react to other things and where they fit in the total or overall picture. How things change and the factors that contribute to change in the physical world.	1, 6, 10	It is the study of how things occur in the world, the interaction of these things and what occurs as a result of these interactions. It is based on observation, experimentation which leads to a body of knowledge	1, 6, 10, 9, 17, 22
	Bridget	It is the study of the world in which we live, including living and non-living things	6	Is the study of living and non-living things and phenomenon in the world.	6

Table continues

Question 1. What is Science?					
Case Study 2	Suzanne	The study of natural or physical phenomenon in the universe	6	Science is something that is forever changing, not stagnant. It is enquiry, testing, retesting, hypothesising, questioning, intriguing. Something that makes you think and re-think what you believe in or thought you believed in. It is simple and complex. It is real and it is your imagination.	13, 16, 7, 20, 22, 14
	Judith	The study of the impact of one or more element on others	10	Observation and understanding of the natural world and its relationships/interactions between its parts. Experimentation to explain/discover the relationships/interactions.	1, 6, 10, 17

In both case studies, the post-test question 1 responses for the higher SETAKIST scoring teachers (Wendy/Suzanne) contain a greater number of coded themes, a pattern generally consistent with their responses for the other question.

The difference in the analysis that follows (Table 5.13) is that in case study 1, the teacher with the highest pre-test score (Wendy) had been present at the debrief of the first lesson and had participated in discussion on the need to pay more attention to NOS questioning:

Table 5.13

Comparison of classroom NOS questions for high SEATKIST pre-test scores

Case Study 1 (Wendy, after debrief)	Case Study 2 (Lesson Plan-Intended)	Case Study 2 (Suzanne, actual)
Who can tell me what a scientist does?	Look at the ice: What shape, colour, size are the pieces?	How did I keep my ice-cream from melting between the shop and the school?
Do you think they know a lot about dinosaurs?	What do you think will happen to each piece of ice when I pour the water on to it?	We're going to find out the difference between dry ice and wet ice. But before we start, we will be doing science.
But they haven't seen a real dinosaur have they?	What happened to each piece of ice? Did the experiment confirm your predictions?	What sort of person does science?
How do bones help?	Did the experiment support your hypothesis?	What does a scientist do?
If we put all the pieces together, is it a real dinosaur?		What are they trying to find out?.
Remember our telephones and stethoscopes? They weren't real!		What are they trying to do by doing an experiment? It's a word starting with 'P'.
How does the sound get from one end of the stethoscope to your ear?		So a scientist has in their head that something might happen. What word do we use for that?
So even though you cannot see the sound you can model how it travels!		We are going to watch what happens. Do you remember a better word for 'watching' in a science experiment?
		What does a scientist make at the end of an experiment when the thoughts and ideas are put together?
		I'm going to add water to each dish now. Let's see what happens after a few minutes. I'll put the dry ice in the fridge. Is that ok?

Table continues

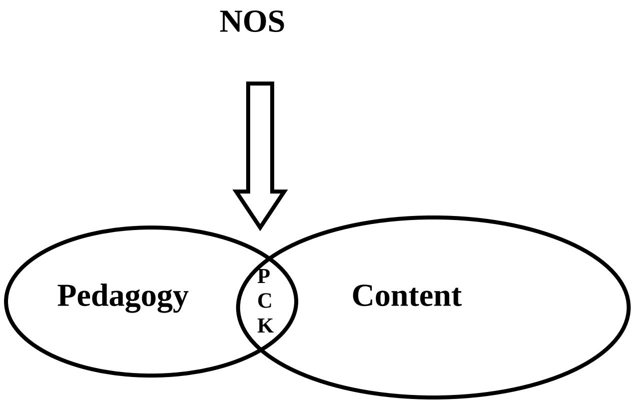
		When you are doing an experiment, the test is meant to be fair. So when we are comparing dry ice to wet ice, what would make our test fair? Why should they be in the same place? To be a fair test the conditions must be the same.

Both Wendy and Suzanne demonstrate more complex questioning techniques on the NOS concepts targeted in the PD program. Wendy had the benefit of participating in the debrief of Bridget's lessons and discussing with the researcher the example in the VNOS form regarding scientists' ideas on dinosaurs. She was then able to lead her students into the use of models using structured questioning to develop students understanding of how models might be useful. Judith's questioning after prompting was explicit but was less complex. Suzanne, who had the highest SETAKIST scores and the greatest number of post-test VNOS responses, employed the most complex, explicit questioning on NOS aspects.

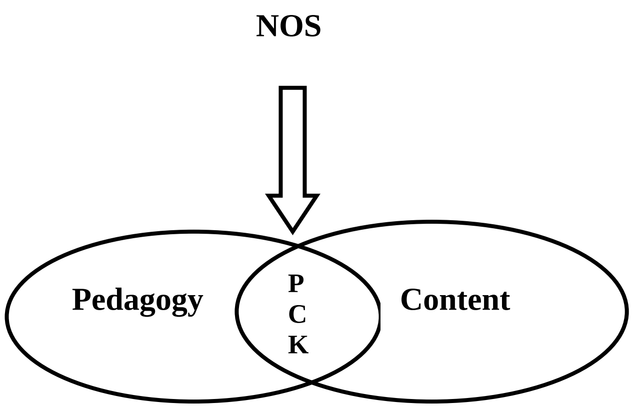
Recalling the theoretical framework from Chapter 1, PCK is the integration of both pedagogical (teaching) and content (knowledge) that ultimately influences classroom practice (Parker, 2004). At the conclusion of Phase 2 in which teachers' attempts at this integration were observed and analysed, a graphical representation of degrees of integration could be presented as:

Figure 5.6 Graphical representation of degree of PCK component integration

Integration by Less Efficacious Teachers



Integration by More Efficacious Teachers



At the end of the Phase 1 time period, no teacher from within the control group had attempted to use the lesson plans or NOS strategies in their classroom. Therefore, no integration of pedagogy and content can be shown for the control group from the data collected and observation provided in this study.

5.5 Experimental Group Final Debrief

At the completion of Phase 2 (the intervention) and after conducting the case studies, a post-program workshop was held for all participants in the experimental group. The experimental group participants were divided into three smaller cohorts. Each cohort was then given the debrief questions and asked to respond. The researcher was not present in the debriefing rooms and the debrief was conducted by and the responses recorded by assistants who had played no role in the PD program. No input, guidance or advice was given to the separate cohorts by either the researcher or the assistants. Below is a table of the responses to each debrief question:

Table 5.14 Debrief responses Question 1

Workshop/Debrief Responses

What prior knowledge or experience did the students have about aspects of the pendulum?

Cohort	Responses
1	little prior knowledge grandfather clock
2	identified pendulum in grandfather clock very little knowledge age dependent: Year 6 knew more than Year 3 social/cultural differences eg refugees language problems in identifying the word pendulum life experiences eg music knowledge – relate pendulum to metronome
3	none whatsoever hardly any knew grandfather clock for “Hickory Dickory Dock” knew about the ‘pendulum’ inside the clock (knew it swings) had something to do with time metronome Yr 2 knew about the pendulum/clock when drawing the nursery rhyme Apart from the clock in Hickory Dickory Dock the children knew nothing none

The pendulum has been recognised as being a powerful context for the teaching of nature of science understanding in schools (Matthews, 2004). For elementary teachers whose confidence in the teaching of science and in science background knowledge is limited, it was considered crucial to provide a scientific concept that both teachers and students good engage with.

As the range of classes spanned Year 2 (seven year olds) to Year 6 (12 year olds), the context of the pendulum allowed the students to bring some prior knowledge to the lessons. In general, students were able to recall, at either the beginning of the first lesson, or by its conclusion, that the pendulum was a component of a grandfather clock or a metronome. This was seen as crucial to enhancing teacher confidence in the ability of their students to participate fully in the lessons. The positive outcome of teaching practice is a significant motivator for teachers attempting changes to pedagogical practice (Bandura, 1977).

The next two questions concerned the questioning used within each lesson and are analysed together:

Table 5.15 Debrief responses Question 2

How important were the questions asked at the beginning and during the lessons?

Cohort	Responses
1	extremely important allow students to make discoveries for themselves generated more questions
2	very important to questions at the beginning-focuses ideas during lessons questions lead to new ideas and tangential concepts questions were important but had to be rewarded for students. Age and first language dependent some questions were ambiguous set atmosphere for lesson. Questions at the beginning serve as reference for later stages in lesson.
3	it provided a springboard to interest and engage the students very – brought about inquiry, curiosity and raised involvement and participation crucial that got them 'fired up' it was crucial to put them in the frame of mind it made the students ask more questions challenged them/excited them/extended the gifted and talented/those that like to scientific argument critical to working at solving a problem essential, vital, the lynch pin of the lesson. It is the questioning that stimulates the inquiry that promotes the key learning of the lessons!! Very – made children think and direct the lesson to solve these questions. at end of lesson students can internalise what they have learnt

Table 5.16 Debrief responses Question 3

How well did students respond to these questions?

Cohort	Responses
1	students were enthusiastic joy of discovery, kids want to know the answer kids were involved competition between boys and girls
2	responded well. Depends on who asks the questions and their background and experience. following answers, students wanted to be shown/given the proof.
3	enthusiastically most seemed interested and engaged – some more than others as you would expect some were disinterested (but that is normal for this class) at first they were apprehensive in case they got it wrong not willing to take risks initially encouraged them to have a go you (ie the teacher) have to accept different class ideas lateral thinking responded very positively, opened up new ideas, they became more creative in their thinking confidence in their own opinions the questions allowed synthesis and analysis of information the questions engaged the children in the learning process and opened the lesson up to a whole range of other enquiry using questions – led to further scientific investigations. quite well they loved the lessons and responded very well to the questioning techniques and the activities

The inclusion of explicit questioning in every lesson plan and intervention classroom activities targeted both teacher content knowledge and pedagogical practice. Teachers were modelled through a new approach to the teaching of science that would require them to develop new understandings of their practice (Sherin, 2002). The responses from each group indicate positive teacher attitudes for the importance of explicit questioning on student engagement with the science concepts.

Direct observation in the context of their own classroom of the effect of this effective questioning technique on student engagement and teacher reflection of the critical nature for student learning was a key determinant in the structure of this PD program. Modelling of successful techniques in situ of the classroom provided teachers with evidence of positive outcomes for student learning, one of the key factors in teacher efficacy. The researcher as classroom teacher, rather than teacher mentor or academic friend, in this stage of the PD program, was seen as providing the opportunity for enhancing the teachers' identification with the model.

Results from the SETAKIST instrument for teacher efficacy changes in both science knowledge and science teaching indicate that in situ experiences were more greatly impacted than by a more traditional PD program conducted outside the teacher's classroom. This increased efficacy, especially for science teaching, would indicate that the teachers identified with the modeller as a classroom teacher and had gained confidence in their pedagogical expertise to carry out similar lessons.

The next two questions concerned the use of the pendulum as the context within the lessons and are analysed together:

Table 5.17 Debrief responses Question 4

How useful is the study of the pendulum for developing children's skills in doing science?

Cohort	Responses
1	practical way of learning about science method, fair testing, procedure easy to use/find materials applicable across age range hands-on experience that is also safe (no flames, sharp objects, mess, water etc.) once kids learn/familiarise with scientific skills, they are more likely to apply to different situations.
2	very useful inspires argument in group learn that science is a process simple to set up simple to design a fair test is hands-on, inspires questioning, investigating, exploring, hypothesising, making conclusions
3	the purpose of experimenting and considering the data was excellently suited to pendulum study; eg replicating each others findings, bias etc. very useful as it can be linked into Maths, HSIE and Creative Arts as well as other KLAs – not just SciTech they could relate to the equipment that was familiar to the. It wasn't high faluting *(sic)* science equipment. You weren't talking beakers, test tubes, tripods etc. developed measuring skills/ reasoning skills/co-operative, negotiating skills/writing skills when writing their reports/language skills, talking/listening students learned about conducting a science experiment correctly following the processes of investigation using appropriate language, testing conditions, variables, fair play "fair test" understood some students thought it was useful for high school not at all for year 4 primary students. Would rather develop enquiry based learning activities related to their world the process followed – the nature of science – is a great basis for studying other areas.(Science Rich tasks) it was good introduction that used everyday equipment that children could relate to. It let them see the scientific process in a non-threatening, familiar situation. They now know what a pendulum is and what it is used for. Lends itself to open ended questions but there would be other topics as well eg electricity?

Table 5.18 Debrief responses Question 5

What new knowledge have you gained from the project?

Cohort	Responses
1	all gained a huge amount of new knowledge gained confidence to give it a go having resources helped having teaching notes have seen it work having a follow up – structure of the pendulum project prompted more involvement /engagement of teachers than just being given background info and/or resources it's more than knowledge: it's questions – what to ask and HOW to ask it
2	learned about kids and their learning styles, interests and abilities length of string is all that matters interrelationships to other areas of knowledge eg history, geography importance of questioning in child learning science is fun
3	everything about the pendulum the characteristics of pendulums – that really intrigued me to have the children redo experiments to check findings I know the basics of how pendulums work. Reinforced using scientific method when studying a topic. We now have some basic scientific knowledge about a pendulum. It made us more aware of the historical aspect behind some of scientific discoveries that we were totally oblivious too (sic) – but find interesting. Some concepts about pendulums Use of open ended questions

The responses indicate that the pendulum as a context for the lessons has a number of key characteristics that address issues with teacher confidence in the teaching of science in elementary schools:

- uses simple, readily available resources that are easy for teachers and students to manipulate
- provides cross-disciplinary teaching opportunities for teachers
- Pendulum concepts are easily understood by teachers increasing their confidence in science knowledge

- develops elementary teachers’ and students’ inquiry skills
- strengthens teachers’ questioning skills
- provides opportunities for teachers to develop students’ critical thinking skills
- provides a mechanism for the introduction of nature of science aspects at the elementary school level through increased teacher NOS knowledge and understanding.

Table 5.19 Debrief responses Question 6

Do you think that introducing aspects of the nature of science into the science lessons is important to developing student's' awareness of what it is to do science?

Cohort	Responses
1	yes kids learn questioning, investigating, exploring, hypothesising, concluding practice applications to world kids are living in stimulated questioning, investigating, exploring, hypothesising, concluding
2	absolutely important to learn how to prove theory important to learn about fair testing and science methodology tentative nature of science introduce bias
3	yes – the nature, the process involved in a scientific investigation sets out explicit criteria for all to work towards and assess yes, I had never really thought this idea through science isn’t absolute, it’s subject to change. They know they do not have to accept “at first” what they think is the answer keep an open mind there’s “bias” in science. Therefore Galileo’s come up with theories, he was called a heretic made to recant there’s still bias today, it’s in everyday life encourages critical thinking/logical argument Nazi’s using “Nazi/Aryan” science to justify experiments they view science and scientists as “nerdy” so it’s good to show it’s creative yes – it’s essential yes. Absolutely!!

The current curriculum in use in these schools has no mandatory teaching and learning outcomes on the nature of science, so prior to this program participating teachers had not included any aspects of NOS in their teaching programs. There is evidence in the responses that the teachers have increased their knowledge of aspects of the nature of science specifically targeted by the observed lessons and recognise how the inclusion of NOS aspects can improve their teaching of science.

During the post-program workshop debriefing, the teachers commented on the importance of questioning throughout the lesson: *….extremely important…allow students to make discoveries for themselves ….generated more questions… during lessons questions lead to new ideas and tangential concepts.* The specific questioning was also strongly recognised by the teachers as significant to their students' increased understanding of nature of science concepts: *…kids learn by questioning, investigating, exploring, hypothesising, concluding ......important to learn about fair testing and science methodology,……tentative nature of science.……,introduce bias.*

A textual analysis was performed to extract from the debrief responses key terms that were identified in the thematic analysis of the VNOS responses for Questions 1 and 2 (Chapter 4). Themes and their frequency ($n > 2$) identified from the debrief responses corresponding to Questions 1 and 2 are shown below:

Table 5.20

VNOS Question 1 and 2 themes in debrief responses

Themes	*n*
Science as a method	6
Questioning	6
Fair testing	5
Investigating	4
Science is tentative	4
Hypothesising	3
Making conclusions	3
Exploring	3
There's bias	3

The corresponding themes in the VNOS analysis are highlighted below:

Table 5.21

Instances of themes in Experimental Group VNOS responses.

Question 1 What is Science?	**PRE**	**POST**
Study of phenomena	20	21
Role of science in explaining phenomena	19	14
Investigating	8	8
How things are connected	6	2
Experimenting	6	6
Technology	3	2
Reasoning	3	1
Analysis	2	1
Testing hypotheses and theories	1	10
Hypothesising	1	7
A body of knowledge	1	1
A way of knowing	1	2
Involves fair-testing	1	4
Observing	1	3
Changeable	0	3
Inferring	0	2

Table continues

Question 2. How is science different to other KLA's you are teaching?	PRE	POST
More hands-on	14	13
Involves investigating	10	14
Involves a lot of time	7	0
Involves experimenting	6	7
Involves hypothesising	5	8
Resource dependent	5	4
More challenging for teacher	5	1
Requires background knowledge	4	3
A specific process	4	9
Involves uncertainty	3	10
Helps develop critical thinking	3	6
Involves interpretation	2	3
Involves observation	0	3
Allows for more questioning	0	4

A number of the more significant changes to teachers' responses at VNOS post-test are reflected in the instances of references made at the debrief session. The importance of teacher questioning and encouraging hypothesising as a teaching and learning strategy in science instruction appears well understood. The experimental group's SETAKIST post-test scores for teaching efficacy were significantly impacted (Chapter 4) and both case study examples demonstrate a shift to more explicit NOS questioning.

Of particular interest is how the questioning techniques and attention to hypothesising in the researcher-delivered pendulum lessons has been applied to different contexts in the case study lessons on Communication and Heat/Ice. Teachers need to be convinced of both their own effectiveness and the currency of new approaches to teaching if they are to incorporate them into classroom practice. Teachers with greater self-efficacy will set for themselves and their students more challenging goals and will persist in the face of obstacles (Ross, 1995; Tschannen-Moran & Woolfolk Hoy, 2001).

A key goal of participation in the PD program was for teachers to turn vicarious experiences into mastery experiences. The suitability of using the pendulum as the context of the intervention lessons as a mechanism for increasing teacher confidence in their ability to turn vicarious experiences into mastery experiences is supported by the responses of the teachers to the debrief questions:

- gained confidence to give it a go
- have seen it work
- very useful as it can be linked into Maths, HSIE and Creative Arts as well as other KLAs – not just SciTech
- having a follow up – structure of the pendulum project prompted more involvement /engagement of teachers than just being given background info and/or resources
- the process followed – the nature of science – is a great basis for studying other areas.(Science Rich tasks)

Aligned with this increase in teaching efficacy of the experimental group is the change in their knowledge efficacy, reflecting the theoretical model for NOS pedagogical content knowledge (PCK) utilised in this study, where PCK is contingent upon both content knowledge and pedagogical knowledge. Again, the responses in the debrief questions support the importance of the pendulum lessons in developing NOS understanding:

- We now have some basic scientific knowledge about a pendulum. It made us more aware of the historical aspect behind some of scientific discoveries that we were totally oblivious too (sic) – but find interesting.

- I know the basics of how pendulums work. Reinforced using scientific method when studying a topic.

- the process followed – the nature of science – is a great basis for studying other areas.(Science Rich tasks)

- all gained a huge amount of new knowledge

- yes, I had never really thought this idea through
- science isn't absolute, it's subject to change. They know they do not have to accept "at first" what they think is the answer
- tentative nature of science

5.6 Summary

In this chapter, two case studies and teacher reflections on the professional development programs were reported. An analysis of teacher questioning (intended and actual) and recorded responses to debrief questions was conducted to investigate the impact of a nature of science approach to the teaching of science in their classrooms.

CHAPTER 6

CONCLUSIONS

6.1 Introduction

The purpose of this chapter is to provide a summary of the research reported in this thesis, and to explicate some conclusions. First, the general aims and research questions of the study are revisited, and then a discussion of the limitations of the thesis is presented, followed by specific recommendations for theory and practice and directions for future research.

6.2 Purpose of the study revisited

The central aims of the study were to expand current understanding of the impact on practicing elementary teachers' self-efficacy and their views of nature of science views through participation in a reform-style professional development program. The research reported in this thesis also sought to provide a unique contribution to an understanding of how these views are integrated with nature of science teaching strategies into classroom practice. To fulfill the explicit aim of the thesis as well as to provide a unique contribution to the field, a mixed methods research approach was adopted where a qualitative study was conducted to illuminate the quantitative findings.

Data gathered from three test instruments used in the quantitative phase suggest that teacher self-efficacy for ***both*** knowledge of and teaching in science, and views on the nature of science are positively impacted through participation in a reform-style professional development program. As well, the data from the case studies suggest that explicit targeting of nature of science concepts during a reform-style professional development program result in the adoption of new NOS teaching and learning strategies by teachers into their classrooms. These findings provide relatively new and valuable insights into the phenomena of practicing elementary teachers' views on the nature of science and the strategies they develop to incorporate these into classroom practice.

Consequently, it appears that the general aim of the study has been fulfilled. The investigation of practicing elementary teachers' views on the nature of science, their self-efficacy beliefs and resultant classroom practice is a relatively new area of inquiry in terms of elementary teachers' pedagogical content knowledge for nature of science. As a result, the research presented here can be considered a unique contribution to the field

6.3 Research questions revisited

The research questions posited in Chapter 1 were investigated in Phase 1 (Chapter 4) of the research. A statistical analysis was conducted on the SETAKIST instrument and was determined to be robust for the group sizes studied. Because of the approach taken in the analysis of the VNOS instrument and the low frequency of some number themes identified in the responses, a predominantly qualitative interpretation was performed for this instrument. Therefore, the answers to the research questions for VNOS should be considered in light of the researcher's interpretation of the participants' written responses.

Research question 1. Does participation in professional development developed on tenets of the nature of science impact on the self-efficacy of elementary teachers for science knowledge and science teaching.

Results from the ANOVA output and paired-samples tests indicate a positive effect on knowledge efficacy for both the experimental and control groups as a result of participation in either the reform-style or the more traditional program.

Teacher efficacy for the control group has not been impacted significantly through participation in a traditional professional development program.

Research question 2. Is there a difference between the impact on self-efficacy of elementary teachers for science knowledge and science teaching through participation in structurally different professional development programs?

Both groups had access to new curriculum materials for science subject knowledge including pendulum studies and aspects of the nature of science. As stated, results from the ANOVA output and paired-samples tests for the SETAKIST instrument, indicate a positive effect on knowledge efficacy for both the experimental and control groups.

The analysis of the means for the pendulum questionnaire indicates that this change in knowledge efficacy was greater for the experimental group. Using the number of *Unsure* responses as indicative of teacher confidence in their knowledge of a pendulum concept, the analysis of the means for *Unsure* responses (Table 4.21) show a significant difference between the experimental and control groups. The experimental group demonstrate a greater preparedness (confidence) to propose answers to the pendulum questionnaire.

Research question 3. Does participation in professional development impact on NOS views of elementary teachers?

There is evidence in the number and frequency of identified VNOS themes that there has been an increase in knowledge and understanding of VNOS aspects in both groups. The analysis and interpretation of the responses in the VNOS survey indicate that changes in teachers' knowledge and understanding of NOS aspects are most pronounced when items within the VNOS instrument were explicitly targeted in both types of professional development program.

Research question 4. Is there a difference between the impact on NOS views of elementary teachers through participation in structurally different professional development programs?

The most significant changes in the VNOS instrument occur when the professional development program is based on a reform-style approach. The reform-style professional development program was designed around providing vicarious experiences in the teaching of VNOS in situ of the teachers' classrooms, with time available for lesson debriefs and general discussion between the teachers and the researcher.

The frequency charts indicate that targeted nature of science aspects in the classroom intervention lessons are either more frequent at post-test (hypothesising, involves uncertainty, conclusions based on individual interpretation, scientists have biases) or missing from the control group responses (fair-testing, changeable, science is dynamic).

6.4 Limitations

Before discussing the implications for theory and practice based on the research findings, it is important to acknowledge limitations of the research in general as well as to revisit limitations identified in the quantitative and qualitative phases of the research. Limitations are limiting conditions or restrictive weaknesses, which are unavoidably present in a study's design (Punch, 2000).

Because of practical constraints, the groups were of unequal size. Although this has been accounted for by applying tests for homogeneity and normality, equal group sizes may have allowed further statistical analysis. Secondly, the experimental group originally consisted of 50 teachers who were to observe 5 lessons. The researcher delivered close to 250 lessons but due to teacher promotion, illness and transfer, the final experimental number who completed both pre-test and post-test instruments had fallen to 37. This was not anticipated at the beginning of the study and was evidence of how some weaknesses in a study are difficult to plan for (Creswell, 2002).

The purposive sampling procedure employed for the phase 2 case studies decreases the generalisability of findings (Creswell, 2002). This study will not be generalisable to the teaching of nature of science in elementary schools. Also, the phase 2 case studies involved participant observation which may have the limitation of participants acting differently or putting up a facade that is in accordance to what they believe the researcher is studying.

In the quantitative component of Phase 1, a quasi-experimental design was employed for non-randomised groups at pre- and post-test. Any choice of research design requires consideration of validity and practicality. In practical terms, quasi-experimental research is more feasible, given the typical time and logistical constraints and the use of such a design presents the situation under investigation in real-world conditions which increases the external validity. However, the lack of random assignment and reductions in the number of variables that can be controlled lead to limits to internal validity and causal claims (Bradley, 2009).

Also in the quantitative component of Phase 1, the test instruments may have the limitations of not accurately describing a complex situation or only providing the respondents with a limited range of response options. The decision was made to use the VNOS instrument without follow-up interviews so the interpretation of responses was limited to the researcher interpretation of themes. The VNOS instrument can give a measure of teacher knowledge efficacy but it cannot be determined from the responses whether any increase in knowledge efficacy is due to an increased understanding on nature of science concepts, pendulum concepts or a combination of both.

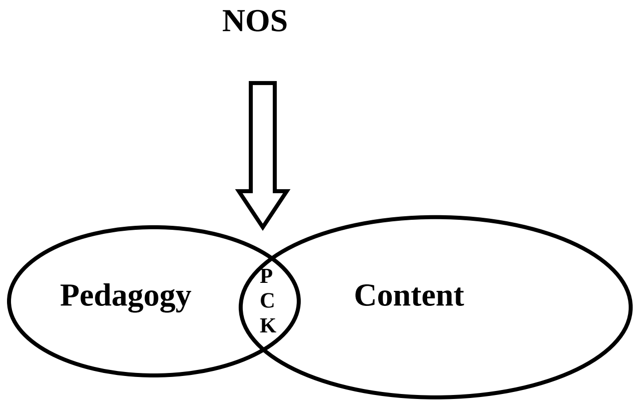
6.5 Implications for Theory

There are a number of implications for theory that emerge from the findings of this research. There are few studies that have investigated the link between nature of science understanding and its influence on elementary teachers' self-efficacy (Hanson & Akerson, 2006). As well, there is limited research on large cohorts of *practicing* elementary teachers' pedagogical approaches to incorporating nature of science teaching and learning strategies into classroom practice. The empirical results reported here, especially in the impact to *both* knowledge and teaching efficacy, are potentially an important contribution to the research on the how teachers build their nature of science pedagogical content knowledge.

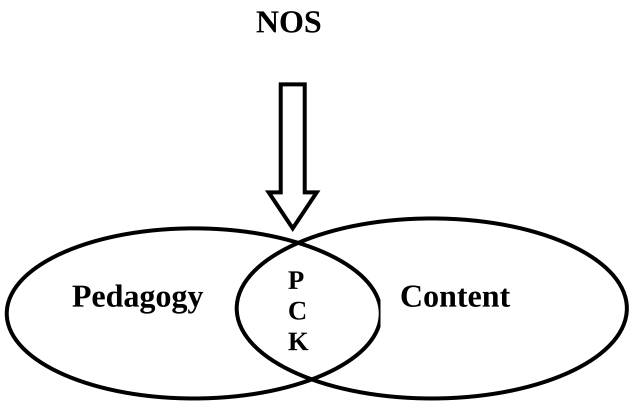
The key implication for theory lies in the ways teachers attempted to *integrate* their enhanced NOS knowledge and involvement in targeted NOS teaching strategies into their classroom practice. As integration increases, the contention of the theoretical model is that a teacher's PCK for NOS increases. The findings from this study support the theoretical model representations (see Figure 5.6 below) proposed by the researcher for teachers of differing efficacies:

Figure 5.6 Graphical representation of degree of PCK component integration

Integration by Less Efficacious Teachers



Integration by More Efficacious Teachers



Teachers in both of the case studies made purposeful attempts to include explicit questioning on NOS aspects (See Section 5.4). There is evidence that those teachers with higher efficacy scores exhibited deeper and more extensive questioning of NOS aspects. But in both case studies, explicit targeting of nature of science concepts was required in the researcher assisting during the lesson (Case Study 1) or as an academic friend (Case Study 2). As well, for both case studies, teachers who had attended a lesson debrief of a colleague prior to conducting their own lesson, commented on how they were encouraged to attempt NOS questioning from colleague's feedback on the outcomes of the lesson.

The degree of integration by practicing elementary teachers therefore seems to be dependent not only on increased teacher efficacy, greater content knowledge and more developed NOS views but on experiencing and observing what works in their classroom context. There is, though, evidence in this study that teachers with lower efficacy scores and less developed NOS views will require more professional development involving classroom modelling than those teachers with higher efficacy scores and more developed views about the nature of science.

The analysis of the SETAKIST instrument to determine a potential division between more and less efficacious teachers can therefore potentially inform the design and impact of subsequent intervention programs customised for the efficacy level of the teachers under study. The identification of more efficacious teachers and utilisation of their leadership role in embedding nature of science teaching and learning practices into school curriculum and classroom practice is supported by the theoretical model proposed here.

One limitation to the model was raised in case study 2, where a teacher commented on the pressures of the normal class and school routines interrupted the flow of NOS lessons. The model does not account for the school context in which the teachers are attempting curriculum and teaching practice reform. As stated earlier, a limitation to the study was the dropout of around a quarter of the original experimental group. Reasons for non-completion of the PD program were not examined and it may have included lack of school executive support, crowded curriculum or greater priority to other learning areas.

6.6 Implications for Practice

6.6.1 SETAKIST and Professional Development Design

The use of the SETAKIST instrument to measure teachers' self-efficacy ***prior*** to participation in a professional development program presents a professional developer with an opportunity to customise the program for the participating teachers. An investigation of using the data from the SETAKIST pre-test and post-test responses for informing the structure of subsequent professional development was carried out. A qualitative analysis of the SETAKIST responses was completed to identify possible divisions within the participants based on both the numerical score (/40) for each efficacy component and the corresponding difference between less and more efficacious responses (/±8).

Using the Likert scale identifiers from *Strongly Disagree* to *Strongly Agree,* each response was coded as either less efficacious (LE – negative score), uncertain (U – zero score), or more efficacious (ME + positive score). Table 3.6 is reproduced below showing the difference (Δ) between less efficacious and more efficacious teachers at both pre-test and post-test.:

Table 3.6

Pre- and Post- Tally for teaching efficacy and knowledge efficacy

TEACHING PRE					TEACHING POST				
	ME	Uncertain	LE	Δ		ME	Uncertain	LE	Δ
16630	1	0	7	6+	220705	0	0	8	8+
220705	2	0	6	4+	16630	1	0	7	6+
AA221173	2	2	4	2+	HM	1	1	6	5+
30762	3	2	3	0	30762	2	1	5	3+
MN020761	3	2	3	0	NW121085	2	3	3	1+
SL0307	3	3	2	1-	ES040328	2	4	2	0
JE120144	5	1	2	3-	RC031250	3	3	2	1-
2209	5	2	1	4-	CW210757	5	0	3	2-
230372	6	1	1	5-	SL0307	4	4	0	4-
KNOWLEDGE PRE					KNOWLEDGE POST				
	ME	Uncertai	LE	Δ		ME	Uncertain	LE	Δ
16630	0	0	8	8+	16630	0	0	8	8+
220705	0	1	7	6+	91098	0	1	7	6+
AA221173	0	3	5	5+	230372	1	1	6	5+
MN020761	1	2	5	4+	SC170605	1 2	1	5	3+
2209	2	2	4	2+	LB040375	2	3	3	1+
30762	3	0	5	2+	30762	3	2	3	0
SL0307	3	1	4	1+	NW121085	3	3	2	1-
JE120144	4	0	4	0	JR281054	5	0	3	2-
230372	4	2	2	2-	RC0301250	5	2	1	4+

Note: There are 8 items in each subscale

This difference (Δ) for pre-test Teaching Efficacy and pre-test Knowledge Efficacy was then aligned (Table 6.2) with the corresponding total teaching and knowledge efficacy scores at *pre-test* for all teachers in the program. A sample of this alignment is shown below:

Table 6.1

Alignment of teaching efficacy and knowledge efficacy differential with score

TEACHING PRE versus SCORE		
	Δ	Score
16630	6+	36
220705	4+	28
AA221173	2+	27
30762	0	23
MN020761	0	23
SL0307	1-	22
JE120144	3-	23
2209	4-	20
230372	5-	19

KNOWLEDGE PRE versus SCORE		
	Δ	Score
16630	8+	40
220705	6+	32
AA221173	5+	30
MN020761	4+	29
2209	2+	26
30762	2+	26
SL0307	1+	25
JE120144	0	24
230372	2-	22

The results for teaching efficacy indicate a division between participants at both a pre- and post-test total score of 24/40. Below 24, participants generally have efficacy totals less than or equal to zero ($n_{pre-test} = 32/53$; $n_{post-test} = 19/53$).The results for knowledge efficacy indicate a division between participants at both a pre- and post-test total score of 25/40. Below 25, participants generally have efficacy totals less than or equal to zero ($n_{pre-test} = 13/53$; $n_{post-test} = 3/53$).

Lower levels of science teaching efficacy are reflected not only in the mean scores but by the addition (Table 6.2) of the total positive efficacious responses (+Δ) and total negative efficacious responses (-Δ) for both teaching and knowledge at pre-test for the experimental group as shown below:

Table 6.2

Pre-Test Efficacy Totals for Experimental Group

Pre-Test	Teaching Efficacy		Knowledge Efficacy	
	(+Δ) =	+121	(+Δ) =	+163
	(- Δ) =	- 119	(- Δ) =	- 70
Total		+ 2		+ 93

At the completion of the PD program the additions had changed to:

Table 6.3

Post-Test Efficacy Totals for Experimental Group

Post-Test	Teaching Efficacy		Knowledge Efficacy	
	(+Δ) =	+172	(+Δ) =	+231
	(- Δ) =	- 81	(- Δ) =	- 27
Total		+ 91		+ 204

The pre-test teaching efficacy difference total is substantially lower than that for the pre-test knowledge efficacy difference total (+121/+172). As PCK is contingent upon a teacher's subject matter knowledge *and* pedagogical practice, knowledge of the subject matter alone may be insufficient for elementary teachers to incorporate innovative teaching practices.

The case could be made for customising a PD program for those participants with teaching efficacy scores below 24 that includes a greater number of vicarious experiences before moving on to mastery experiences. These participants may also require more in class support from the principal researcher or peers who have already begun mastery experiences. Those participants above 24 may be able to move on to mastery experiences earlier in the PD program or be given more advanced pedagogical strategies to trial.

6.5.2 Continuing Professional Development

The intervention phase had a duration of close to 12 months for the delivery of the workshops and lessons to all the experimental group. As mentioned as a limitation to the study, a number of the experimental group did not complete all post-test instruments and so are not included in the data analysis. They did however participate in the intervention giving close to 250 lessons to 50 teachers delivered in a 12 month period. As this study proposes that a reform-style PD program results in improved outcomes for teaching of NOS in elementary schools, it is worth comparing the financial cost to an educational authority in replacing a standard PD program with a reform-style.

The standard PD program would be structured around workshops provided either after during after-school hours, where attendance might be voluntary or workshops delivered as part of a professional development day during teachers' normal working hours, where teachers register and whose classes are covered by a substitute teacher. If the latter, each attending teacher covered by a substitute would generate a day's pay for the substitute. Assuming that a similar number (50) of teachers to this study attend, that would represent approximately 10 weeks of a teacher's salary. Over a 40 teaching week school year, this model would allow

200 teachers to attend a typical one-day, “one-off” inservice staff professional development with no follow-up (Villegas-Reimers, 2003) with an approximate cost to the educational authority of a teacher’s salary for one year.

A feature of the two case studies conducted was the role played by the teacher within each case study with the highest pre/post efficacy scores. During the period where the researcher was conducting the case study, the most efficacious teacher incorporated more NOS teaching and learning strategies into classroom practice and gave continual verbal persuasion (Bandura, 1977) to their peers. It was possible for the researcher whilst in situ at each school to identify other highly efficacious teachers from the experimental group that performed a similar role. A proposal could be put that giving these more efficacious teachers the required skill set for professionally developing their peers.

A reform-style style PD program, similar to that described in this study, could then be developed where the professional development is sustained and where the teachers participating in the program have sufficient hours with the program deliverer in situ (Appleton, 2008) to gain the necessary classroom experiences with the innovative strategies (Garet et al, 2001). Given that the researcher was able to provide a program for an original 50 teachers, it would require four upskilled teachers to deliver such a reform-style program for 200 teachers. As each of the schools from where the upskilled teachers are drawn would require a new member of staff, the educational authority would be funding, in effect, 8 teacher salaries.

The difference in funding between the two models is not unsubstantial. Traditional models are attractive because they are cost efficient and providing highly efficient but potentially cost intensive PD presents a dilemma for educational systems (Appleton, 2008). However, given that the research evidence points to the ineffectiveness of the standard PD program models that can still be found in operation, and the identified issues with the teaching of science in elementary schools, real change in classroom practice and teacher confidence will require such investment.

6.7 Directions for Future Research

What were not reported in this study were the outcomes for the students in the classroom of the participating teachers. Although approval was sought from the educational authority to gather both teacher and student data, unfortunately, approval to conduct this study was limited to the gathering and reporting of teacher data only. Although the teacher debrief responses provide some indication of how the teachers perceived the benefits of nature of science instructions for the their students, further research into student outcomes may lead to confirmatory evidence on the currency of a reform-style professional development program on nature of science instruction. There is a corresponding test instrument on nature of science views (VNOS Form E) for use with elementary students and research could be conducted on the impact on students' views in classrooms with explicit nature of science instruction.

The findings from both the quantitative and qualitative phases indicate that targeted nature of science concepts are most likely to be incorporated into classroom instruction. A mixed methods approach provided both empirical and observational evidence on the impact on teacher confidence to change teaching practice. There are implications from this study on how further mixed methods research into practicing elementary teachers' development of pedagogical content knowledge in other science knowledge may be conducted.

This study was conducted in schools implementing the existing New South Wales Science and Technology syllabus and all comparisons were reported with other State and Territory science syllabus documents at this time. All States and Territories are now either implementing or trialling new syllabus documents in response to the Australian National Science Curriculum (ACARA, 2011), with New South Wales elementary schools requires to begin teaching a new syllabus in 2014.

A major strand of the Australian national curriculum is *Science as a Human Endeavour* which focuses on the nature and influence of science. The new NSW Science K–10 (incorporating Science and Technology K–6) syllabus (BoS, NSW, 2011) includes aspects of NOS in the rationale for Kindergarten to Year 6:

> As students engage in posing questions, testing ideas, developing and evaluating arguments based on evidence, they demonstrate honesty and fairness in using the skills of Working Scientifically.
>
> Through applying the processes of Working Scientifically, students use scientific inquiry to develop their understanding of science ideas and concepts, and the importance of scientific evidence in making informed decisions about the uses of science and technology in their lives. They recognise that science advances through the contributions of many different people (BoS, NSW, 2011).

Further studies should be conducted on professional development programs designed to assist elementary teachers in the implementation of the syllabus objectives related to this section of the rationale and the student outcomes from classroom instruction.

6.8 Summary

This is the final chapter of the thesis. In this chapter the general aims and research questions were revisited. In addition, the limitations of the research program were discussed which was followed by specific recommendations for theory and practice and directions for future research.

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APPENDIX 1

Letters to Principals and Participants

The Principal
Port Jackson School Education Area
Dear Colleague,

As part of a professional development initiative, the University of New South Wales will be gathering data on participating teachers self-efficacy for science teaching, and their knowledge and understanding of the pendulum and the Nature of Science.

The data will be gathered using three questionnaires administered to the teachers as pre- and post- testing. At all times the strictest confidentiality and anonymity will be maintained for both the school and participating teachers.

It is hoped that the information gathered will assist in the professional development of the teachers and lead to improved outcomes on teaching and learning not only in the Science and Technology but across other KLAs.

Participants will be required to sign a consent form as per University Ethics guidelines and may revoke consent at any time.

Thank you for your support of this research. If you have any questions about the conduct of the research please conduct either Associate Professor Michael Matthews, 9385 1951, (m.matthews@unsw.edu.au) or Mr. Rick Connor, 9385 2842. (rconnor@unsw.edu.au)

Rick Connor

Approval No (when available)

THE UNIVERSITY OF NEW SOUTH WALES and DEPARTMENT OF EDUCATION

PARTICIPANT INFORMATION STATEMENT AND CONSENT FORM

IMPACT OF PENDULUM TEACHING ON NATURE OF SCIENCE KNOWLEDGE AND TEACHER EFFICACY

You are invited to participate in a PD program designed to study the impact of observing and participating in lessons on the pendulum on your understanding of the Nature of Science and your self-efficacy in teaching science. You were selected as a possible participant in this study because of the support of the Port Jackson, Bondi District project "Isolation to Collaboration.

If you decide to participate, we will assist with preparation of classroom lessons, development of resources, ask you to complete three questionnaires and maintain a journal of lesson observations.

We cannot and do not guarantee or promise that you will receive any benefits from this study.

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or except as required by law. If you give us your permission by signing this document, we plan to publish the results as part of the International Pendulum Project. In any publication, information will be provided in such a way that you cannot be identified.

Complaints may be directed to the Ethics Secretariat, The University of New South Wales, SYDNEY 2052 AUSTRALIA (phone 9385 4234, fax 9385 6648, email ethics.sec@unsw.edu.au).

Your decision whether or not to participate will not prejudice your future relations with The University of New South Wales or the Port Jackson, Bondi District Office.. If you decide to participate, you are free to withdraw you consent and to discontinue participation at any time without prejudice.

If you have any questions, please feel free to ask us. If you have any additional questions later, Mr. Rick Connor (0412 861 546) will be happy to answer them.

You will be given a copy of this form to keep.

THE UNIVERSITY OF NEW SOUTH WALES and DEPARTMENT OF EDUCATION

PARTICIPANT INFORMATION STATEMENT AND CONSENT FORM (continued)

IMPACT OF PENDULUM TEACHING ON NATURE OF SCIENCE KNOWLEDGE AND TEACHER EFFICACY

You are making a decision whether or not to participate. Your signature indicates that, having read the information provided above, you have decided to participate.

……………………………………………………	……………………………………………………
Signature of Research Participant	Signature of Witness
……………………………………………………	……………………………………………………
(Please PRINT name)	(Please PRINT name)
……………………………………………………	……………………………………………………
Date	Nature of Witness

……………………………………………………
Signature(s) of Investigator(s)

……………………………………………………
Please PRINT Name

REVOCATION OF CONSENT
IMPACT OF PENDULUM TEACHING ON NATURE OF SCIENCE KNOWLEDGE

I hereby wish to **WITHDRAW** my consent to participate in the research proposal described above and understand that such withdrawal **WILL NOT** jeopardise any treatment or my relationship with The University of New South Wales, Bondi District Office/Department of Education.

……………………………………………………	……………………………………………………
Signature	Date

……………………………………………………
Please PRINT Name

The section for Revocation of Consent should be forwarded to Associate Professor Michael Matthews, School of Education UNSW, 9385 1951

APPENDIX 2

Test Instruments

Science Teaching Efficacy Belief Instrument*

Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters to the right of each statement.

SA = Strongly Agree A = Agree UN = Uncertain D = Disagree SD =Strongly Disagree

1. When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	SA	A	UN	D	SD
2. I am continually finding better ways to teach science.	SA	A	UN	D	SD
3. Even when I try very hard, I don't teach science as well as I do most subjects.	SA	A	UN	D	SD
4. When the science grades of students improve, it is most often due to their teacher having found a more effective teaching approach.	SA	A	UN	D	SD
5. I know the steps necessary to teach science concepts effectively.	SA	A	UN	D	SD
6. I am not very effective in monitoring science experiments.	SA	A	UN	D	SD
7. If students are underachieving in science, it is most likely due to ineffective science teaching.	SA	A	UN	D	SD
8. I generally teach science ineffectively.	SA	A	UN	D	SD
9. The inadequacy of a student's science background can be overcome by good teaching.	SA	A	UN	D	SD
10. The low science achievement of some students cannot generally be blamed on their teachers.	SA	A	UN	D	SD
11. When a low achieving child progresses in science, it is usually due to extra attention given by the teacher.	SA	A	UN	D	SD
12. I understand science concepts well enough to be effective in teaching elementary science.	SA	A	UN	D	SD
13. Increased effort in science teaching produces little change in some students' science achievement.	SA	A	UN	D	SD
14. The teacher is generally responsible for the achievement of students in science.	SA	A	UN	D	SD
15. Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	SA	A	UN	D	SD
16. If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher.	SA	A	UN	D	SD
17. I find it difficult to explain to students why science experiments work.	SA	A	UN	D	SD
18. I am typically able to answer students' science questions.	SA	A	UN	D	SD
19. I wonder if I have the necessary skills to teach science.	SA	A	UN	D	SD
20. Effectiveness in science teaching has little influence on the achievement of students with low motivation.	SA	A	UN	D	SD
21. Given a choice, I would not invite the principal to evaluate my science teaching.	SA	A	UN	D	SD
22. When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand it better.	SA	A	UN	D	SD
23. When teaching science, I usually welcome student questions.	SA	A	UN	D	SD
24. I don't know what to do to turn students on to science.	SA	A	UN	D	SD
25. Even teachers with good science teaching abilities cannot help some kids learn science.	SA	A	UN	D	SD

*In Riggs, I., & Knochs, L. (1990). Towards the development of an elementary teachers science teaching efficacy belief instrument. *Science Education, 74*, 625-637.

I D **Date** ____________

SETAKIST

Please indicate the degree to which you agree or disagree with each of the following statements by circling the appropriate number to the right of each statement.

	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
1. When teaching science, I usually welcome student questions.	1	2	3	4	5
2. I do not feel I have the necessary skills to teach science.	1	2	3	4	5
3. I am typically able to answer students science questions.	1	2	3	4	5
4. Given a choice, I would not invite the principal to evaluate my science teaching.	1	2	3	4	5
5. I feel comfortable improvising during science lab experiments.	1	2	3	4	5
6. Even when I try very hard, I do not teach science as well as I teach most other subjects	1	2	3	4	5
7. After I have taught a science concept once, I feel confident teaching it again.	1	2	3	4	5
8. I find science a difficult subject to teach	1	2	3	4	5
9. I know the steps necessary to teach science concepts effectively.	1	2	3	4	5
10. I find it difficult to explain to students why science experiments work.	1	2	3	4	5
11. I am continually finding better ways to teach science.	1	2	3	4	5
12. I generally teach science ineffectively.	1	2	3	4	5
13. I understand science concepts well enough to teach science effectively.	1	2	3	4	5
14. I know how to make students interested in science.	1	2	3	4	5
15. I feel anxious when teaching science content that I have not taught before.	1	2	3	4	5
16. I wish I had a better understanding of the science concepts I teach.	1	2	3	4	5

VIEWS OF NATURE OF SCIENCE
(VNOS-D)

Primary Teacher Version

Date: ______________ ID [ ]

Sex: M [ ] F [ ]

Years Teaching Experience

Less 5 yrs [ ] 5 – 10 yrs [ ] 11- 15 yrs [ ] 15+ yrs [ ]

Instructions

- Please answer each of the following questions. You can use all the space provided and the backs of the pages to answer a question.
- Some questions have more than one part. Please make sure you write answers for each part.
- This is not a test and will not be graded. There are no “right” or “wrong” answers to the following questions. I am only interested in your ideas relating to the following questions.

1. What is science?

2. How is science different from the other KLA subjects you are teaching?

3. Scientists produce scientific knowledge. Some of this knowledge is found in your science books. Do you think this knowledge may change in the future? Explain your answer and give an example.

4. (a) How do scientists know that dinosaurs really existed?

(b) How certain are scientists about the way dinosaurs looked?

(c) Scientists agree that about 65 millions of years ago the dinosaurs became extinct (all died away). However, scientists disagree about what had caused this to happen. Why do you think they disagree even though they all have the same information?

5. In order to predict the weather, weather persons collect different types of information. Often they produce computer models of different weather patterns.

(a) Do you think weather persons are certain (sure) about these weather patterns?

(b) Why or why not?

6. What do you think a scientific model is?

7. Scientists try to find answers to their questions by doing investigations / experiments. Do you think that scientists use their imaginations and creativity when they do these investigations / experiments? **YES** **NO**

a. If **NO**, explain why?

b. If **YES**, in what part(s) of their investigations (planning, experimenting, making observations, analysis of data, interpretation, reporting results, etc.) do you think they use their imagination and creativity? Give examples if you can.

VIEWS OF NATURE OF SCIENCE

TEACHER VERSION (VNOS D)

(ANNOTATED SCORING GUIDE)

EACH QUESTION ON THE FOLLOWING PAGES IS FOLLOWED BY A DESCRIPTION OF WHAT IS BEING ASSESSED AND WHAT IS CONSIDERD TO BE AN ANSWER CONSISTENT WITH REFORM DOCUMENTS AND CONTEMPORARY VIEWS ABOUT SCIENCE. "SCORING" OF ANSWERS IS NOT MEANT TO YIELD A NUMERICAL VALUE, BUT RATHER A DESCRIPTION OF WHETHER THE RESPONDENT HAS THE DESIRED VIEW.

NB

THE QUESTIONS THAT FOLLOW, ALTHOUGH DESIGNED TO ASSESS STUDENTS', WERE GIVEN TO PRACTICING ELEMENTARY TEACHERS' IN PREFERENCE TO THE VNOS(C) FORM WHICH WAS TRIALLED PRIOR TO THE STUDY. THE TRIAL DEMONSTRATED THAT THE PRACTICING ELEMENTARY TEACHERS WERE MORE COMFORTABLE WITH THE SCIENCE LITERACY LEVEL OF FORM (D) AND MORE CONFIDENT IN THEIR ABILITY TO GIVR MEANINGFUL RESPONSES.

THE QUESTIONS ASSESS TEACHERS' UNDERSTANDINGS THAT SCIENCE IS TENTATIVE, INVOLVES HUMAN CREATIVITY AND SUBJECTIVITY, NECESSARILY INVOLVES BOTH OBSERVATION AND INFERENCE, IS NOT LIMITED TO A SINGLE APPROACH, AND IS AT SOME POINT EMPIRICALLY-BASED. THE TEACHERS MAY NOT USE THESE WORDS, BUT THEY WILL USE WORDS THAT ARE CONSISTENT OR NOT CONSISTENT WITH THESE IDEAS.

1. What is science?

RESPONSE SHOULD INCLUDE REFERENCES TO A BODY OF KNOWLEDGE (OFTEN THE SCIENCE CONTENT TEACHERS ARE CURRENTLY TEACHING) AND PROCESSES (OBSERVING, EXPERINMENTING, ETC.) FOR THE DEVELOPMENT OF THE KNOWLEDGE.

TEACHERS MAY NOT REFER TO ANYTHING RELATED TO EPISTEMOLOGY OR CHARACTERISITICS OF THE KNOWLEDGE THAT RESULTS FROM THE PROCESSES.

RARELY DO THE TEACHERS REFER TO SCIENCE AS A “WAY OF KNOWING”.

2. How is science different from the other subjects you are teaching?

THE DESIRED RESPONSE SHOULD REFER TO RELIANCE ON DATA FROM THE NATURAL WORLD (EMPIRICAL BASIS), SYSTEMATIC OR ORGANIZED APPROACH TO COLLECTION OF DATA. IT IS ALSO COMMON FOR TEACHERS TO FOCUS ON THE SPECIFIC SUBJECT MATTER OR OBJECTS OF SCIENCE’S ATTENTION.

TEACHERS MAY INCORRECTLY STATE THAT SCIENCE FOLLOWS A SINGLE METHOD (THE SCIENTIFIC METHOD) AND THAT SCIENCE IS A TOTALLY OBJECTIVE ENDEAVOR. THEY MOST LIKLEY WILL NOT INCLUDE THE ALTERNATIVE TO THESE VIEWS, BUT THE INCORRECT VIEWS ARE COMMONLY INCLUDED.

3. Scientists produce scientific knowledge. Some of this knowledge is found in your science books. Do you think this knowledge may change in the future? Explain your answer and give an example

THIS QUESTION FOCUSES ON THE IDEA THAT ALL SCIENTIFIC KNOWLEDGE IS TENTATIVE OR SUBJECT TO CHANGE. SO, YOU ARE LOOKING FOR THE TEACHER TO AGREE THAT THE KNOWLEDGE IN THE TEXT WILL POSSIBLY CHANGE.

ON A SUPERFICIAL LEVEL, MOST TEACHERS WILL RECOGNIZE THAT KNOWLEDGE CHANGES BECAUSE WE NOW KNOW MORE DUE TO OF ADDITIONAL EXPERIMENTS/INVESTIGATIONS, NEW EVIDENCE OR AVAILABILITY OF NEW TECHNOLOGY.

A MORE IN-DEPTH, BUT NOT COMMON, ANSWER WOULD INCLUDE THE IDEA THAT KNOWLEDGE CHANGES BECAUSE SCIENTISTS VIEW THE SAME DATA IN A DIFFERENT WAY THAN BEFORE**.**

4. (a) How do scientists know that dinosaurs really existed?

THE FOCUS HERE IS ON OBSERVATION AND INFERENCE AND EMPHERICAL NATURE OFF SCIENCE. A SOPHISTICATED, BUT UNCOMON ANSWER WOULD INCLUDE THAT SCIENTISTS HAVE SOME DATA ABOUT DINOSAURS AND HAVE INFERRED FROM THIS DATA THAT CREATURES DEFINED AS "DINOSAURS" EXISTED.

(b) How certain are scientists about the way dinosaurs looked?

THE ANSWER TO THIS QUESTION WILL OVERLAP WITH WHAT YOU MAY GET FOR PART A. AGAIN, THIS QUESTION FOCUSES ON THE ROLES OF OBSERVATION AND INFERENCE IN SCIENCE. THE DESIRED ANSWER WOULD INCLUDE THAT SCIENTISTS HAVE SOME DATA, BUT HAVE INFERRED FROM THIS DATA WHAT DINOSAURS LOOKED LIKE.

ANSWERS TO PART A AND B MAY ALLOW YOU TO DETERMINE WHETHER A TEACHER UNDERSTANDS THAT THE DEVELOPMENT OF SCIENTIFIC KNOWLEDGE (VIA INFERENCES) INVOLVES HUMAN CREATIVITY AND SUBJECTIVITY.

Occasionally, TEACHERS give a percentage for how certain they think scientists are (I.E." Scientists are 80% sure of how dinosaurs look !) relfecting their views of the tentativeness of science.

(c) Scientists agree that about 65 millions of years ago the dinosaurs became extinct (all died away). However, scientists disagree about what had caused this to happen. Why do you think they disagree even though they all have the same information?

THIS QUESTION REFLECTS TEACHERS' VIEWS ABOUT THE SUBJECTIVE AND TENTATIVE NATURE OF SCIENCE. THE DESIRED RESPONSE WOULD BE THAT DIFFERENT SCIENTISTS BRING DIFFERENT BACKGROUNDS AND DIFFERENT BIASES TO THE INTERPRETATION OF DATA.

IT IS IMPORTANT TO DISCERN WHETHER THE TEACHER UNDERSTANDS THAT DIFFERENT INTERPRETATIONS DO NOT NECESSARILY MEAN THAT SOMEONE IS RIGHT AND SOMEONE IS WRONG.

5. In order to predict the weather, weather persons collect different types of information. Often they produce computer models of different weather patterns.

(a) Do you think weather persons are certain (sure) about the weather patterns?

THIS QUESTION IS LOOKING FOR IDEAS ABOUT OBSERVATION AND INFERENCE AND TENTATIVENESS. AGAIN AND YOU WOULD BE LOOKING FOR ANSWERS SIMILAR TO THOSE IN QUESTION #4. ONLY THE CONTEXT OF THE QUESTION IS DIFFERENT.

(b) Why or why not?

JUST ADDITIONAL INFORMATION TO SUPPORT A TEACHER'S IDEA IS BEING ASKED FOR HERE.

6. What do you think a scientific model is?

THIS QUESTION FOCUSES ON THE ROLE OF OBSERVATION AND INFERENCE, BUT ALSO MAY PERMIT YOU TO GATHER DATA ON TEACHERS' UNDERSTADNING THAT A MODEL IS AN INFERENCE THAT IS NOT "REAL" OR NOT AN EXACT COPY OF NATURE.

AT A DEEPER LEVEL, YOU MAY ALSO HAVE DATA CONCERNING TEACHERS' UNDERSTANDING THAT THE CREATION OF MODELS INVOLVES THE SUBJECTIVITY AND CREATIVITY OF SCIENCE, AND IT IS FOR THIS REASON THAT MODELS ARE TENTATIVE.

7. Scientists try to find answers to their questions by doing investigations / experiments. Do you think that scientists use their imagination & creativity in their investigations / experiments? **YES** **NO**

a. If **NO**, explain why.

THE DESIRED ANSWER HERE IS "YES" AND MOST TEACHERS WILL ANSWER THIS WAY. HOWEVER, PART B WILL GIVE YOU MORE INFORMATION ABOUT THE ADEQUACY OF TEACHERS' BELIEFS.

b. If **YES**, in what part of their investigations (planning, experimenting, making observations, analyzing data, interpretation, reporting results, etc.) do you think they use their imagination and creativity? Give examples if you can.

THE TEACHERS MAY ONLY UNDERSTAND, OR AT LEAST SAY, THAT SCIENTISTS USE THEIR CREATIVITY AND IMAGINATION IN THE PLANNING OF INVESTIGATIONS. SOME MAY TELL YOU THAT SCIENTISTS USE CREATIVITY AND IMAGINATION AND CREATIVITY DURING AN EXPERIMENT/INVESTIGATION AND IN THE INTERPRETATION OF DATA AND REPORTING OF RESULTS.

THIS QUESTION RELATES BACK TO TEACHERS' UNDERSTADNING OF WHY SCIENCE IS TENTATIVE AND HOW CREATIVITY, SUBJECTIVITY, AND INFERENCE PERMEATE ALL OF SCIENCE.

Views of Nature of Science (form C)*

VNOS (C)

* Reference:

Abd-El-Khalick, F. (1998). The influence of history of science courses on students conceptions of nature of science. Unpublished doctoral dissertation. Oregon State University, Corvallis.

Lederman, N. G., Schwartz, R. S., Abd-El-Khalick, F., & Bell, R. L. (2001). Pre-service teachers understanding and teaching of the nature of science: An intervention study. *Canadian Journal of Science, Mathematics, and Technology Education, 1,* 135-160.

VNOS (C)

Name:______________________________

Date: /   /

Instructions

- Please answer each of the following questions. Include relevant examples whenever possible. You can use the back of a page if you need more space.
- **There are no "right" or "wrong" answers to the following questions. We are only interested in your opinion on a number of issues about science.**

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

2. What is an experiment?

3. Does the development of scientific knowledge **require** experiments?

- If yes, explain why. Give an example to defend your position.
- If no, explain why. Give an example to defend your position.

4. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence, or types of evidence, **do you think** scientists used to determine what an atom looks like?

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

6. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?

- If you believe that scientific theories do not change, explain why. Defend your answer with examples.
- If you believe that scientific theories do change:

(a) Explain why theories change?

(b) Explain why we bother to learn scientific theories. Defend your answer with examples.

7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence **do you think** scientists used to determine what a species is?

8. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?

- If yes, then at which stages of the investigations do you believe that scientists use their imagination and creativity: planning and design; data collection; after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
- If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

9. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these **different conclusions** possible if scientists in both groups have access to and **use the same set of data** to derive their conclusions?

10. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

- If you believe that science reflects social and cultural values, explain why and how. Defend your answer with examples.
- If you believe that science is universal, explain why and how. Defend your answer with examples.

The Pendulum

Dear Participant,

Thank you for agreeing to complete the following questionnaire. The questions are designed to gain information on your knowledge of the principles that govern the action of a pendulum and its historical significance for science and society.

Please choose the response that most closely reflects your knowledge of the question at this time. Do NOT use any means to seek new information for your answers.

Your responses and all information gathered from them will be held in strictest confidence.

ID Number [ ]

Shade in the circle below your chosen response.

e.g.

	False	**Dont Know**	**True**
I look forward to the holidays	O	O	●

	False	**Dont Know**	**True**
1. Two pendulums have the same shape and size but one had a light mass and the other a heavy mass:			
(i) When released from the same height the pendulums stop swinging at the same time	O	O	O
(ii) The light-mass pendulum stops swinging earlier than the heavy-mass pendulum because of air resistance	O	O	O
(iii) The heavy-mass pendulum stops swinging earlier than the light-mass pendulum because of air resistance	O	O	O
(iv) Air resistance has no effect on the swing of a pendulum	O	O	O

	False	Dont Know	True
2. A pendulum of given mass and length was taken on a trip to Mars:			
(i) As the spacecraft orbited the Earth before leaving for Mars, this pendulum would swing normally.	O	O	O
(ii) As the spacecraft orbited the Earth before leaving for Mars, this pendulum would not swing.	O	O	O
(iii) After the spacecraft landed on Mars, this pendulum would swing slower when compared to its swing on Earth	O	O	O
(iv) After the spacecraft landed on Mars, this pendulum would swing faster when compared to its swing on Earth	O	O	O
(v) After the spacecraft landed on Mars, this pendulum would swing the same as when compared to its swing on Earth	O	O	O
3. The period of a pendulums swing depends on gravity.	O	O	O
4. (i) A pendulum of given mass and length swings with the same period (time to make one complete swing) at the Equator as it has at the North or South Pole	O	O	O
(ii) A pendulum of given mass and length swings faster at the Equator than it does at the North or South Pole	O	O	O
(iii) A pendulum of given mass and length swings slower at the Equator than it does at the North or South Pole	O	O	O
5. A metre-long pendulum takes approximately one second to swing away and approximately one second to swing back.	O	O	O
6. A pendulum can be used to determine a value for gravity	O	O	O
7. A pendulum swings slow as it swings up and swings fast as it swings down	O	O	O

8. The shape and size of the bob (the mass hanging on the end of the pendulum) has no effect on the swing of the pendulum	O	O	O
9. To obtain accurate measurements of a pendulums period it is better to release the pendulum from small angles only	O	O	O
10.(i) A pendulum bob at the end of the first swing will return to the release height on most occasions	O	O	O
(ii)A pendulum bob at the end of the first swing will return higher than the release height on most occasions	O	O	O
(iii)A pendulum bob at the end of the first swing will return lower than the release height on most occasions	O	O	O
11.The early Greeks were the first to realise that the pendulum could be used measure time	O	O	O
12.Galileos use of mathematics to analyse the swing of a pendulum was a common method of science inquiry at that time	O	O	O
13.The early pendulum clocks used on long sea voyages remained accurate even during bad weather and rough seas	O	O	O
14.The early pendulum clocks used on long sea voyages could help navigators determine a ships position	O	O	O

Thank you for taking the time to complete this questionnaire.

APPENDIX 3

Lesson Plans

1. When a student does better than usual in science, it is often because the teacher exerted a little extra effort.

2. I am continually finding better ways to teach science.

Lesson Plan Title:

Hickory Dickory Dock

Grade Levels: 3 - 4

Outcomes: **Stage Two**

- INVS 2.7 Conducts investigations by observing, questioning, predicting, testing, collecting, recording and analysing data, and drawing conclusions.
- VA2 Exhibits curiosity and responsiveness to scientific and technological ideas and evidence.
- VA45 Works cooperatively with others in groups on scientific and technological tasks and challenges.

Rationale:

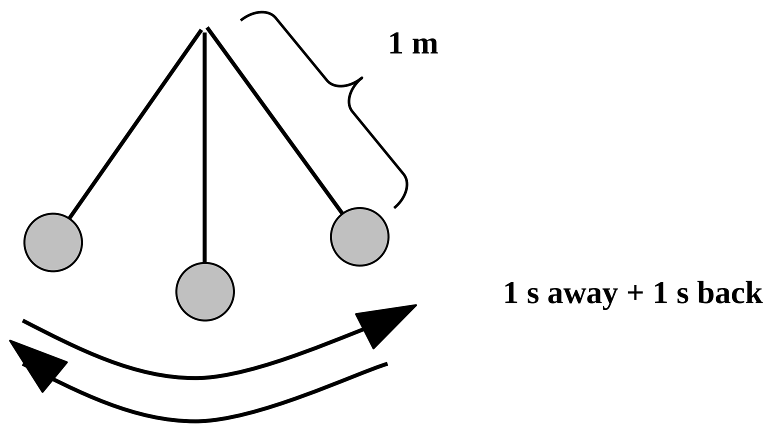
This is the first lesson in this program. It is designed to introduce the pendulum through a familiar nursery rhyme. Through teacher questioning, the students should be able to recall what the clock in the nursery rhyme looks like, what sound it makes (tick tock) and (in some cases) what swings inside the clocks cabinet.

Using a familiar context and students prior experiences should increase student engagement in the scientific processes of observing, hypothesising, predicting and testing.

Background:

- The pendulum used for this lesson is assembled from a string with a weight at one end
- **Galileo** was the first to examine the unique characteristics of the pendulum
- Galileo found that each pendulum has a constant period, ie the time it takes to complete a full swing away and back is always the same and unique for each different length of the pendulum
- In 1637, he had the idea of using a swinging weight to control the speed of a clock

- In 1656, **Christiaan Huygens** built the worlds first pendulum clock. It was far more reliable than any previous mechanical timepiece. For nearly 300 years, the most accurate clocks in the world all used pendulums
- A traditional grandfather clock uses the principles behind the swing of the **seconds pendulum** to maintain time
- The **seconds pendulum** is 1 metre in length to give a swing of 1 second on each pass



Materials needed:

Any assembled pendulum could be used but for maximum effect, using a very large ball on the end of the string (oversized tennis ball or basketball) better engages the students in the lesson.

NB The length of the pendulum (with a ball shaped bob) should be measured from the point where you hold the string to the centre of the ball.

Time Allotted:

35 - 40 minutes

Teaching and Learning Activities:

Teacher Strategy	Student Activity
1. Tell students you are going to start saying a famous nursery rhyme and they can join in as soon as they know what it is.	1. Sitting and listening.
2. Start off: "Hickory dickory dock, The mouse ran **UNDER** the clock!!"	2. Students start saying the nursey rhyme and stop you when you say the wrong thing.
3. The students will quickly tell you that you have it wrong. So start again. "Hickory dickory dock, The mouse ran **BEHIND** the clock!!"	3. Same as above!
4. Ask the students if they are sure the mouse ran **UP** the clock and ask them why it did that rather than **under** or **behind.** **(Most students will tell you a cat was chasing it and it was safer on top)**	4. Students propose reasons for the mouse running up the clock.
5. Have students draw the nursery rhyme, making sure they include the clock, the mouse and the cat chasing it.	5. Students draw nursery rhyme. **NB You should see at least 1 student drawing a grandfather clock.**
6. As they are drawing, tell them to draw themselves standing next to the clock.	6. Students complete drawing.
7. Select students to present their drawing to the class. **NB** **Select those who drew a grandfather clock with one example without the pendulum and one with the pendulum.**	7. Selected students come to front of class and present drawings.

If no student draws the pendulum in the clock have a picture of a grandfather clock ready and question students on how their drawing differs from the picture.

8. Ask students if they can see a difference in the drawings. **(Students will normally point out how some drawings have the "swinging thing" inside the clock)**	8. Students observe drawings and point out differences.
9. Question the students on what the object inside the clock does. **" Does it swing?"** **"What sound does the clock make as this object swings back and forth?"** **"What is this swinging thing called?"**	9. Students make sound of the clock: **"TICK" "TOCK"**
10. As students are saying: "TICK/TOCK swing a short pendulum (say 1/2 metre) **"What wrong with my pendulum?"** **(Students should recognise that the pendulum swings TOO FAST."**	10. Students observe swinging pendulum whist trying to say "TICK/TOCK" at the correct speed.
" What do I have to do to the pendulum to get it to swing in time with a clock?" **(Students normally suggest changes to length but if weight is mentioned tell them that the class will look at length first and then look at weight later.)**	Students suggest changes to the pendulum.
11. As students are saying: "TICK/TOCK" have them keep time with a wall clock that has a seconds hand. Swing a 1 metre pendulum in time with The students and the wall clock.	11. Students keep time with wall clock.

12. Using students drawings as a reference, finish with questioning: **"What time does the pendulum keep?"** **"Should it be long or short?"** **"Did you draw a clock taller than you?"** **"Why is a grandfather clock tall?"** 13.Ask students to suggest how long the pendulum is. Tell them they will attempt to find out in the next lesson.	12. Answers: **"Seconds"** **"Long"** **"So the pendulum can fit inside."**

Websites:

Websites:
http://home.howstuffworks.com/clock.htm
http://www.sciencemuseum.org.uk/on-line/huygens/index.asp
http://www.uh.edu/engines/epi1307.htm
http://www.ernie.cummings.net/escape.htm

PENDULUM LESSONS

Lesson Plan Title:

Length of the Pendulum V Period of Swing

Grade Levels: 3 - 6

Outcomes:

Stage Two

- INVS 2.7 Conducts investigations by observing, questioning, predicting, testing, collecting, recording and analysing data, and drawing conclusions.
- VA2 Exhibits curiosity and responsiveness to scientific and technological ideas and evidence.
- VA45 Works cooperatively with others in groups on scientific and technological tasks and challenges.

Stage Three

- INVS 3.7 Conducts their own investigations and makes judgements based on the results of observing, questioning, predicting, testing, collecting, recording and analysing data, and drawing conclusions.
- VA2 Exhibits curiosity and responsiveness to scientific and technological ideas and evidence.

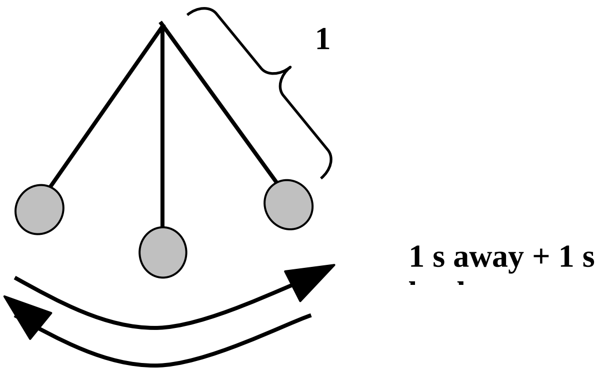
VA45 Works cooperatively with others in groups on scientific and technological tasks and challenges.

Rationale:

This lesson follows directly from the lesson on the **seconds** pendulum. The Nature of Science aspects that the students should be explicitly introduced to here are the **tentativeness** of science. What do we do when our prediction does not match our testing and observation? Is it permissible in science to change our mind? Is science always certain?

Background:

- The pendulum used for this lesson is assembled from a string with a weight at one end
- **Galileo** was the first to examine the unique characteristics of the pendulum
- Galileo stated that each pendulum has a constant period, ie the time it takes to complete a full swing away and back is always the same and unique for each different length of the pendulum
- The shorter the pendulum the faster the swing, the longer the pendulum the slower the swing.
- Christian Huygens confirmed the **isochronicity** of the pendulum.
- The **seconds pendulum** is 1 metre in length to give a swing of 1 second on each pass



Materials needed:

Any assembled pendulum could be used from the provided kit but for this investigation a golf ball or rubber ball should be used.

(Lighter pendulums will be investigated in following lessons.)

NB The length of the pendulum (with a ball shaped bob) should be measured from the point where you hold the string to the centre of the ball.

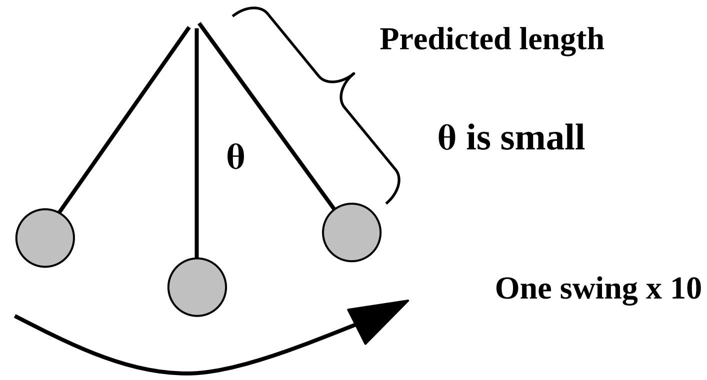
Stopwatch, student wristwatch or wall clock.

Time Allotted:

35 - 40 minutes

Teaching and Learning Activities:

Teacher Strategy	Student Activity
1. Revise previous lesson and list the students prediction for length **(Predictions should be limited to multiples of 10 or 5 for ease of measurement) (Make judgement based on students ability)**	1. Students suggest a length for a swing (1 swing is away, 2 swings is away and back).
2. Instruct students to use the golf ball or rubber ball pendulum . Measurements for length can be made using a metre ruler or tape measure. **(Remind students that the length of the pendulum is measured from where they hold it to the CENTRE of the BOB**	2. Students use appropriate measuring device to measure their predicted length.

3. Question students on how they intend to time 10 swings of the pendulum. **(A swing is one pass away from release point)** **(Two swings is one pass away and one back)** A wall clock with a seconds hand will be sufficient but stopwatches or the students wristwatch could also be used.	3. Students should **consistent** in their chosen method. **(NB guide students to measurement of a swing at the END of the swing)**
4. Before students begin the investigation, instruct them to release the pendulum from a small angle off-centre.	4. Students practice their release and timing.
	
5. Assist students with investigation, noting those groups with incorrect procedures for later class discussion.	5. Students conduct the investigation
6. Have students report back to class on their findings **"Who found 10 swings in 10 seconds?"** **NB Usually, more than one length is proposed to give the 10 swings.**	6. Students report back and demonstrate to rest of class.

Have each group who think their pendulum is correct to demonstrate their procedure. Allow other groups to critique the timing method employed. **NB** **Common procedural errors will be groups not allowing the pendulum to complete a full swing when counting or not beginning the timing of the pendulum on the correct seconds hand position.**	Students give reasons why other procedures may be incorrect.
7. Have students repeat the investigation with correct procedure. 8. Teacher-led class discussion on group findings. Pose the following: **"Why did some of us have to change our prediction?"** **"Do scientists sometimes have to change their ideas?" "Why?"** 9. **"Would a lighter pendulum (say a ping pong ball pendulum) swing 10 times in 10 seconds?"** Students will suggest that **weight** will be a factor in the timing of the swings. **"For our next lesson, you will design the investigation on weight using the pendulum kits."** Tell students these experiments are 400 years old!!	7. Students repeat procedure. 8. Students suggest times where scientists may need to change their first ideas. 9. Students propose answer and reasons for their choice. **NB A usual reason given by students is that a heavier ball pushes through the wind/air.** **OR** **Another reason given involves the effect of the wind/air on each ball.**

"Does anyone know the name of the scientist who did these experiments?"	

Websites:

http://pbskids.org/zoom/pendulum/
http://www.galileosf.net/pendulum/
http://es.rice.edu/ES/humsoc/Galileo/
http://muse.tau.ac.il/museum/galileo/pendulum.html#lab
http://www.pbs.org/wgbh/nova/galileo/expe_pend_1.html

PENDULUM LESSONS

Lesson Plan Title:

Weight of the Pendulum V Period of Swing

Grade Levels: 3 - 6

Outcomes:

Stage Two

- INVS 2.7 Conducts investigations by observing, questioning, predicting, testing, collecting, recording and analysing data, and drawing conclusions.
- VA2 Exhibits curiosity and responsiveness to scientific and technological ideas and evidence.
- VA45 Works cooperatively with others in groups on scientific and technological tasks and challenges.

Stage Three

- INVS 3.7 Conducts their own investigations and makes judgements based on the results of observing, questioning, predicting, testing, collecting, recording and analysing data, and drawing conclusions.
- VA2 Exhibits curiosity and responsiveness to scientific and technological ideas and evidence.

VA45 Works cooperatively with others in groups on scientific and technological tasks and challenges.

Rationale:

Students will test their idea that weight of the pendulum will influence the period of its swing. The general idea held by most of the students is that a heavy pendulum swings **faster** than a light pendulum. More importantly, when students come to carry out an investigation on the weight of the pendulum, because they firmly hold this belief they will report back that a heavy pendulum **does** swing faster.

The Nature of Science aspects that the students should be explicitly introduced to here is not only the **tentativeness** of science, but the **subjective nature** of theory. Why do we observe what we want to observe? Can scientists **miss** an important piece of evidence because they are not objective?

Background:

- The pendulum used for this lesson is assembled from a string with a weight at one end
- **Galileo** was the first to examine the unique characteristics of the pendulum
- Galileo stated that each pendulum has a constant period, ie the time it takes to complete a full swing away and back is always the same and unique for each different length of the pendulum
- For small number of swings, the weight of the pendulum did not affect the period of the swing
- However, Galileo identified that a light pendulum comes to rest faster than a heavy pendulum
- Galileo was unaware of **friction** so could not explain why this was so
- There is an equation for the period of a pendulum swing:

$$\mathbf{T = 2\pi\sqrt{L/g}}$$

NB The period (T) of the swing is dependent on the length, L, and gravity, g, BUT not weight(mass).

That is, there is no symbol, m, in the expression.

Materials needed:

Any assembled pendulum could be used from the provided kit but for this investigation golf balls, rubber balls and foam balls should be compared.

NB The length of the pendulum (with a ball shaped bob) should be measured from the point where you hold the string to the centre of the ball.

Stopwatch, student wristwatch or wall clock.

<table>
<tr><td colspan="2">Time Allotted:

35 - 40 minutes</td></tr>
<tr><td colspan="2">Teaching and Learning Activities:</td></tr>
<tr><th>Teacher Strategy</th><th>Student Activity</th></tr>
<tr><td>1. Conduct a class poll on whether weight will influence the swing of the pendulum.

Place results on the board:

Heavy Light No difference</td><td>1. Students propose a hypothesis on the swing and its relationship to weight of the pendulum.</td></tr>
<tr><td>2. Ask students how to ensure that the investigation will be a fair test

(Assist students through questioning on what features of the test should be kept constant:

• length of pendulum
• release point
• number of swings (only 10!!!)
• same student release, another always times etc.</td><td>2. Students propose features to be kept constant.</td></tr>
<tr><td>3. Assist students with investigation, noting those groups with incorrect procedures for later class discussion</td><td>3. Students conduct the investigation

(When assisting the groups during the task, you will notice that if the swings do not match the students prediction - especially that a heavy pendulum swings faster - the students will still say that they have done something wrong!!)</td></tr>
</table>

4. Have students report back to class on their findings **"Who found 10 swings in 10 seconds for both a heavy pendulum and a light pendulum?"** **There will be quite some argument here so have a number of groups conduct the task again and have the whole class record time.**	4. Students report back to class.
5. Have students repeat the investigation with correct procedure.	5. Students repeat procedure and report back.
6. Have a show of hands from the students who want to change their hypothesis. **Especially question those groups who observed ONLY what supported their original hypothesis that weight did matter.**	6. Students present an argument for changing or persisting with their original hypothesis.
7. Teacher-led class discussion on group findings. Pose the following: **"Why did some of us not want to change our hypothesis?"** **"Is it a good thing for scientists to change their ideas?" "Why?"** 8. **"I made you only swing the pendulum 10 times. What happens if we let it swing more than 10?"** Demonstrate a swinging golf ball pendulum and a light foam pendulum.	7. Students suggest reasons for scientists changing/not changing their ideas. 8. Students propose answer and reasons for their choice. **NB A usual answer given by students is that the lighter ball slows down.** **NB Some students will suggest that air "stops" the lighter ball.**

You should get over 50 swings for the golf ball but only 20+ swings for the light foam ball. **"The lighter ball was not slow over 10 swings but it was for more swings." "Why?"** Tell students that Galileo saw the difference beyond a small number of swings between a heavy and light pendulum but could not explain it. **"Can anyone help Galileo with the term we give to the way air can stop a pendulum?"**	
Websites: http://pbskids.org/zoom/pendulum/ http://www.galileosf.net/pendulum/ http://es.rice.edu/ES/humsoc/Galileo/ http://muse.tau.ac.il/museum/galileo/pendulum.html#lab http://www.pbs.org/wgbh/nova/galileo/expe_pend_1.html	

PENDULUM LESSONS

Lesson Plan Title:

What Makes It Go? V What Holds It Back

Grade Levels: 3 - 6

Outcomes:

Stage Two

- INVS 2.7 Conducts investigations by observing, questioning, predicting, testing, collecting, recording and analysing data, and drawing conclusions.
- VA2 Exhibits curiosity and responsiveness to scientific and technological ideas and evidence.
- VA45 Works cooperatively with others in groups on scientific and technological tasks and challenges.

Stage Three

- INVS 3.7 Conducts their own investigations and makes judgements based on the results of observing, questioning, predicting, testing, collecting, recording and analysing data, and drawing conclusions.
- VA2 Exhibits curiosity and responsiveness to scientific and technological ideas and evidence.

VA45 Works cooperatively with others in groups on scientific and technological tasks and challenges.

Rationale:

This lesson follows directly from the lessons on the relationship between weight and period.

Students will be asked to investigate which of two differently weighted pendulums **(of equal length)** will come to rest (stop) first when released from the same position.

Background:

- The pendulums used for this lesson is assembled from a string with a different weights. (one heavy/one light)
- Galileo stated that each pendulum has a constant period, ie the time it takes to complete a full swing away and back is always the same and unique for each different length of the pendulum
- The period is independent of the weight of the pendulum
- **However, Galileo also observed that a light pendulum came to rest faster than a heavier pendulum**
- The **seconds pendulum** is 1 metre in length to give a swing of 1 second on each pass

Materials needed:

Any assembled pendulums could be used from the provided kit but for this investigation a golf ball and ping pong ball should be used.

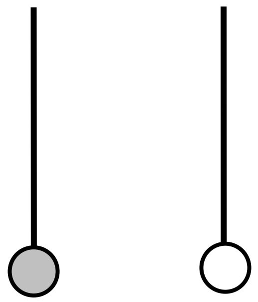
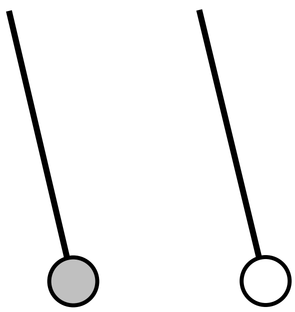
NB The length of the pendulum (with a ball shaped bob) should be measured from the point where you hold the string to the centre of the ball.

Stopwatch, student wristwatch or wall clock.

Time Allotted:

35 - 40 minutes

Teaching and Learning Activities:

Teacher Strategy	Student Activity
1. Revise previous lesson with questioning about the relationship between weight and swing period.	1. Students should recall that weight did not affect the time for a swing.
2. Have two pendulums (the golf ball and ping pong ball pendulums) of length 1 metre .  **heavy** **light ball** Now pull the two pendulums away an **EQUAL** distance. **“Which one will stop swinging first?”**  **heavy** **light ball** **“Why did you think the (light/heavy) pendulum will stop first?”**	. 2. Students predict which ball-light or heavy – will stop first. **Students usually give reasons that show some understanding of the importance of the weight and the air it is “pushing through”.**

3. **"What are we testing?"** **"To make it a fair test, what should be the same for each pendulum?"** Either question students on how the investigation is to be done OR instruct students to simply count the number of swings until the pendulum stops. **NB** **(Before students begin the investigation, instruct them to release the pendulum from a small angle off-centre.)** **(Remind students that the length of the pendulum is measured from where they hold it to the CENTRE of the BOB)**	3. Students perform investigation and should **consistent** in their chosen method.
4. Assist students with investigation, noting those groups with incorrect procedures for later class discussion.	4. Students practice their release and counting.
5. Have students report back to class on their findings **NB You should get groups who correctly identify that the light ball comes to rest first.** **"Why did the light pendulum stop first?"**	5. Students report back. **Keep your questioning to the REASONS for stopping not just that it weighs less.** **If any student hints at the effect of the air try to lead in with a question like:** **"So the air stops it!!??"**

6. Now question students on what makes the pendulum swing. **"So if the air stops it, what makes it go?"** Demonstrate one of the pendulums by pulling it away from the rest position and asking students: **"Is the pendulum higher than before?"** **"What will happen if I let it go now?"**	6. Students make suggestions on what makes the pendulum swing. **NB Students do have difficulty with the concept that gravity makes the pendulum swing.** Students identify that the pendulum will fall.
7. Take a flat sheet of paper and hold it vertically and release. Now hold the paper horizontally and release. **(The horizontal paper falls SLOWER!)** Pose the following: **"Why is there a difference?"** **"What held the paper back?"** **"What makes it fall to the ground??"** Try to get the term "GRAVITY" from the students. Otherwise you may have to introduce the term.	7. Students suggest a reason for the difference in fall of the paper. **Usually, they recognise that air is important.** Students **may** come up with the term "gravity" for what makes the paper fall. Students **may** come up with the term "air resistance" for what makes the paper fall slower.
8. Now ask the following: **"What the paper fall if I let it go on the moon?"** **"Is there gravity on the moon?"** **"Is there air on the moon?"**	8. A number of students will say that the paper will NOT fall and that it will FLOAT because the moon does not have gravity!

“Would a pendulum swing on the moon?”	**Explain that the moon does have gravity but it is LESS than the Earth .** **“Would it swing differently?”**

Websites:

http://www.novaspace.com/AUTO/Hammer.html
Excellent for showing the famous feather and hammer experiment on the moon.(Apollo 15)

http://www.solarviews.com/cap/apo/apo15g.htm
Video of the experiment!

http://pbskids.org/zoom/pendulum/
http://www.galileosf.net/pendulum/
http://es.rice.edu/ES/humsoc/Galileo/
http://muse.tau.ac.il/museum/galileo/pendulum.html#lab
http://www.pbs.org/wgbh/nova/galileo/expe_pend_1.html

PENDULUM LESSONS

Lesson Plan Title:

THE LOLLY TEST

Grade Levels: 3 - 6

Outcomes:

Stage Two

- INVS 2.7 Conducts investigations by observing, questioning, predicting, testing, collecting, recording and analysing data, and drawing conclusions.
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- INVS 3.7 Conducts their own investigations and makes judgements based on the results of observing, questioning, predicting, testing, collecting, recording and analysing data, and drawing conclusions.
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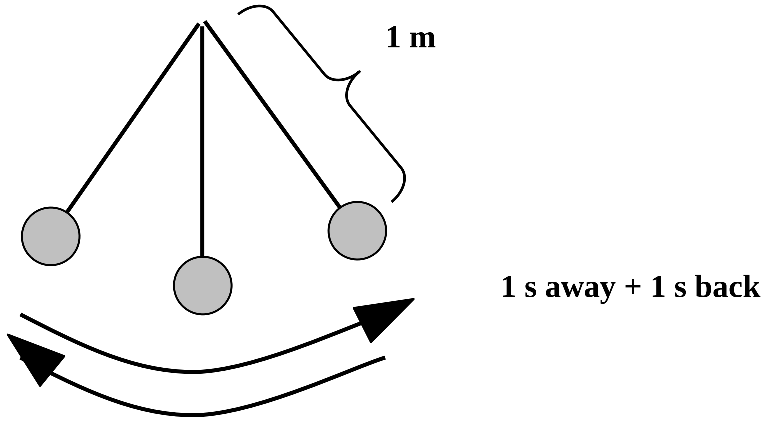
VA45 Works cooperatively with others in groups on scientific and technological tasks and challenges.

Rationale:

What is a FAIR TEST? The Nature of Science aspect that the students should be explicitly introduced to here is that science is **empirical**. A hypothesis may be supported by the collection of data from investigations carried out ina scientific manner.

Background:

- The pendulum used for this lesson is assembled from a string with a weight at one end
- The length chosen is 1 metre to give a **seconds** pendulum
- The **seconds pendulum** is 1 metre in length to give a swing of 1 second on each pass



Materials needed:

Any assembled pendulum could be used from the provided kit..

NB The length of the pendulum (with a ball shaped bob) should be measured from the point where you hold the string to the centre of the ball.

Lots of mixed lollies.

Time Allotted:

35 - 40 minutes

Teaching and Learning Activities:	
Teacher Strategy	**Student Activity**
1. Have students sit in a circle around a pile of lollies. Ask them who they think will be faster at picking up as many lollies in 10 swings of the **seconds** pendulum: **"Boys or Girls?"**	1. Students argue who is better.
2. Choose a male student, have him sit close to the lollies and tell him to pick up as many lollies as he can in 10 swings. Tell the student to use the hand he writes with and only pick up 1 lolly at a time. Repeat with 2 other male students.	2. Students pick up lollies and count how many they collect.
3. Now choose a female student and have her sit next to the lollies. Just before you swing the pendulum, tell her to use her **non-writing hand.** **(Female students will quickly protest!!)** **"What wrong with (the female student) using the non-writing hand?"**	3. Female students will give reasons for the unfairness of using the non-writing hand where the boy where the male student was allowed to use the writing hand. **"It isn't fair!!"**
4. Tell the female student that she **can** use her writing hand. Just before you swing the pendulum, tell her to move back away from the lollies.	4. Female students will give reasons for the unfairness of using the non-writing hand where the boy where the male student was allowed to use the writing hand.

(Female students will quickly protest!!) **"What wrong with (the female student) being further away?"**	**"It isn't fair!!"**
5. Question students as to how the test can be made fair. **"What must we keep the same when we do a test?"** **Stage Three** For Stage 3 students, introduce the concepts of : • **dependent variable** • **independent variable**	5. Students suggest what features of the test must be the same during each attempt. **Stage Three** Students identify the dependent and independent variables in the lolly test: • **keep distance from lollies the same** • **always use writing hand** • **have same number of lollies** **Stage Two** Same as above but without terminology (dependent, independent, variable) **NB This is suggested only and will vary from class to class.**
6. Set the test up again with a student but just before swinging the pendulum, spread the lollies out so that they are wide apart. .	6. Students identify another variable: • **lollies should be in same original pattern on floor before starting**
7. Have students conduct the test for girls versus boys. Have each group report back.	7. Students report their findings.

"Who were faster, girls or boys?" **"How many girls and boys did you test?"** **"Does it matter?"**	Students give reasons for whether many test should be done.
8. Lead a discussion on how many trials can allow an average to be obtained. **"Why is repeating the trial important?"** Ask students if they have heard about the taste test between Coke and Pepsi. **"How many people do you think they tested?"**	8. Students propose reasons fpr repeating the test a number of times. **"One boy might be fast but another one slow, so it might matter if you only test the fast one."** **"You might get a fast girl but a slow boy. The average will cancel this out."**

9. Finish lesson with discussion on the importance of **fair test** and **repeat trials** for science. Give examples from advertising where claims are made without the evidence from a fair test.	9. Students offer examples of where advertising claims might not be supported by fair testing.
Websites: http://pbskids.org/zoom/pendulum/ http://www.galileosf.net/pendulum/ http://es.rice.edu/ES/humsoc/Galileo/ http://muse.tau.ac.il/museum/galileo/pendulum.html#lab http://www.pbs.org/wgbh/nova/galileo/expe_pend_1.html	

APPENDIX 4

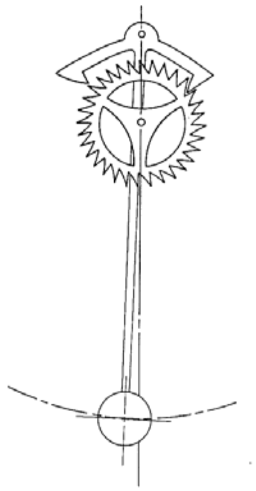
Factsheets

Christiaan Huygens

Born: 14 April 1629 in The Hague, Netherlands
Died: 8 July 1695 in The Hague, Netherlands

Pendulum Clock and Watches

In 1656, Huygens invented the first pendulum clock, as described in his 1658 article "Horologium". The time-pieces previously in use had been balance-clocks, Chris Huygens' pendulum clock was regulated by a mechanism with a "natural" period of oscillation and had an error of less than 1 minute a day, the first time such accuracy had been achieved. His later refinements reduced his clock's errors to less than 10 seconds a day.



Pendulum Clock Escapement Mechanism

Around 1675, Huygens developed the balance wheel and spring assembly, still found in some of today's wrist watches. This improvement allowed 17th century watches to keep time to 10 minutes a day. Watches or portable clocks had been invented early in the sixteenth century, however, they were clumsy and unreliable, being driven by a main spring and regulated by a conical pulley and verge escapement. The first watch whose motion was regulated by a balance spring was made in Paris under Huygens' directions, which he gave as a gift to Louis XIV the King of France.

This new invention brought precision to the daily schedules of people's lives. Earlier clocks could not keep accurate minutes far less seconds. The pendulum clock allowed people to synchronize schedules as well as perform more accurate scientific measurements. Much of Newton's work on gravity depended on just such a precise timing machine.

http://www.physics.northwestern.edu/classes/2001Spring/135-1/Projects/5/page4.html

http://inventors.about.com/library/inventors/bl_huygens.htm

Chronometer

From Wikipedia, the free encyclopedia.

http://en.wikipedia.org/wiki/Chronometer

A chronometer is a clock designed to have sufficient long-term accuracy that it can be used as a portable time standard on a vehicle, usually in order to determine longitude by means of celestial navigation.

Until the mid 1750s, navigation at sea was an unsolved problem. Navigators could determine their latitude by measuring the sun's angle at noon. However to find their longitude, they needed a portable time standard that would work on a ship. Conceptually, at local high noon they could compare the chronometer's time to determine their longitude.

In modern practice, a navigational almanac and trigonometric sight reduction tables permit navigators to measure the Sun, Moon, visible planets or any of 57 navigational stars at any time of day or night.

The problem of the clock was difficult. At the time, the best clocks were pendulum clocks, and the rolling of a ship at sea caused these to be inaccurate. John Harrison, a carpenter, developed a clock based on a pair of counter-oscillating weighted beams connected by springs, whose motion was not influenced by gravity or the motion of a ship. His chronometers H1-H3 were all of this design but were large and heavy, and required to be suspended from a beam in a ship.

He finally solved the problem with his H4 chronometer, essentially a large 5" diameter watch, winning a prize from the British Admiralty. His design used a temperature-compensated balance wheel. This method remained in use till microchips reduced the cost of a quartz clock to the point that electronic chronometers became commonplace.

Harrison's clocks are still ticking, in the museum in Greenwich, England. For more information on longitude, see the Web site: http://www.pbs.org/wgbh/nova/longitude

The Longitude problem

"Whereas, in order to the finding out of the longtitude of places for perfecting navigation and astronomy, we have resolved to build a small observatory within Our Park at Greenwich..."
Charles II

Latitude and Longitude

Two co-ordinates define any position on the earth's surface

Latitude: The distance north or south of the equator
Longitude: The distance east or west from an agreed place or meridian

Latitude was easy for sailors to calculate by taking observations of the position of the Sun or the Pole Star depending on the time of day. The lines of longitude, which run from pole to pole, were far more difficult to calculate. The circle of the globe can be divided into 360º and as the world takes 24 hours to revolve on its axis one hour is equivalent to 15º. This explains the time differences as you travel around the globe.

For every 15° that one travels eastward, the local time moves one hour ahead. Similarly, travelling West, the local time moves back one hour for every 15° of longitude.

Therefore, if we know the local times at two points on Earth, we can use the difference between them to calculate how far apart those places are in longitude, east or west.

This idea was very important to sailors and navigators in the 17th century. They could measure the local time, wherever they were, by observing the Sun, but navigation required that they also know the time at some reference point, e.g. Greenwich, in order to calculate their longitude. Although accurate **pendulum clocks** existed in the 17th century, the motions of a ship and changes in humidity and temperature would prevent such a clock from keeping accurate time at sea.

Between 1690 and 1707 there were a number of incidents in which English naval ships were lost at sea because they had lost their positions. In the most serious incident in 1707 over 2000 men were lost when four ships ran aground on the Scilly Islands while returning to England. More and more pressure was mounting for a solution to the longitude problem as the continuing failure to solve it was costing England vast sums of money. Everyone believed that mathematicians and astronomers would provide the solution but it is not to be.

King Charles II founded the Royal Observatory in 1675 to solve the problem of finding longitude at sea. If an accurate catalogue of the positions of the stars could be made, and the position of the Moon then measured accurately relative to the stars, the Moon's motion could be used as a natural clock to calculate Greenwich Time. Sailors at sea could measure the Moon's position relative to bright stars and use tables of the Moon's position, compiled at the Royal Observatory, to calculate the time at

Greenwich. This means of finding Longitude was known as the 'Lunar Distance Method'.

In 1714, the British Government offered, by Act of Parliament, £20,000 for a solution which could provide longitude to within half-a-degree (2 minutes of time). The methods would be tested on a ship, sailing

...over the ocean, from Great Britain to any such Port in the West Indies as those Commisioners Choose... without losing their Longitude beyond the limits before mentione and should prove to be...tried and found Practicable and Useful at Sea.

A body known as the Board of Longitude was set up to administer and judge the longitude prize. They received more than a few weird and wonderful suggestions. Like squaring the circle or inventing a perpetual motion machine, the phrase 'finding the longitude' became a sort of catchphrase for the pursuits of fools and lunatics. Many people believed that the problem simply could not be solved.

Clocks based on swinging **pendulums** were tried but do not at all perform well onboard a heaving and swaying ship, not to speak of the temperature shifts. This had clearly been confirmed during several attempts to use clocks as a means for navigation.

The longitude problem was eventually solved by a working class joiner from Lincolnshire with little formal education. **John Harrison** took on the scientific and academic establishment of his time and won the longitude prize through extraordinary mechanical insight, talent and determination.

Harrison started making clocks as a teenager using the skills learnt in his father’s workshop and he completed his first clock pendulum in 1713, aged 20 years   The clock was built almost entirely of wood with only small amounts of brass and steel. Harrison’s knowledge of the qualities of wood ensured his clocks did not wear or break with time as he used the strength of the grain pattern in the teeth of his wheels. After making several more clocks John teamed up with his brother James. The Harrison brothers (John and James) worked together until 1739, building a number of clocks and also working on the inventions of the grid iron **pendulum.**

Captain James Cook

On Cook’s second voyage to look for the southern continent (Antarctica) he tested a chronometer, or sea clock, designed by John Harrison. Its successful performance meant that Cook and all future navigators were able to fix longitude much more accurately than before.

http://www.nmm.ac.uk

http://www.harrisonclocks.co.uk/home.htm

http://www.kellnielsen.dk/bol.htm

The Pendulum and the Shape of the Earth

Jean Richer

Born: 1630 in France Died: 1696 in Paris, France

Nothing is known of **Jean Richer**'s education. He became a member of the Académie Royale des Sciences in 1666 with the title of 'astronomer'. By 1670, however, he had been given the title 'mathematician' by the Académie. He spent most of his life after this time undertaking work for the Académie.

In 1670 Richer was sent by the Académie to La Rochelle to measure the heights of the tides there at both the spring and vernal equinoxes. Also in 1670 he set out on a voyage to Canada (France controlled parts of the country). On the voyage he had the task of testing two clocks made by Huygens. Accurate clocks were important in determining longitude. However there was a storm and Huygens's clocks stopped.

On his return Richer reported the failure of the clocks to Huygens and to the Académie. Huygens accused Richer of incompetence but this was certainly untrue. Richer had made many important observations on the voyage and the problem with Huygens's clocks was certainly not his fault.

In 1671 Richer was sent on an expedition to Cayenne, French Guyana by the French Government. His first task there was to measure the parallax of Mars and the observations were to be compared with that taken at other sites to compute the distance to the planet. This data enabled the scale of the solar system to be computed, the first reasonably accurate results to be found.

Richer's second important work was to examine the periods of pendulums at different points on the Earth. He examined the period of a pendulum while on the expedition to Cayenne, French Guyana and found that the pendulum beat more slowly than in Paris. From this Richer deduced that gravity was weaker at Cayenne, so it was further from the centre of the Earth than was Paris.

Richer published his observations in his only written work *Observations astronomiques et physiques faites en l'isle de Caienne.*

Newton and Huygens used Richer's gravity data to show that the Earth is an oblate sphere.

http://www-gap.dcs.st-and.ac.uk/~history/Mathematicians/Richer.html

Sir Edward Sabine

Born: 14 October 1788, Dublin, Ireland
Died: 26 June 1883, Richmond, Surrey, England

Education: Royal Military Academy, Woolwich, London

Edward Sabine was an Irish geophysicist, astronomer, and explorer, who made extensive pendulum measurements to determine the shape of the earth, and established magnetic observatories to relate sunspot activity with disturbances in terrestrial magnetism.

Sabine was commissioned in the Royal Artillery, served in Gibraltar and Canada, and eventually rose to the rank of major-general in 1859, retiring in 1877.

In 1818, he travelled as the expedition's astronomer with his friend, Sir Clark Ross, to find the North-West Passage. He also joined the 1819-20 Arctic expedition of William Parry. During 1821-23, Sabine travelled in the Southern hemisphere, using careful pendulum experiments to determine the shape of the earth.

http://www.todayinsci.com/cgi-bin/indexpage.pl?http://www.todayinsci.com/S/Sabine_Edward/Sabine_Edward.htm

APPENDIX 5

Anova Assumption Testing

Homogeneity of Variance

Levene's test was used for the first assumption of homogeneity of variance. For the experimental group the F-values are 1.976 (Teaching efficacy) with a p-value of 0.166 and 1.600 (Knowledge) with a p-value of 0.211. In the case of the control group Levene's test reported F-values of 0.021 (Teaching Efficacy) with a p-value of 0.885 and 0.797 (Knowledge Efficacy) with a p-value of 0.376. For both the experimental and control group across teaching and knowledge efficacy the null hypothesis that equal variances are assumed is not rejected for each case.

Normality

A test for normality was conducted on pre- and post-data for each group using the Shapiro-Wilk analysis in SPSS:

Test of Normality

Test of Normality

	Shapiro-Wilk		
	Statistic	df	Sig.(p value)
Experimental Teaching Efficacy Pre	0.915	18	0.104
Control Teaching Efficacy Pre	0.91	18	0.086
Experimental Teaching Efficacy Post	0.968	18	0.75
Control Teaching Efficacy Post	0.92	18	0.131
Experimental Knowledge Efficacy Pre	0.958	18	0.558
Control Knowledge Efficacy Pre	0.932	18	0.208
Experimental Knowledge Efficacy Post	0.956	18	0.528
Control Knowledge Efficacy Post	0.87	18	0.018

Based on this Shapiro-Wilk test, all variables analysed, except Control Group Knowledge Efficacy Post, are normally distributed with p-values > 0.05 where the null hypothesis is that the sample is from a normally distributed population. Although there is one variable that appears to be not distributed normally, this represents only the control knowledge efficacy post variable and parametric testing procedures are still used.

The p-value for knowledge efficacy in the control group shows significant differences in mean scores between pre- and post-testing at 1% level of significance ($p = 0.034$). For teaching efficacy the p-value shows no significant differences in mean scores between pre- and post-testing ($p = 0.436$). The mean score for teaching efficacy has decreased for the control group and the standard deviation has increased (Teaching Efficacy: Mean Pre/Post = 25.11/24.44, SD: Pre/Post = 4.562/6.070). The mean score for knowledge efficacy has increased for the control group and the standard deviation has decreased (Teaching Efficacy: Mean Pre/Post = 27.89/29.83, SD: Pre/Post = 3.787/2.875).